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INTRODUCING SCIENCE — PHYSICS

WHAT IS SCIENCE ?

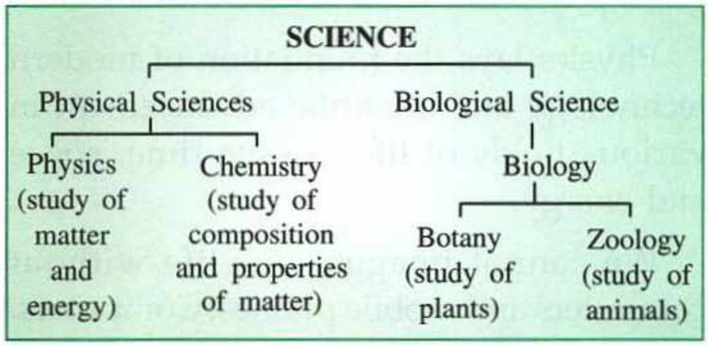
Since earlier times, man was always curious to know more about his surroundings and the world at large. Human beings have constantly tried to understand how nature works — how days and nights occur, how seasons change, how the heavenly bodies like the earth, moon, stars and planets move, how the plant and animal kingdoms function and so on.

Science is the end-result of these human attempts to understand and explain the basic principles underlying all such occurrences in nature involving both living and non-living things.

Nature always presents us with strange happenings. *For example*, a piece of paper catches fire while an iron piece or a steel block does not. A piece of iron sinks in water, but a huge ship floats on water. When we throw an object, it immediately falls down. A magnet attracts iron filings, but does not attract aluminium. Lots of researches were carried out by scientists to explain the peculiar happenings we all experience in nature.

Hence, *science can be defined as a systematic study of nature performed through observations and experimentations and lastly their interpretations before drawing any conclusion.*

The collective study of this knowledge gave birth to the various branches of Science. Science is basically divided into two main branches — Physical Sciences and Biological Sciences.



MORE ABOUT PHYSICS

The word Physics was taken from the Greek word *'Fusis'*, which means nature. It is a branch of science which deals with the study of matter and energy by making measurements and forming laws governing the various phenomenon in nature.

Physics is classified into different sections such as heat, light, sound, electricity, magnetism, mechanics, nuclear physics, etc.

MARVELS OF PHYSICS

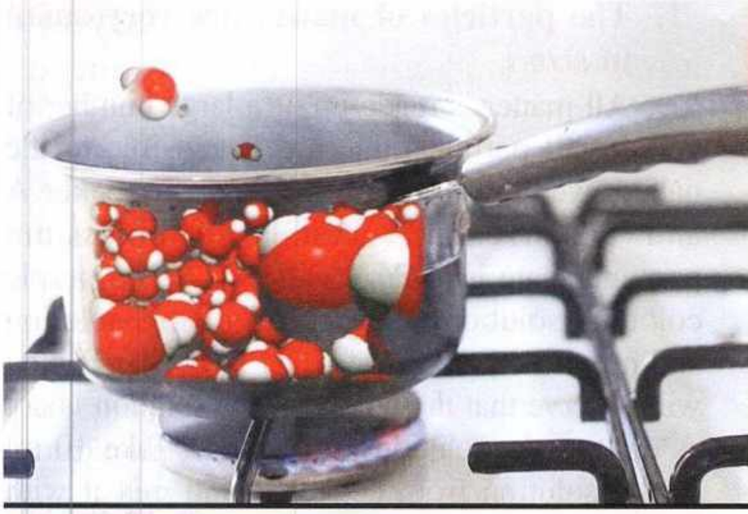
Physics plays an important role in our day-to-day life. In most of the natural activities, directly or indirectly, laws of physics are involved. The twinkling of stars, the motion of planets, Sputnik, satellites, etc. are all based on laws of Physics. The radar, telephone, television, air conditioner, CD player, computer, laptop, mobile phone and so many other electrical and electronic gadgets, all are based on some laws which are the fruits of the efforts of our scientists. To prove the facts of various laws of physics and to determine the accuracy of such facts, we use different tools contributed by the great physicists from time to time.

Physics lays the foundation of modern technology and scientific advancement in various fields of life to save time, space and energy.

We cannot imagine our life without computers and mobile phones. Computers, the modern mechanical innovations and information technology have transformed our lives and businesses. In today's times, computer, internet facility and mobile phones are the most important contributions of Physics.

To conclude, Physics has made our life exciting and meaningful. The comforts of life which we enjoy today, are all miracles of Physics. This could all happen because of the untiring efforts of our scientists who devoted their lives in carrying out researches in the best interest of mankind.

The desire for new inventions will never end and the scientists all over the world are putting in and will continue to put in their best efforts to discover new devices and gadgets to make human life more interesting, comfortable and charming. The authors wish you to be one of them.



1 Matter

Theme : Objects that take shape and have mass are called matter. A block of wood, milk and air are all made of matter. Matter is made up of tiny particles called atoms and molecules that cannot be seen by the human eye as they are very small. Matter exists in the form of solid, liquid or gas. A solid has a certain size and shape, like a block of wood. A liquid, like water, has a size but does not have a definite shape. It takes the shape of the container it is put in. A gas, like air, is a form of matter that has no definite shape or size.

In this chapter you will learn :

Matter : Its meaning and composition

States of Matter

- Solids, liquids and gases.
- Characteristics of solids, liquids and gases (shape, texture, volume).
- Distinguishing properties of solids, liquids and gases.

LEARNING OBJECTIVES

The children will be able to :

- define matter
- describe what matter is made of
- list the distinguishing properties of solids, liquids and gases
- classify different objects as solids, liquids and gases.

MATTER : ITS MEANING AND COMPOSITION

Definition : *Matter is defined as anything which occupies space and has mass. It can be perceived by our senses of smell, touch, sight, hearing and taste.*

Examples : Air, water, hydrogen, oxygen, sugar, sand, silver, steel, copper, coal, iron, wood, ice, alcohol, milk, oil, kerosene, petrol, carbon, sulphur, rocks and minerals are all different kinds of matter because all of them occupy space and have mass. Things like food, clothes, table, chair, human beings, animals, plants and trees are also examples of matter.

Thus *the word matter is used to cover all the substances and materials — living and non-living — of which universe is composed of.*

Do You Know ?

The universe is composed of matter and energy. Both matter and energy are inter-convertible.

COMPOSITION OF MATTER

Ancient Indian philosophers thought that matter is made up of five elements — air, water, earth, sky and fire (*panchtatvas*).

Maharishi Kannada, an Indian philosopher, was perhaps the first to suggest that all forms of matter are composed of **extremely** small particles known as ***anu*** and that each ***anu*** may be made up of still smaller particles called ***parmanu***.

Greek thinker Democritus called the smallest particle (*parmanu*) of matter as **atom**. Thus, it was concluded that matter is composed of a very large number of tiny particles known as atoms. A small drop of water contains about hundreds of millions of atoms in it!

However, it was later found out that most of the atoms cannot exist freely in nature.

John Dalton, an English chemist experimentally found that matter is made up of **molecules**. A molecule is made up of one or more than one atoms of the same kind or of different kinds. A molecule can exist freely in nature. It simply means that a molecule is the simplest and smallest particle of a substance that is capable of independent existence. Both atoms and molecules are so small that we cannot see them even with a simple microscope.

Do You Know ?

A molecule consisting of one atom is called a monoatomic molecule (*examples* : neon, argon, etc.). A molecule having two atoms is called a diatomic molecule (*examples* : hydrogen molecule, oxygen molecule, etc.). A molecule having more than two atoms is called a polyatomic molecule (*examples* : water molecule, ammonia molecule, etc.)

CHARACTERISTICS OF PARTICLES OF MATTER

The particles of matter called *molecules*, have the following *four* characteristics :

1. They are very small in size.
2. They have spaces between them.
3. They are in constant random motion.
4. They always attract each other.

1. The particles of matter are very small in size :

All matter is made up of a large number of very small particles that are not visible to the naked eye. Take 100 ml of water in beaker A and dissolve 2-3 crystals of potassium permanganate in it. You will get a deep purple coloured solution. Take 10 ml of this solution and mix it with 90 ml of water in beaker B. You will observe that the colour of the solution is not as dark as the solution in beaker A. Take 10 ml of the solution from beaker B and mix it with 90 ml of water taken in beaker C. The colour of the solution becomes still lighter. Keep on diluting the potassium permanganate solution like this a number of times and you will find that the colour of the solution becomes fainter and fainter, but it is still pink. This experiment shows that a single crystal of potassium permanganate is made up of a large number of tiny particles which can colour a large volume of water.

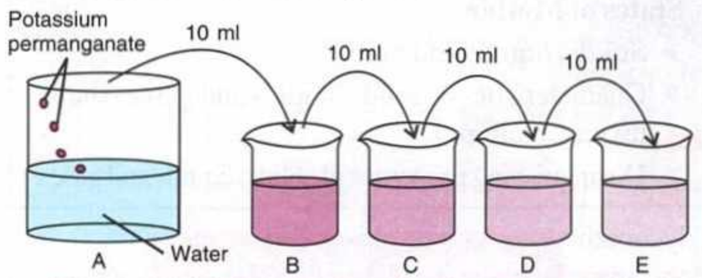


Fig. 1.1 (a) Experiment showing that matter is made up of very small particles

2. The particles of matter have spaces between them :

The spacing between molecules of matter is called **inter-molecular space**. Take 100 ml of water in a measuring cylinder.

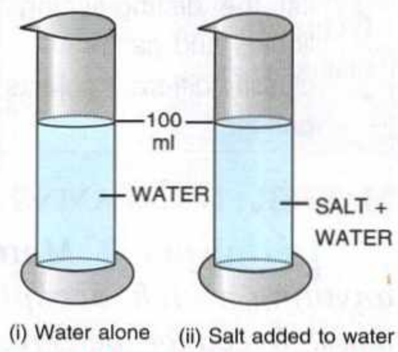


Fig. 1.1 (b) The particles of salt occupy the spaces between the particles of water

Add 20 gram of salt in water gently and stir it well so as to dissolve the salt well in water. It is noticed that the level of water does not change [Fig. 1.1(b)]. It shows that the particles of salt have occupied the spaces between the particles of water.

3. The particles of matter are in constant random motion :

The particles of matter are not at rest, but they move randomly in all possible directions in a zig zag path.

You might have noticed that in the sunlight coming through a minute opening in a darkened room, the fine dust particles appear to dance in a random and zig zag manner. This is because the air particles surrounding the dust particles are in random motion and they hit the dust particles causing them to move in a zig zag path as shown in Fig. 1.2.

It is due to random motion of particles of perfume that when it is sprayed in one corner of a room, it soon spreads throughout the room.

ACTIVITY 1

Take a beaker. Fill it partly with water. Add some lycopodium powder in the beaker containing water. Stir the contents of the beaker with a glass rod. Take out few drops of this suspension on a glass plate. Place the plate on the table and illuminate it with a table lamp. Observe the glass plate through a microscope. It is found that the fine particles of lycopodium powder move rapidly in a random manner and their path is zig zag as shown in Fig. 1.2.

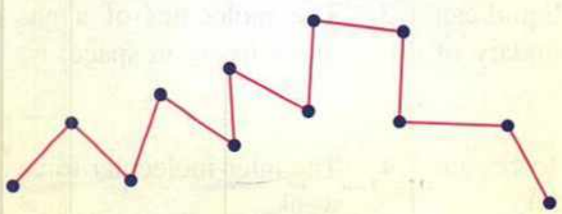


Fig. 1.2 Zig zag path of a fine particle of lycopodium powder

The reason is that the particles of water are in random motion which collide with the suspended fine particles of lycopodium powder and make them move in a zig zag path.

4. The particles of matter attract each other:

Each particle of matter always attracts other particles in its surroundings. The force of attraction between the constituent particles is called **intermolecular force of attraction**. This force keeps the particles of matter together.

It is our common experience that around us, some substances can be changed into powder, some others can be changed into small crystals and some cannot be broken easily. The reason is that the magnitude of intermolecular force of attraction varies from one type of matter to another. Thus, the inter-molecular force depends on the nature of each matter.

If the force of attraction between the particles of matter of a substance is less, the substance can easily be broken, but if it is more, it is difficult to break it.

Some examples : (i) It is easy to move our hand through water but difficult to move the hand in glycerine. The reason is that the attractive intermolecular forces are stronger in glycerine than in water.

(ii) It is easy to break a chalk into pieces but difficult to break a piece of coal. The reason is that the intermolecular forces are weaker in chalk than in coal.

(iii) It is easy to move a body in air than in water because the force of attraction between the air particles is very small and thus the distance between them is more as compared to that between the water particles.

In general, the intermolecular force of attraction between the particles is more in solids, less in liquids and still less in gases.

Do You Know ?

The force of attraction between the particles of same substances is called the **force of cohesion** (or **cohesive force**), while the force of attraction between the particles of two different substances is called the **force of adhesion** (or **adhesive force**). Water sticks to the glass material because adhesive force between water particles and glass particles is more than the cohesive force between water molecules. Conversely, mercury does not stick to glass because adhesive force between mercury particles and glass particles is less than the cohesive force between the mercury particles.

Conclusion : Matter is made up of molecules which are very small in size ($\sim 10^{-9}$ m). The molecules are in constant random motion. They exert a force of attraction amongst each other. They have inter-molecular spaces between them.

Note : A molecule or a cluster of several molecules is called a *nanoparticle*.

STATES OF MATTER

There are *three* physical states of matter — (i) solid, (ii) liquid and (iii) gas. *For example*, steel is a solid, oil is a liquid and oxygen is a gas, while air is a mixture of gases.

Water can exist in all the three states, viz. ice (solid state), water (liquid state) and steam (gaseous state).

Do You Know ?

Plasma is the fourth state of matter which is found at a very high temperature, when a gas occurs in the form of positive ions and free electrons.

The *three* properties which decide the state of a substance as a solid, liquid or gas are :

(i) inter-molecular space,
(ii) force of attraction between the molecules and
(iii) movement of molecules.

Solid state : When inter-molecular force of attraction is very strong, the inter-molecular space is negligible and the molecules are not free to move, matter exists as a **solid**.

Liquid state : When inter-molecular force of attraction between the constituent molecules is weak, inter-molecular space is more as compared to solids and the molecules are free to move to and fro within a limited space, matter exists as a **liquid**.

DISTINCTION BETWEEN SOLIDS, LIQUIDS AND GASES

Solids	Liquids	Gases
1. A solid has a definite shape and a definite size (*i.e.*, length, area and volume).	1. A liquid has a definite volume, but not a definite shape.	1. A gas has neither a definite volume nor a definite shape.
2. The molecules in a solid are closely packed.	2. The molecules in a liquid are loosely packed.	2. The molecules in a gas are wide apart.
3. The molecules in a solid are fixed at their positions. They can only vibrate about their mean positions.	3. The molecules in a liquid can move within the boundary of the liquid.	3. The molecules of a gas can move freely in space.
4. The inter-molecular forces are very strong.	4. The inter-molecular forces are less strong (moderate).	4. The inter-molecular forces are weak.
5. The molecules in a solid are closely packed, therefore solids are highly rigid.	5. The molecules in a liquid are less closely packed, therefore, liquids are less rigid.	5. The molecules in a gas are loosely packed, therefore gases are non-rigid.

Gaseous state : When inter-molecular force between the constituent molecules is very weak or negligible, inter-molecular space is far more as compared to liquids and the molecules are free to move to and fro anywhere, matter exists as a **gas**.

PROPERTIES OF SOLIDS

1. A solid has a definite shape and size (length, area and volume).
2. A solid can not be compressed.
3. A solid can not flow.
4. A solid is highly dense.
5. A solid has its constituent molecules very closely packed.
6. A solid exerts pressure due to its weight only on its base, downwards.
7. A solid has strong inter-molecular force of attraction.
8. A solid has a low thermal expansion, *i.e.* it expands a little on heating.
9. In a solid, the molecules are not free to move from their positions. They simply vibrate on either side of their mean positions.
10. A solid can have *any number* of free surfaces.
11. A solid is highly rigid but some solids can be stretched into wires or beaten into sheets.
12. A solid does not easily diffuse into other solids.

The above mentioned properties of solids can be explained by the molecular model of solid state.

Molecular model of solid state

(1) There is a strong force of attraction (strong inter-molecular force) between the molecules of a solid.

(2) The molecules in a solid are closely packed, *i.e. inter-molecular space is negligible. Therefore, solids cannot be compressed much.*

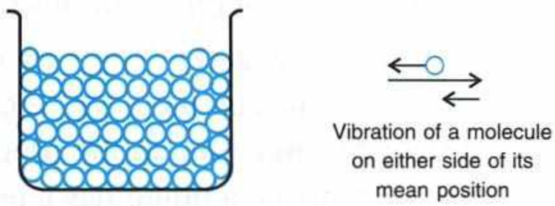


Fig. 1.3 Molecules of a solid are arranged closely and in a definite manner, not free to move about

The molecules are arranged in a definte manner, therefore they have a definite shape.

(3) The molecules vibrate on either side of their mean positions but they do not leave their positions. Therefore solids have a definite size.

(4) The molecules of a solid are packed tightly and so they generally have a high density. Thus,

> ***Solids** are rigid, they have a definite size, definite shape and a definite volume.*

Note : A rubber band changes its shape when a force is applied to it. But it returns to its original shape when the force is removed. Thus, rubber is elastic but is treated as a solid.

PROPERTIES OF LIQUIDS

1. Liquids have a definite volume, but no definite shape because they acquire the shape of the container in which they are kept.
2. Liquids are almost incompressible.

3. Liquids can flow.
4. Liquids are viscous *i.e.* each liquid opposes the relative motion between its different layers. Hence, each liquid opposes the motion of an object on it.
5. Liquids have a tendency to occupy minimum surface area, *i.e.* they have surface tension. Due to the property of surface tension, a liquid has a tendency to form a spherical drop.
6. Liquids have only *one* free surface.
7. A liquid can easily diffuse into other liquids.
8. Liquids are less rigid.
9. The molecules in a liquid are less closely packed.
10. The inter-molecular force of attraction is weak in a liquid than in a solid.
11. Liquids have high thermal expansion, *i.e.* liquids expand more on heating than solids.
12. The molecules of a liquid are free to move within the boundary of the liquid.
13. A liquid exerts pressure in all directions.

The above properties of liquids can be explained by the molecular model of liquids.

Molecular model of liquids

(1) The attractive force between the molecules of a liquid is not as strong as it is in solids, so they are loosely packed and are not fixed. The molecules can move over one another, within the boundary of the liquid. Thus, a liquid has a definite volume, but no definite shape.

(2) The inter-molecular space in a liquid is greater than that in a solid, so they generally have low density as compared to a solid, *i.e.* they are more compressible.

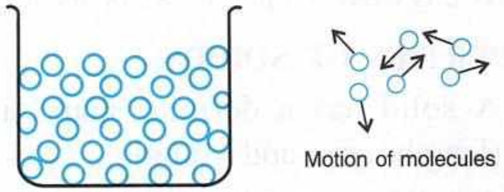


Fig. 1.4 Molecules of a liquid are arranged less closely and are free to move about, within the liquid

(3) The motion of molecules in a liquid is irregular and random within the boundary of the liquid. Thus,

> *Liquids do not have a definite shape, but have a definite volume and can flow from a higher to a lower level. They show the property of viscosity and surface tension because of the cohesive forces.*

PROPERTIES OF GASES

1. A gas has neither a definite shape nor a definite volume. It acquires the shape and volume of its container.
2. Gases are highly compressible.
3. Gases can flow. They are also viscous, but less viscous than liquids.
4. Gases are not rigid.
5. A gas diffuses into other gases very fast.
6. A gas has *no* free surface.
7. In a gas, the molecules are least closely packed.
8. In a gas, there is negligible force of attraction amongst its molecules.

9. The thermal expansion of gases is very large.
10. In a gas, the molecules are free to move in a random manner in zig-zag paths everywhere.
11. Gases do not show the property of surface tension because they do not have free surfaces.
12. A gas exerts pressure on the walls of its container from all directions due to change in momentum on collisions of its molecules with the wall.

The above properties of gases can be explained by the molecular model of gases.

Molecular model of gases

(1) The molecules of a gas lie much farther apart than they lie in a liquid or a solid. Thus, the density of gases is very low.

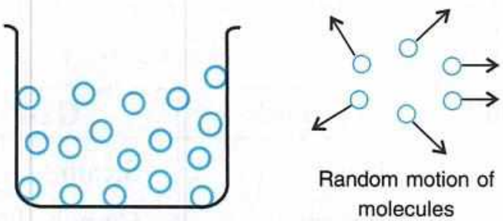


Fig. 1.5 Molecules of a gas are far apart and are free to move about

(2) *There is negligible force of attraction between* the molecules of a gas, so they are free to move in the entire space available to them.

(3) The molecules of a gas move much faster than they move in liquids, and therefore they are infact in a state of *incessant random motion*, moving in all possible directions at all possible speeds.

DISTINGUISHING PROPERTIES OF SOLIDS, LIQUIDS AND GASES

Properties	Solids	Liquids	Gases
1. Mass	Definite	Definite	Definite
2. Shape	Definite	Acquires the shape of the container	Acquires the shape of the container
3. Volume	Definite	Definite	Indefinite, acquires the volume available
4. Compressibility	Not compressible	Negligibly compressible	Highly compressible
5. Fluidity	Not possible	Can flow	Can flow
6. Rigidity	Highly rigid	Less rigid	Not rigid
7. Diffusion	Slow	Fast	Very fast
8. Number of free surfaces	Any number of free surfaces	Only one free surface	None
9. Packing of molecules	Very closely packed	Less closely packed	Least closely packed
10 Inter-molecular force	Strongest	Slightly weaker than in solids	Negligible
11. Expansion on heating	Low	More than solids	More than liquids
12. Motion of constituent molecules	Only vibrate on either side of their mean positions	Move in all directions but within the boundary of the liquid	Move in a random manner in all space available
13. Pressure	Only at base downwards	At all points in all directions inside the boundary of the liquid	On the walls of the container
14. Viscosity	No	More viscous	Least viscous
15. Surface tension	No	Due to cohesive force tends to occupy minimum surface area	No

(4) The molecules of a gas are far apart and there is enough space available for compression. Thus, *gases can easily be compressed.*

(5) During motion, the molecules of a gas collide with one another and also with the wall of the vessel. In each collision, the direction of motion of the molecule changes, so the momentum changes.

(6) A gas exerts pressure on the wall of its container due to the continuous collisions of its molecules with the wall. Thus,

> A *gas has neither a definite shape nor a definite volume, but it can flow and is easily compressible.*

CHANGES IN STATE OF MATTER

The change in state of matter of a substance from solid to liquid or from liquid to gas is brought about by imparting heat energy to it at a constant temperature.

1. Change from solid state to liquid state

The process of changing of a substance from the solid state into its liquid state on absorption of heat at a particular temperature, called the *melting point*, is called ***melting*** or ***fusion*** *i.e.*,

$$\text{Solid} \xrightarrow[\text{Heat absorbed}]{\text{Melting}} \text{Liquid}$$

The heat energy absorbed by the substance increases the amplitude of vibrations of the molecules of the solid and a stage is reached at the melting point when the molecules acquire sufficient energy to overcome the force of attraction between them and they become free to move. The solid thus changes into a liquid.

2. Change from liquid state to gaseous state

The process of change of a substance from the liquid state to its gaseous state at a particular temperature, called the boiling point, is called ***boiling*** or ***vaporisation***. *i.e.*,

$$\text{Liquid} \xrightarrow[\text{Heat absorbed}]{\text{Boiling}} \text{Gas}$$

The heat energy absorbed by a substance in liquid state increases the energy of its molecules due to which they begin to move rapidly. Thus a liquid changes into a gas.

Important

Melting point of ice is 0°C.

Boiling point of water is 100°C.

List of few solids, liquids and gases

Solids	Liquids	Gases
Ice	Water	Steam
Aluminium	Benzene	Carbon dioxide
Silver	Chloroform	Oxygen
Calcium	Oil	Hydrogen
Gold	Honey	Chlorine
Iron	Glycerine	Nitrogen
Salt	Milk	Ammonia
Sugar	Nitric acid	Sulphur dioxide
Wood	Alcohol	Nitric oxide
Plastic	Spirit	Helium
Wax	Dettol	Argon

ACTIVITY 2

Classify 20 objects around you as solids, liquids and gases

Solids ....

....

Liquids ....

....

Gases ....

....

RECAPITULATION

- Matter is any substance that occupies space and has mass.
- The three states of matter are (i) solid, (ii) liquid and (iii) gas.
- Matter is composed of a large number of molecules.
- A molecule is the smallest particle which can exist freely in nature by itself and it retains the properties of the substance.
- All molecules of a substance are identical, but the molecules of different substances are different.
- A molecule is very small in size (10^{-10} m to 10^{-9} m).
- The molecules are separated from each other with spaces called inter-molecular space.
- The molecules in a substance are held together by the forces acting between the molecules which are called inter-molecular forces.
- The force of attraction between the molecules of the same substance is called the force of cohesion, while the force of attraction between the molecules of two different substances is called the force of adhesion.
- The molecules in a substance are not at rest, but they are constantly in motion.
- In a solid, the molecules are rigid, the inter-molecular spacing is the least, the inter-molecular forces are strongest and the molecules remain in their fixed positions. They vibrate to and fro about their mean positions, but they do not leave their positions, so a solid has a definite shape and a definite volume.
- In a liquid, the molecules are not rigid, the inter-molecular spacing is more than that in solids, the inter-molecular forces are weak and the molecules are free to move within the boundary of the liquid, so the liquid has a definite volume, but it does not have a definite shape.
- In gases, the molecules are not rigid, the inter-molecular spacing is more than that in liquids and solids, the inter-molecular forces are the weakest and the molecules are free to move anywhere in space. So a gas has neither a definite volume nor a definite shape.

TEST YOURSELF

A. Objective Questions

1. Write true or false for each statement :
   (a) The molecules of each substance are identical.
   (b) The inter-molecular forces are effective at all distances between the two molecules.
   (c) The molecules in a substance are in random motion.
   (d) In a gas, the molecules can move anywhere in space.
   (e) Liquids are less viscous than gases.

   Ans. (a) F (b) F (c) T (d) T (e) F

2. Fill in the blanks :
   (a) All the molecules of a substance are ....
   (b) The inter-molecular spacing is .... in solids .... in liquids and .... in gases.
   (c) The molecular motion in liquid and gas is in .... path.
   (d) In a solid, the molecules .... but they remain at their fixed positions.
   (e) The inter-molecular forces are the weakest in ....
   (f) A solid exerts pressure ....
   (g) Gases are .... dense.
   (h) Solids are .... rigid.

   Ans. (a) identical (b) least, more, still more (c) zig-zag (d) vibrate on either side (e) gases (f) downwards on its base (g) least (h) most

3. Select the correct alternative :
   (a) The diameter of a molecule is approximately
   (i) 1 cm (ii) 10 cm
   (iii) 10^{-10} m (iv) 1 m
   (b) The inter-molecular forces are strongest in
   (i) solids (ii) liquids
   (iii) gases (iv) both (i) and (ii)
   (c) The molecules
   (i) in solid, liquid and gas, move freely anywhere.
   (ii) in a solid, move freely within its boundary.
   (iii) in a liquid, move within its boundary.
   (iv) in a gas, move only within its boundary.
   (d) Solids are
   (i) more dense (ii) less dense
   (iii) least dense (iv) highly compressible
   (e) The inter-molecular forces in liquids are
   (i) as strong as in solids
   (ii) stronger than in solids
   (iii) weaker than in solids
   (iv) weaker than in gases

   Ans. (a) (iii), (b) (i), (c) (iii), (d) (i), (e) (iii)

4. Match the following columns :

	Column A		Column B
(a)	A molecule is composed of	(i)	does not exist free in nature.
(b)	Ice, water and water vapour	(ii)	can vibrate only up to about 10^{-10} m from their mean positions.
(c)	An atom	(iii)	atoms.
(d)	Gases	(iv)	are the three states of water.
(e)	The molecules of a solid	(v)	occupy space

   Ans. (a)-(iii), (b)-(iv), (c)-(i), (d)-(v), (e)-(ii)

B. Short/Long answer questions

1. Define matter. What is its composition ?
2. Name the *three* states of matter.
3. What is a molecule ?
4. Mention *one* example each of a monoatomic and a diatomic molecule.

5. What do you mean by inter-molecular spacing ?
6. Describe a simple experiment to illustrate the existence of inter-molecular spacing.
7. What do you mean by inter-molecular forces ?
8. What are the forces of cohesion and adhesion ?
9. State *three* characteristics of molecules of matter which determine its solid, liquid and gaseous state.
10. How do solids, liquids and gases differ in their following properties :
    (a) Size (b) Shape (c) Density ?
11. The molecules in a substance are in motion. What type of path do they follow ?
12. Describe a simple experiment to illustrate that molecules are not at rest, but they constantly move.
13. Write down five general properties of solids, liquids and gases.
14. Give the molecular model for a solid and use it to explain why a solid has a definite volume and a definite shape.
15. Describe the molecular model for a liquid. How does it explain that a liquid has no definite shape, but has a definite volume ?
16. A gas has neither a definite volume nor a definite shape. Describe the molecular model to explain it.
17. Distinguish between the *three* states of matter — solid, liquid and gas on the basis of their molecular models.
18. Distinguish between solids, liquids and gases on the basis of their following properties :
    (a) compressibilty (b) fluidity
    (c) rigidity (d) expansion on heating
19. What do you mean by change of state of matter ? Explain :
    (a) the change of a solid into a liquid at a constant temperature, and
    (b) the change of a liquid into a gas at a constant temperature.
20. Complete the following :
    (a) Solid $\xrightarrow{\text{..........}}$ Liquid
    (b) .... $\xrightarrow{\text{Boiling}}$ Gas

Project Work

- Using colour pencils, draw the molecular models of solids, liquids and gases.
- Make a list of substances that exist in nature as solid, liquid and gas.

2 Physical Quantities and Measurement

Theme : Whenever we make a measurement, we require a number which answers the 'how' part of it and a unit which tells us that we are talking about. The unit that is used for a physical quantity is universally accepted and used so that science is communicated and understood all over the world, without any ambiguities. Length, mass, time and temperature are some of the physical quantities that are discussed in detail. They have their own units and symbols for representation. Different devices are required to make measurements of these quantities. How to use a device properly for measurement is an important aspect of learning physics. Area is an example of a physical quantity that can be expressed in terms of a product of two measurements in length. Children learn to develop skills of converting the magnitude of a physical quantity from one unit to its other related unit.

In this chapter you will learn

Measurement of length

- Concept of length as distance between two points
- Measurement of length (ruler, measuring tape)
- Units (with symbol and full name)

Name of unit	Symbol
centimetre	cm
metre	m
Kilometre	km
inch	inch
foot	ft

Measurement of Mass

- Concept of mass as matter contained in an object
- Measurement of mass (Beam Balance, Electronic Balance)
- Units (with symbol and full name)

Name of unit	Symbol
milligram	mg
gram	g
kilogram	kg

Measurement of Time

- Concept of time and explanation in terms of hours, minutes and seconds
- Measurement of time (Clock, watch, stop watch.)
- Units (with symbol and full name)

Name of unit	Symbol
Second	s
Minutes	min
Hour	h

(No distinction of S.I., metric, MKS, CGS)

Measurement of Temperature

- Temperature as a measure of degree of hotness or coldness of body
- Measurement of temperature (clinical thermometer, laboratory thermometer)
- Normal temperature of a human body
- Units (with symbol and full name)

Name of unit	Symbol
Celsius	°C

Measurement of Area

- Concept of area
- Area of regular shapes (using graph paper)

LEARNING OBJECTIVES

The children will be able to :

- define length, mass and time;
- express length, mass, time, temperature and area in proper units with proper symbols;
- measure length of objects using a ruler and a measuring tape;
- measure mass of an object using a beam balance and an electronic balance;
- measure time using a clock, a watch and a stop-watch;
- relate temperature of an object with its hotness or coldness;
- measure temperature of a person using a clinical thermometer;
- measure temperature of an object using a laboratory thermometer;
- measure area of a irregular object using a graph paper;
- convert a physical quantity from one unit into other related units

MEASUREMENT – ITS IMPORTANCE

We all make measurements in our daily life. *For example*, when we give a certain piece of cloth to the tailor for stitching a trouser, he takes the measurement for length of our trouser with his measuring tape. The peon in the school has to ring the bell after each period. For this, he measures time interval with a clock. When we buy fruits and vegetables, the vegetable seller measures their mass by his balance. When we are suffering from fever, the doctor measures our body temperature with a thermometer.

Our senses of touch or sight are not reliable for measurement. The senses are subjective, therefore we must make use of tools or instruments to get an exact measurement.

Measurement is basically a process of comparison : For measurement, we need a universally accepted unit and then we find how many times that unit is contained in the given quantity. *For example*, if we say that the length of a room is 5 metre, we mean that the unit of length is metre and the length of room is 5 times of the unit metre. If we say that the mass of sugar is 2 kilogram, we mean that the unit of mass is kilogram and the mass of sugar is 2 times the unit kilogram. Thus, a measurement needs *two* things :

1. The unit u, and
2. The number n which tells us how many times that unit is contained in that quantity.

Thus, a measurement is expressed as :

Measurement = $n \times u = n\,u$

CHOICE OF UNIT

The unit must have the following properties :

(i) It should be of convenient size, and

(ii) It must be universally accepted, *i.e.* its value must remain same at all places and at all times. It should not change with the change of place or time.

Thus, to measure a quantity, we choose a known fixed quantity of that kind as the unit and then find how many times that fixed quantity (or unit) is contained in the given quantity, *i.e.*

> Measurement is a comparison of an unknown quantity with a known fixed quantity of the same kind.

The value obtained on measuring a quantity is called its magnitude. The magnitude of a quantity is expressed as numbers in its unit. *For example*, to measure the length between two points, we take a ruler of length one metre as unit and if the length on measuring, is 15 times of the unit metre, then we write length = 15 metre.

Do You Know ?

In the past, different units were used to measure the length, mass and time in different countries. There were the following three systems of units:

1. Centimetre-gram-second (C.G.S.) system
2. Foot-pound-second (F.P.S.) system, and
3. Metre-kilogram-second (M.K.S.) system or metric system.

The units of length, mass and time in these systems are listed below:

System	Unit and symbol of length	Unit and symbol of mass	Unit and symbol of time
1. C.G.S.	centimetre (cm)	gram (g)	second (s)
2. F.P.S.	foot (ft)	pound (lb)	second (s)
3. M.KS.	metre (m)	kilogram (kg)	second (s)

BASIC PHYSICAL QUANTITIES

A quantity that can be measured is called a physical quantity. In our daily life, we measure the following four basic physical quantities :

1. Length   2. Mass
3. Time   4. Temperature

In 1960, the scientists all over the world accepted a set of units for measuring the basic physical quantities length, mass, time and temperature. This set of units is called the standard international units which in short form is written as S.I. units. The S.I. units o basic quantities and their symbols are give in the following table.

S.I. units of basic quantities and their symbol

Quantity	S.I. unit	Symbol for S.I. unit
1. Length	metre	m
2. Mass	kilogram	kg
3. Time	second	s
4. Temperature	kelvin	K

Sometimes, the size of S.I. unit t express a physical quantity is not of convenient size, it is either too small or to big. Then we use submultiple or multiple the S.I. unit to express that physical quantit using prefixes such as milli, centi or kilo wit that unit. The table below shows the meanin of prefixes milli, centi and kilo :

Meaning of the prefixes

Prefix and symbol	Meaning
1. milli (m)	$\frac{1}{1000} = 10^{-3}$
2. centi (c)	$\frac{1}{100} = 10^{-2}$
3. kilo (k)	$1000 = 10^{3}$

For example, if diameter of a pin i 0·0001 metre, it can be written a 0·1 millimetre (or 0·1 mm). Similarly, distance between two cities is 2000 metre, can be written as 2 kilometre (or 2 km).

Convention while writing the S.I. Units

1. Symbols used for units (other than th names of the scientists) are alway written in small letters. *For example* :

Symbol of Kilogram — kg and not Kg

Symbol of metre — m and not M

Symbol of second — s and not S

2. Some units are named after the scientists. In words such units are written in lower letters. *For example*, the unit of current is named after the scientist Ampere. In words the unit of current is written as ampere and not as Ampere.
3. Symbol for a unit named after a scientist is always written with a capital letter. *For example* :

   Symbol of Fahrenheit — F and not f

   Symbol of Ampere — A and not a

   Symbol of Newton — N and not n

   Symbol of Kelvin — K and not k
4. The unit and its symbol are never written in plural.
5. In words the unit is written in small letters. *For example*, metre, not Metre; kelvin, not Kelvin etc.
6. A space is left between the symbols of two units when they are used as product. *For example*, the symbol of unit newton x second is N s.
7. Negative powers are used for the compound units formed by dividing one unit by the other. *For example*, the unit of speed is metre/second (m/s). It can also be expressed as m s^{-1}.

MEASUREMENT OF LENGTH

Length is the distance between two points. When we measure the width (or thickness), breadth, depth, diameter, height etc., we actually measure the length.

Units of length

The S.I. unit of length is metre. In short form it is written as m.

A metre was intially defined as the distance between two points on a rod of platinum alloy kept at 0°C in the International Bureau of Weights and Measures at Sevres near Paris.

Nowadays one metre is defined as the distance travelled by light in air in $\frac{1}{299,792,458}$ of a second (or in $\frac{1}{3\times10^8}$ of a second).

Simple multiples and sub-multiples of the metre : It is not convenient to express the long lengths in terms of metre. They are expressed in kilometre (in short form km).

i.e. a kilometer is a multiple of metre.

One kilometre is equal to 1000 metre

1 kilometre = 1000 metre

In short form, 1 km = 1000 m (or 10^3 m)

Thus, the distance between Delhi and Agra, instead of writing as 200,000 metre is more conveniently written as 200 kilometre.

Similarly, it is convenient to express the lengths which are shorter than a metre in centimetre. *For example*, the length of a pen is expressed in centimetre. A centimetre is a sub-multiple of metre. In short form, we write centimetre as cm.

One centimetre is one-hundredth part of a metre or 100 centimetre make 1 metre. Thus,

1 metre = 100 centimetre (or1 m = 100 cm)

or 1 centimetre = $\frac{1}{100}$ metre (or 1 cm = $\frac{1}{100}$ m)

The lengths still shorter than a centimetre are expressed in **millimetre**. *For example*, the thickness of a coin is expressed in millimetre. A millimetre is another sub-multiple of metre. In short form, millimetre is written as mm.

One millimetre is one thousandth part of a metre or 1000 millimetre make one metre. Thus,

1 metre = 1000 millimetre (or 1 m = 1000 mm)

or 1 millimetre = $\frac{1}{1000}$ metre (or 1 mm = $\frac{1}{1000}$ m)

The sub multiple and multiple units of length are summarized in the following table.

Multiples and submultiples of a metre :

Multiple

Kilometre (symbol km)

1 km = 1000 m

Submultiples

(1) *Centimetre* (symbol cm)

$1 \text{ cm} = \frac{1}{100} \text{ m or } 10^{-2} \text{ m}$

(2) *Millimetre* (symbol mm)

$1 \text{ mm} = \frac{1}{1000} \text{ m or } 10^{-3} \text{ m}$

In F.P.S. system, the unit of length is **foot** (symbol **ft**). Its smaller unit is inch (symbol inch). They are related as :

1ft = 12 inch

The bigger unit than foot is **yard** (symbol yd) where

1 yard = 3 foot = 36 inch

or 1 yd = 3 ft = 36 inch

In C.G.S. system, the unit of length is **centimetre** (symbol **cm**).

Relationship between ft, inch and cm:

1 inch = 2·54 cm

1 ft = 30·48 cm

and, 1 yd = 91·44 cm or 0·91 m (nearly)

Do You Know ?

1. Apart from millimetre (mm) and centimetre (cm), sometimes we also use decimetre (symbol dm) as sub multiple of metre.

   1 decimetre = $\frac{1}{10}$ metre = 10^{-1} metre

2. Apart from kilometre, sometimes we also use decametre (dam) and hectometre (hm) as multiples of metre.

   1 decametre = 10 metre

   and 1 hectometre = 100 metre

Devices for measuring length

We use mainly the following two devices for measuring the length :

1. A metre ruler and 2. A measuring tape

1. Use of a metre ruler to measure length

Description of a metre ruler : Generally, we use a wooden (or plastic) ruler to measure the length. It is 1 metre long and is divided into 100 equal parts. Each part is a centimetre. Each centimetre is further divided into 10 equal parts. Each small part is a millimetre. Thus, a metre ruler is marked in centimetre and millimetre. Smaller rulers measuring 50 cm, 30 cm and 15 cm are also available. Fig. 2.1 shows a ruler of length 15 cm.

Fig. 2.1 A ruler 15 centimetre long with each division equal to 1 millimetre

Thus, a metre ruler has a small division of 1 mm. It can measure a length correct up to 1 mm.

Measurement of length of an object with a metre ruler : To measure the length of an object with a metre ruler, the ruler is placed with its markings close to the object. Then the zero mark on the ruler is made to coincide with one end of the object. Now the position of the other end of the object is read on the ruler. This reading gives the length of the object. But a ruler has some thickness, so while looking at the reading on the scale, we get different readings when the eye is kept at different positions. *This is called the error of parallax. To avoid it, the correct reading is obtained when the eye is kept in front of and in line with the reading to be taken.*

Fig. 2.2 illustrates the measuring of length of a rod *PQ*. The end *P* of the rod coincides with the zero mark on the ruler. If the end *Q* of the rod is read by keeping the eye at the position *A*, the reading is 4·2 cm. If the eye is at the position *C*, the reading is 4·4 cm. Both these readings are wrong. The correct position of the eye is *B*, vertically above the end *Q*. When the eye is at the position *B*, the reading is 4·3 cm. So the correct length of the rod is 4·3 cm.

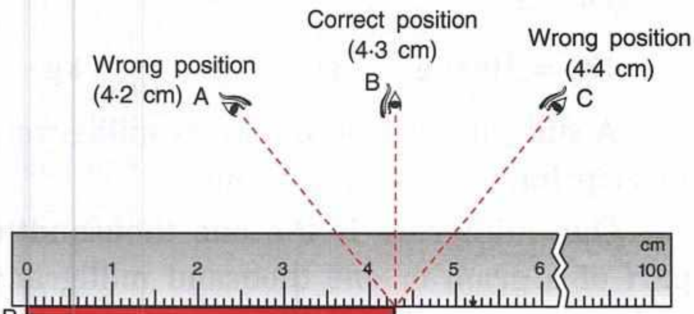


Fig. 2.2 Measuring the length of a rod PQ with a metre ruler

Note : Sometimes, the ends of the ruler get damaged with use and its zero mark may not be visible. To measure the length of an object with such a ruler, the object is placed close to a specific marking on the ruler and positions of both ends of the object are read on the ruler. The difference of the two readings gives the length of the object. In Fig. 2.3, the reading on ruler at the end *X* is 1·0 cm and at the end *Y* is 4·3 cm. So the length of the rod *XY* is 4·3 – 1·0 = 3·3 cm.

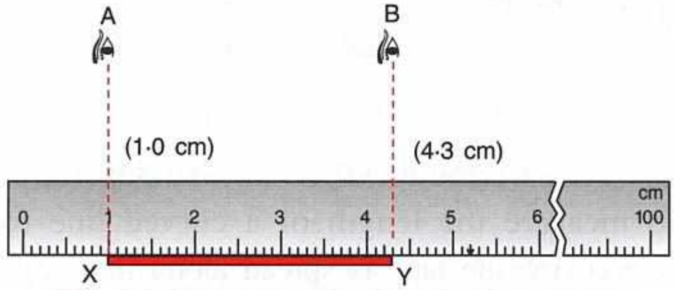


Fig. 2.3 Measuring the length of a rod XY with a damaged metre ruler

Thus, a metre ruler can measure a length up to 1 mm. A metre ruler can only be used to measure the length of straight objects.

Do You Know ?

1. A metre ruler can be used to measure the thickness of a coin even if it is less than 1 mm. For this, the height of a stack of few number of coins (say 10) is measured by using the metre rule and then the thickness of a coin is obtained by dividing the height with the number of coins in the stack.

2. To measure a length smaller than 1 mm, vernier callipers is used that measures lengths up to 0·1 mm and screw gauge is used which measures length up to 0·01 mm.

2. Use of measuring tape to measure a length

Description of a measuring tape : A measuring tape is a flexible ruler. It consists of a ribbon of cloth, plastic, fiber glass or metal strip with lines as markings in cm and mm on it. It can easily be carried in your pocket or tool-kit. It is available in various lengths say 1 m, 5 m, 10 m, 50 m and 100 m. Surveyors use a tape of length 100 m. Fig. 2.4 shows different measuring tapes.

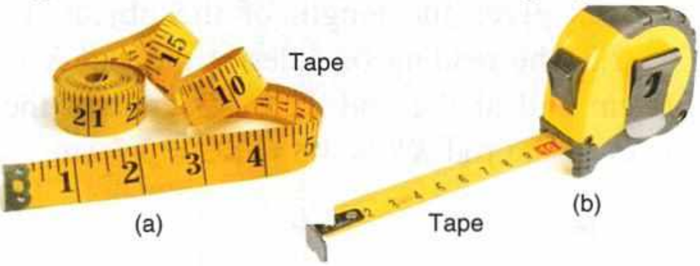


Fig. 2.4 Measuring tapes

Measurement with a measuring tape : To measure the length of a curved line (or object) *AB*, the tape is spread along the length of the curved line as shown in Fig. 2.5. The ends of the line *A* and *B* are read on the tape. The difference of these readings gives the length of the curved line. In Fig. 2.5, the length of curved line *AB* is 8·2 cm – 5·0 cm = 3·2 cm.

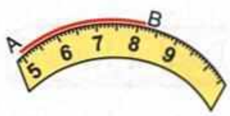


Fig. 2.5 Measuring the length of a curved line by a measuring tape

Fig. 2.6 Measuring the length of a trouser by a tailor using a measuring tape.

MEASUREMENT OF MASS

The mass of a body is the quantity of matter contained in it.

Unit of mass

The S.I. unit of mass is kilogram. In short form, it is written as kg.

In 1889, one kilogram was defined as the mass of a cylinder of platinum-iridium alloy kept at the International Bureau of Weights and Measures at Sevres near Paris.

However, at present, the mass of 1 litre (= 1000 ml) of water at 4°C is taken as 1 kilogram.

Multiple and submultiple units of mass

A bigger unit of mass is **quintal**.

One hundred kilogram make one quintal *i.e.* 1 quintal = 100 kg

A still bigger unit of mass is **metric tonne**.

Ten quintal make one metric tonne *i.e.*

1 metric tonne = 10 quintal = 1000 kg

The mass of a light body is expressed in a smaller unit of mass called **gram**. The short form of it is **'g'**.

One gram is the one-thousandth part of a kilogram or one thousand gram make one kilogram *i.e.*

$$1\text{kg} = 1000 \text{ g} \quad \text{or} \quad 1 \text{ g} = \frac{1}{1000} \text{ kg}$$

A still smaller unit of mass is **milligram**. In short form it is written as mg.

One milligram is the one thousandth part of a gram or **one thousand milligram make one gram,** *i.e.*

$$1 \text{ g} = 1000 \text{ mg} \quad \text{or} \quad 1 \text{ mg} = \frac{1}{1000} \text{ g}$$

The table below gives the different multiple and submultiple units of mass.

Multiple and submultiple units of mass :

Multiples :

(1) *Quintal* : 1 quintal = 100 kg

(2) *metric tonne* :

1 metric tonne = 10 quintal = 1000 kg

Submultiples :

(1) *Gram* (symbol g)

$$1 \text{ g} = \frac{1}{1000} \text{ kg} = 10^{-3} \text{ kg}$$

(2) *Milligram* (symbol mg)

$$1 \text{ mg} = \frac{1}{1000} \text{ g} = 10^{-3} \text{ g} = 10^{-6} \text{ kg}$$

In F.P.S. system, the unit of mass is pound (symbol 1b).

In C.G.S. system, the unit of mass is gram (symbol g).

Relationship between gram, kilogram and pound :

$$1 \text{ g} = \frac{1}{1000} \text{ kg} = 10^{-3} \text{ kg}$$

$$1 \text{ lb} = 453{\cdot}59 \text{ g}$$

Devices for measuring the mass

For measuring the mass of a body, we generally use the following *two* balances :

1. The beam balance, and
2. The electronic balance.

1. Use of a beam balance to measure the mass of a body.

Fig. 2.7 shows the simple form of a beam balance, which is most commonly used. It consists of a straight beam of wood (or metal) of length about 50 cm. The beam has a support just at its middle, having a pointer. Two identical pans are suspended at the ends

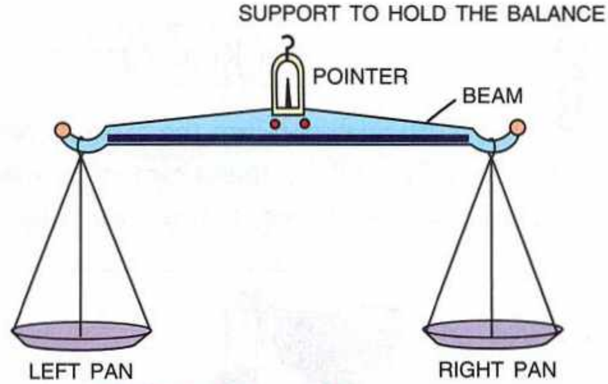


Fig. 2.7 A beam balance

of the beam by means of strings of equal length. Each pan is at the same horizontal distance from the support *i.e.* the length of beam of each pan from the support is equal. The balance can be held up by the support.

To measure the mass of an object, standard weights are used. Fig. 2.8 shows some standard weights 20 kg, 10 kg, 5 kg, 2 kg and 1 kg. However, smaller weights of 500 g, 200 g, 100 g, 50 g, 20 g, 10 g and 5 g are also available.

Fig. 2.8 Some standard weights used to measure mass

For measuring, the beam balance is first held up. On holding up the balance, it is noticed that when there is nothing on either pan, the beam is horizontal. The body whose mass is to be measured is placed on the left pan. The standard weights are placed on the right pan. They are so adjusted that the beam is again horizontal on holding the balance up. The total of the standard weights gives the mass of the given body.

Do You Know ?

Some shopkeepers use the grocer's balance shown in Fig. 2.9 for measurement of mass of objects like vegetables, pulses, rice, sugar, salt etc.

Fig. 2.9 Grocer's balance

A goldsmith requires an accurate and sensitive balance, so he uses a physical balance shown in Fig. 2.10. This balance is also used in the laboratory.

Fig. 2.10 A physical balance

2. Use of electronic balance to measure the mass of an object.

Nowadays, for the precise and accurate measurement of mass of an object, electronic balance is used. They are available to measure a small mass of 1 mg, as well as a large mass of the order of quintal. The small electronic balances are portable while the big electronic balances are fixed at a place.

Fig. 2.11 shows a simple electronic balance.

An electronic balance has the following *three* parts :

1. **The structure :** It is the load bearing part which transfers the load of the object to the load cell.
2. **The load cell :** It converts the load (*i.e.* force) into electrical signals.
3. **The signal conditioner :** It is the electronic part which processes the electrical signal and displays the mass.

Fig. 2.11 Electronic balance

Electronic balances measure the mass automatically without any prior setting or using a separate weight box. They directly measure the mass of the object and display it in the digital form on the screen.

MEASUREMENT OF TIME

The interval between two instances or events is called time. We measure time in terms of the **mean solar day**. A solar day is the time taken by the earth to complete one rotation about its own axis. The mean of 365 solar days in a year is called the mean solar day.

Units of time

The S.I. unit of time is second. In short form, it is written by the letter **s**.

One second is defined as $\frac{1}{86400}$ part of a mean solar day. *i.e.*,

$$1 \text{ s} = \frac{1}{86400} \times \text{one mean solar day.}$$

If you look at the pendulum of a wall clock, the pendulum moves from one extreme to the other extreme in one second. Thus,

One second is the time interval between two consecutive ticks that we hear from a pendulum wall clock.

> *Note :* In MKS or metric system, F.P.S. system as well as in CGS system, the unit of time is second (symbol s).

The second is a smaller unit of time.

A bigger unit of time is **minute** (symbol min). **60 second make one minute,** *i.e.*

1 minute = 60 second or 1 min = 60 s

A still bigger unit of time is **hour** (symbol h). **60 minute makes one hour** *i.e.*

1 hour = 60 minute or 1 h = 60 min

Thus, 1 h = 60 min = 60 × 60 s = 3600 s

Another bigger unit of time is **day**. 24 hour make one day. One day is the time taken by the earth to rotate once on its own axis. Thus

1 day = 24 hour
= 24 × 60 min = 1440 min
= 24 × 60 × 60 s = 86400 s

A **year** is another bigger unit of time. **365 days make one year**. One year is the time taken by the earth to complete one revolution around the sun, *i.e.*

1 year = 365 days
= 365 × 86400 s
= $3{\cdot}15 \times 10^7$ s

These units of time are summarized below:

> 1 min = 60 s
> 1 h = 60 min = 3600 s
> 1 day = 24 h = 86400 s
> 1 year = 365 days = $3{\cdot}15 \times 10^7$ s

Devices for measuring time

We use (1) Pendulum clock and (2) A watch, to find the time in our daily life.

1. **A pendulum clock :** Fig. 2.12 shows a pendulum clock. In it, time is measured by making use of the time taken by its pendulum to complete one oscillation. The pendulum completes one to and fro oscillation in 2 s *i.e.* it moves from one extreme to the other extreme in 1 s and then returns from the other extreme to the first extreme in next 1 s. The circular dial has 12 markings divided in four quadrants. Each marking is further divided in five small divisions, so there are in all 60 small divisions. There are three needles joined to the axle of the gear wheels at the centre of the dial. These needles are named as second's arm, minute's arm and hour's arm. The second's arm moves by one small division in the time interval when the pendulum moves from one extreme to the other extreme (*i.e.* in 1 s). The minute's arm moves by a small division when the second's arm completes one round (*i.e.* in 60 s) and the hour's arm moves by 5 small divisions when the minute's arm completes one round (*i.e.*, 1 h).

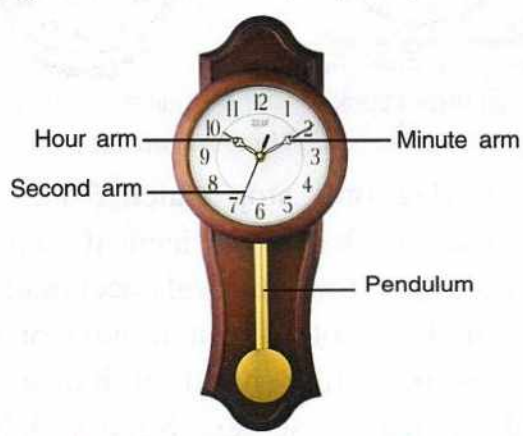


Fig. 2.12 Pendulum clock

2. **A watch :** Fig. 2.13 shows a watch. A watch makes use of the gear wheels. These wheels set up the speed of rotation of the second's, minute's and hour's arms. The second's arm is driven by a wound up spring. The dial of a watch is graduated similarly as that of the pendulum clock.

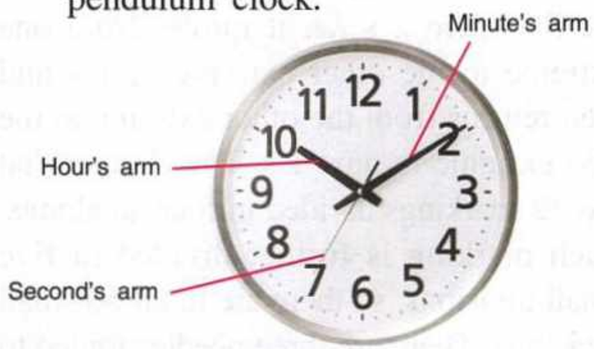


Fig. 2.13 Watch

Measuring devices for a short time interval

The short time interval of an event is measured with the help of a stop clock or a stop watch. Fig. 2.14 shows a stop clock and a stop watch. They have arrangements 'to start', 'to stop' and 'to reset at zero'.

Fig. 2.14 Short time interval measuring devices

An electronic stop watch (Fig. 2.15) is more accurate than a mechanical stop watch. It can measure time intervals accurately up to 0·01s. It does not have a minute or second arm. On the other hand, it has a digital (number) display screen. Such watches are used for measuring the timings of athletic activities such as time taken by the atheletes to complete a 100 m race.

Fig. 2.15 An electronic stop watch

MEASUREMENT OF TEMPERATURE

If we touch an object, it appears hot to us if heat passes from the object to our hand while it appears cold if heat passes from our hand to the object. Thus, hotness or coldness of an object depends on the direction of flow of heat. Heat always flows from high temperature to low temperature. Thus

> The temperature is the measure of degree of hotness or coldness of an object.

Units of temperature

The S.I. unit of temperature is **kelvin** (symbol **K**).

Apart from kelvin, the other *two* most commonly used units are :

1. **Degree celsius or degree centigrade (symbol °C) :** It was given by the scientist Andrews Celsius, and
2. **Degree fahrenheit (symbol °F) :** It is named after the name of the scientist G.D. Fahrenheit.

These units and their symbols are given below :

Unit of temperature	Symbol
1. kelvin	K
2. Degree celsius or degree centigrade	°C
3. Degree fahrenheit	°F

Note : **(1)** The unit kelvin is never written as degree kelvin (or K is not written as °K).

(2) The ice point (*i.e.* freezing point of water), the steam point (*i.e.* the boiling point of water) and the number of degrees in between the ice point and boiling point on the three scales are as follows :

Scale of temperature	Ice point	Steam point	Number of degrees in between the ice point and steam point
1. Kelvin	273 K	373 K	100
2. Celsius	0°C	100°C	100
3. Fahrenheit	32°F	212°F	180

3. One degree on Celsius scale is equal to one degree on Kelvin scale.
4. One degree on Celsius scale is equal to $\frac{9}{5}$ (or 1·8) degree on Fahrenheit scale.
5. There are 100 divisions between the ice point and steam point in the Celsius scale, so it is also called the centigrade scale.

Device used to measure the temperature of an object

Temperature is measured with a thermometer.

Description of a thermometer : Fig. 2.16 shows a laboratory thermometer. It consists of a glass capillary tube with a bulb at one end. The bulb is filled with mercury. The long part of capillary is called the stem. The stem has markings from –10°C to 110°C.

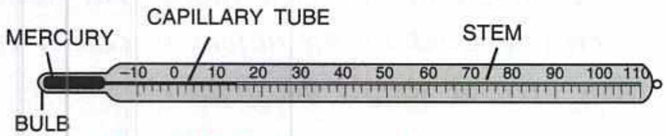


Fig. 2.16 Laboratory thermometer

The zero mark is at the level of mercury in the capillary when its bulb is placed in melting ice, while the 100 mark is at the level of mercury in the capillary when its bulb is placed in boiling water. The space between the 0 mark and 100 mark is divided into 100 equal divisions. Each division is called a degree.

Measuring the temperature of an object using a laboratory thermometer

To measure the temperature of an object with the help of a laboratory thermometer, the bulb of the thermometer is kept in contact with the object. The mercury rises in the capillary. Wait for some time. When the mercury does not rise further and gets stabilised, look at the mark up to which the mercury has risen, keeping your eye in the horizontal line of the level of mercury. Fig. 2.17 shows measuring the temperature of water. In Fig. 2.17, the temperature of water is 30°C.

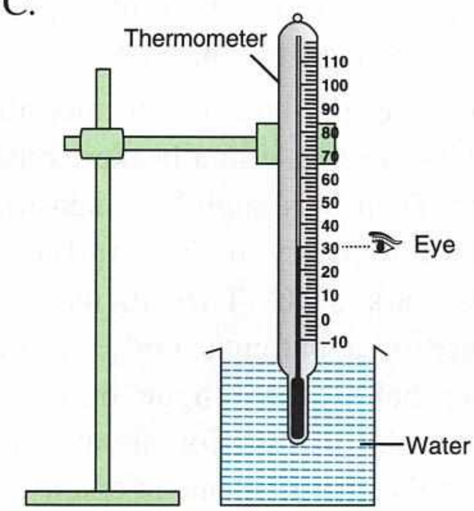


Fig. 2.17 Measuring the temperature of water

Clinical thermometer

Doctors use a special thermometer called the **clinical thermometer** for measuring the temperature of a patient's body.

Description of a clinical thermometer : A clinical thermometer has markings from 35°C to 42°C. It has a slight bend or kink in the stem just above the bulb. This kink is called constriction. This constriction prevents the mercury from falling back all by itself. The temperature of a healthy person is 37°C. This temperature is marked by a red arrow.

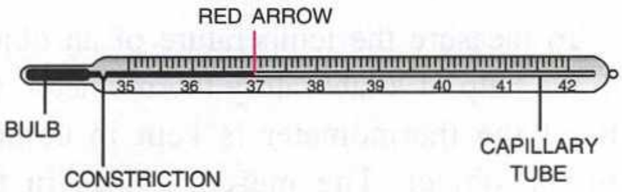


Fig. 2.18 Clinical thermometer

Note : Clinical thermometers marked in °F are also available. They have markings from 95°F to 110°F. The red arrow indicating the temperature of a healthy person is at 98·6 °F.

Measuring the temperature of a patient's body with a clinical thermometer

Before use, the bulb of the thermometer is washed by keeping it in a beaker containing cold water. Then it is slightly jerked to bring the level of mercury in its capillary tube below the mark 37°C. Then to measure the temperature of a patient's body, its bulb is kept either below the tongue or under the arm's pit of the patient for about a minute after which the thermometer is taken out and its reading is noted. If the temperature of the patient's body is above 37°C, he/she is said to be suffering from fever.

Do You Know ?

1. Normal temperature of human body is 37°C or 98·6°F.
2. Nowadays, instead of the mercury thermometers, digital thermometers are used.
3. A clinical thermometer can not be used to measure the temperature of boiling water (*i.e.* 100 °C) because it can measure only up to 42 °C.

Note : The physical quantities like length, mass, time and temperature are independent of each other. They are not related amongst themselves. Such quantities are called fundamental quantities. On the other hand, area, volume, speed etc. are the quantities which are expressed in terms of the measurable fundamental quantities like, length, mass, time etc. They are called derived quantities. *For example :*

$$\text{Area} = \text{Length} \times \text{breadth}$$

$$\text{Volume} = \text{Length} \times \text{breadth} \times \text{height}$$

$$\text{Speed} = \frac{\text{Length of path}}{\text{Time}} = \frac{\text{Distance}}{\text{Time}}$$

MEASUREMENT OF AREA

Each object has a surface. *For example*, a brick, a matchbox, a leaf, a piece of paper, etc. all have a surface. A brick and matchbox have the surface consisting of six faces. A leaf and a piece of paper have th surface consisting of two faces. *The tota surface occupied by an object is called it surface area or simply the area.*

The area can be expressed in terms of the product of two measurements in length.

For example : To find the area of the base of a geometrical box, we measure its length and breadth. If the length of the geometrical box is 20 cm and its breadth is 7 cm, then area of the geometrical box is given as :

Area of the base of a geometrical box

$= \text{length} \times \text{breadth}$

$= 20 \text{ cm} \times 7 \text{ cm}$

$= 140 \text{ cm}^2$

Area of regular shapes

The area of an object of a regular shape can be calculated by using the following formulae:

1. Area of a square of side l

   $= \text{side} \times \text{side} = l \times l = l^2$

2. Area of a rectangle of length l and breadth b

   $= \text{length} \times \text{breadth} = l \times b = lb$

3. Area of a triangle of length of base l and height h

   $= \frac{1}{2} \text{ length of base} \times \text{height}$

   $= \frac{1}{2} lh$

4. Area of a circular lamina of radius r

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

   Where $\pi = \frac{22}{7}$ or 3·14.

Use of graph paper to find the area of a regular or irregular surface

The area of a regular or irregular surface can also be obtained by using a graph paper, A graph paper has small squares each side of which is 1 mm *i.e.*, the area of one small square is 1 mm × 1 mm = 1 mm^2. But it is very difficult to count these small squares, so we count the squares of each side 1 cm, the area of which is 1 cm × 1 cm = 1 cm^2. This therefore gives an approximate area of the given surface.

Note : In this chapter on graph, 1 cm has been divided into 5 divisions for the clarity of diagrams.

Procedure : Place the given surface on a graph paper. Draw its outline on the paper and remove it. Now count the number of complete squares. To this add the number of incomplete squares which are half or more than half (within the outline). Ignore the squares which are less than half (within the outline). This number when multiplied by the area of one square gives the approximate area of the given surface. Thus,

Approximate area = (No. of complete squares + No. of half or more than half of incomplete squares) × Area of one square.

Examples :

1. In Fig. 2.19 the complete squares marked as (√) are 7 and the half or more than half squares marked as (•) are 3.

   ∴ Area of triangular lamina

   $= (7 + 3) \times 1 \text{ cm}^2$

   $= 10 \text{ cm}^2$

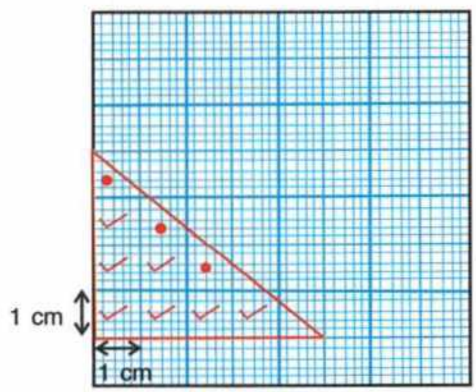


Fig. 2.19 Measurment of area of a triangular lamina

2. In Fig. 2.20 the complete squares are marked as ($\surd$) and the half or more than half squares are marked as (•)

The number of complete squares = 13

The number of half or more than half squares = 7

Area of surface

$= (13 + 7) \times 1\ cm^2 = 20\ cm^2$

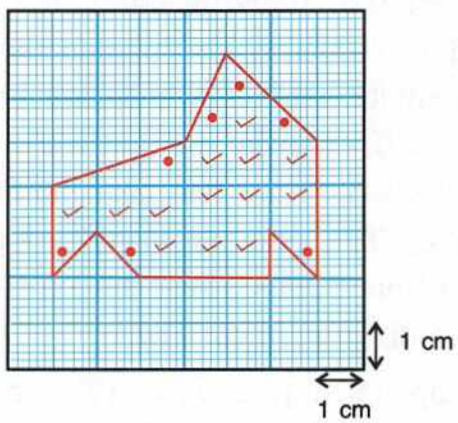


Fig. 2.20 Measuring the area of an irregular surface using a graph paper

3. In Fig. 2.21, the number of complete squares ($\surd$) = 22, the number of half or more than half squares (•) = 9

Area of surface

$= (22 + 9) \times 1\ cm^2 = 31\ cm^2$

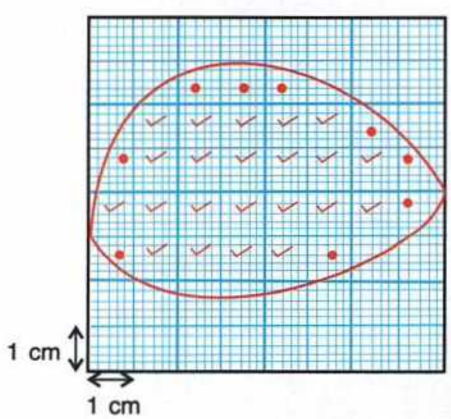


Fig. 2.21 Measuring the area of an irregular surface using a graph paper

Units of area

The S.I. unit of area is square metre or metre^2 which in short form is written as m^2.

One square metre is the area of a square of each side of 1 metre (Fig. 2.22).

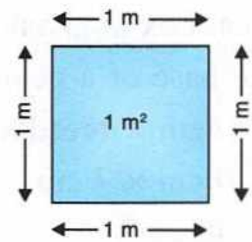


Fig. 2.22 A square of area = 1 m^2

Multiple and sub multiple units of area

The square metre is a convenient unit to express the area of a room or the area of a plot of land for a building, etc. But to express the area of a big agricultural field or a city, we use the bigger units of area called the **decametre^2 (are) hectare** and **square kilometer**.

Decametre square (are) : *One square decametre (or are) is the area of a square of each side 1 decametre i.e., 10 metre.* Thus,

$$1\ \text{decametre}^2 = 10\ \text{metre} \times 10\ \text{metre} = 100\ \text{metre}^2$$

$$\text{or } 1\ \text{decametre}^2\ (\text{or } 1\ \text{are}) = 100\ m^2$$

Hectare : *One hectare is the area of a square of each side 100 metre.* Thus,

$$1\ \text{hectare} = 100\ \text{metre} \times 100\ \text{metre} = 10000\ \text{metre}^2\ (\text{or } 10^4\ m^2)$$

Square kilometre : *One square kilometre is the area of a square of each side 1 kilometre.* Thus,

$$1\ km^2 = 1\ km \times 1\ km = 1000\ m \times 1000\ m = 10^6\ m^2$$

But to express the area of small objects such as a book, matchbox, pin head, pencil etc. small units such as square decimetre (dm^2), square centimetre (cm^2) and square milimetre (mm^2) are used.

Square decimetre : *One square decimetre is the area of a square of each side 1 decimetre* (= 10 cm). Thus,

$$1\ dm^2 = 10\ cm \times 10\ cm = 100\ cm^2$$

Square centimetre : *One square centimetre is the area of a square of each side 1 centimetre*. Thus,

$$1\ cm^2 = \left(\frac{1}{100}\ m\right) \times \left(\frac{1}{100}\ m\right) = \frac{1}{10000}\ m^2$$

$$= 10^{-4}\ m^2$$

Similarly $1\ mm^2 = 1\ mm \times 1\ mm$

$$= \frac{1}{1000}\ m \times \frac{1}{1000}\ m$$

$$= 10^{-6}\ m^2$$

Thus, the different units of area are related as follows :

$$1\ \text{are} = 100\ m^2$$
$$1\ \text{hectare} = 10000\ m^2 = 100\ \text{are}$$
$$1\ km^2 = 10{,}00{,}000\ m^2$$
$$= 100\ \text{hectare}$$
$$1\ dm^2 = 100\ cm^2 = 10^2\ m^2$$
$$1\ cm^2 = (1/10000)\ m^2 \text{ or } 10^{-4}\ m^2$$
$$\text{and } 1\ mm^2 = 10^{-6}\ m^2$$

Do You Know ?

(1) 1 square yard = 1 yard × 1 yard

= 0·9144 m × 0·9144 m

= 0·836 m^2 (or 0·84 m^2 nearly)

(2) 1 square ft = 0·09290 m^2

(3) 1 acre = 4046·856 m^2

RECAPITULATION

- The observation of a phenomenon is made possible by using the five senses: sight, smell, touch, hearing and taste.
- Our senses are not always reliable. They are subjective.
- Sometimes it is necessary to make an exact measurement.
- Physics is a science of measurement.
- We use instruments to get an exact measurement.
- Four basic measurements in our daily life are: measurement of length, measurement of mass, measurement of time, and measurement of temperature.
- Measurement is basically a process of comparison of the given quantity with a standard unit.
- For measuring a quantity we need a unit, and then we find the number of times that unit is contained in that quantity.
- The unit selected for measurement should be of a convenient size internationally acceptable and it must not change with place or time.

- The distance between two fixed points is called length.
- The S.I. unit of length is metre (m). Its multiple is kilometre (km), where 1 km = 1000 m. Its sub multiples are centimetre (cm) and millimetre (mm), where 1 cm = 10^{-2} m and 1mm = 10^{-3} m.
- The FPS unit of length is foot (ft) and its sub multiple is inch where 1 ft = 12 inch and 1 ft = 30·48 cm.
- The most common instruments used to measure length are the metre ruler and the measuring tape which are marked in cm and mm.
- To measure a length accurately with a metre ruler, the ruler should be placed with its markings close to the object and parallel to its length. The eye is kept in front of and in line with the reading to be taken.
- The quantity of matter contained in a body is called its mass.
- The S.I. unit of mass is kilogram (kg). Its multiples are quintal and metric tonne. 1 quintal=100 kg and 1 metric tonne = 10 quintal = 1000 kg. Its sub multiples are gram (g) and milligram (mg) where 1 g = 10^{-3} kg and 1 mg = 10^{-6} kg.
- The FPS unit of mass is pound (lb) where 1lb = 453·59 g.
- Mass of a body is measured by using a beam balance or an electronic balance.
- The interval between two instances or events is called time.
- The S.I. unit of time is second (s). 1 s = $\frac{1}{86400}$ of a mean solar day. The C.G.S. and F.P.S. unit of time is also second (s).
- The multiple units of time are minute (min), hour (h), day and year where 1 min = 60 s, 1 h = 3600 s, 1 day = 86400 s and 1 year = $3{\cdot}15 \times 10^7$ s.
- The time at any instant is recorded by a pendulum clock or watch and the time interval of an event is measured by using a stop watch or a stop clock.
- Temperature is the measure of the degree of hotness or coldness of a body. It is measured by a laboratory thermometer.
- The S.I. unit of temperature is kelvin (K), but the common unit of temperature are degree celsius (°C) and degree fahrenheit (°F).
- Doctors use a clinical thermometer to measure a patient's body temperature.
- The normal temperature of the human body is 37°C or 98·6°F.
- The total surface occupied by an object is called its area. Area is expressed as the product of measured lengths of two sides.
- The S.I. unit of area is square metre (m^2).
- One square metre is the area of a square of each side one metre.
- The bigger (or multiple) units of area are square decametre, hectare and square kilometre (km^2), where 1 dk m^2 = 100 m^2, 1 hectare = 10^4 m^2 and 1 km^2 = 10^6 m^2.
- The smaller (or sub multiple) units of area are dm^2, cm^2 and mm^2 where 1 cm^2 = 10^{-4} m^2 and 1 mm^2 = 10^{-6} m^2.

TEST YOURSELF

A. Objective Questions

1. Write *true* or *false* for each statement :
   (a) S.I. unit of temperature is fahrenheit.
   (b) Every measurement involves two things – a number and a unit.
   (c) Mass is the measure of quantity of matter.
   (d) The S.I. unit of time is hour.
   (e) The area can be expressed as the product of lengths of two sides.

   Ans: True : (b), (c), (e) **False :** (a), (d)

2. Fill in the blanks :
   (a) The S.I. unit of length is ...., of time is ...., of mass is ....
   (b) °C is the unit of ....
   (c) 1 metric tonne = ... kg.
   (d) The zero mark in Celsius thermometer is the melting point of ....
   (e) The thermometer used to measure the human body temperature is called the .... thermometer.
   (f) The normal temperature of human body is .... °C or .... °F.
   (g) The .... of an object is measured with the help of a beam balance.

   Ans: (a) metre, second, kilogram (b) temperature (c) 1000 (d) ice (e) clinical (f) 37, 98·6 (g) mass.

3. Match the following columns :

Column A	Column B
(a) Length of a housing plot	(i) Clock
(b) Breadth of a book	(ii) Beam balance
(c) Mass of an apple	(iii) Thermometer
(d) Period of time for study	(iv) Measuring tape
(e) Temperature of a body	(v) Graph paper
(f) Surface area of a leaf	(vi) Metre ruler

   Ans: (a)-(iv), (b)-(vi), (c)-(ii), (d)-(i), (e)-(iii), (f)-(v)

4. Select the correct alternative :
   (a) The symbol of degree celsius is :
   (i) °C (ii) °F
   (iii) K (iv) °K
   (b) 10 mm is equal to :
   (i) 1 cm (ii) 1 m
   (iii) 10 dm (iv) 10 cm
   (c) The amount of surface occupied by an object is called its :
   (i) volume (ii) area
   (iii) mass (iv) length
   (d) A metre ruler is graduated in :
   (i) m (ii) cm
   (iii) mm (iv) km
   (e) A thermometer is graduated in :
   (i) kelvin (ii) °C
   (iii) g (iv) cm

   Ans : (a)-(i), (b)-(i), (c)-(ii), (d)-(iii), (e)-(ii)

B. Short/Long Answer Questions

1. What is measurement ? How is a measurement expressed ?
2. State *two* characteristics of a unit.
3. Name four basic measurements in our daily life.
4. What are the S.I. units of (i) mass (ii) length (iii) time and (iv) temperature ? Write their names and symbols.
5. Define one metre, the S.I. unit of length. State its *one* multiple and *one* sub multiple.
6. Convert the following quantities as indicated :
   (a) 12 inch = ……… ft
   (b) 1 ft = ….. cm
   (c) 20 cm = …….m
   (d) 4·2 m = …… cm
   (e) 0·2 km = …… m
   (f) 0·2 cm = …… mm
   (g) 1 yard = …… m

   Ans: (a) 1 (b) 30·48 (c) 0·2 (d) 420 (e) 200 (f) 2 (g) 0·91

7. (a) Describe in steps how would you measure the length of a pencil using a metre ruler. Draw a diagram if necessary.

   (b) Explain with an example how you will use the metre ruler in part (a) if the ends of the ruler are broken.

8. Name the device which you will use to measure the perimeter of your play ground. Describe in steps how you will use it.

9. The diagram below shows a stick placed along a metre ruler. The length of the stick is measured keeping the eye at positions A, B and C.

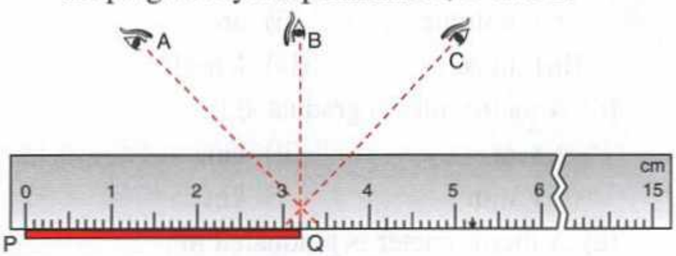


Fig. 2.23

   (a) Write the length of stick PQ as observed, for each position of the eye. Are they all same ?

   (b) Which is the correct position of the eye ? Write the correct length of the stick.

10. Define mass. State its (i) S.I. (ii) C.G.S and (iii) F.P.S units. How are they related ?

11. Convert the following quantities as indicated :

   (a) 2500 kg = ……..metric tonne

   (b) 150 kg = ……quintal

   (c) 10 lb = …….kg

   (d) 2500 g = …..kg

   (e) 0·01 kg =…. g

   (f) 5 mg =…. kg

   Ans: (a) 2·5 (b) 1·5 (c) 4·5359 kg (d) 2·5 (e) 10 (f) 5×10^{-6}

12. Name the instrument which is commonly used to measure the mass of a body. State how it is used.

13. Define one kilogram, the S.I. unit of mass. How is it related to (i) quintal (ii) metric tonne and (iii) gram ?

14. Name and define the S.I. unit of time. How is it related to (i) minute (ii) hour, (iii) day and (iv) year ?

15. Name two devices used to measure the short time interval of an event.

16. Express in second (i) 3 minute 15 second, and (ii) 5 hour 2 minute 5 second.

   Ans: (i) 195 s (ii) 18125 s

17. What does the temperature measure ?

18. Name the (i) S.I. unit and (ii) one common unit of temperature. Write their symbols also.

19. Name the instrument used for measuring the temperature of a person. Draw its neat labelled diagram.

20. Write the temperature of (i) melting ice (ii) boiling water. **Ans:** (i) 0°C, (ii) 100°C

21. What is a clinical thermometer ? State its special features. Draw a neat labelled diagram of a clinical thermometer showing the range of temperature marked on it.

22. What is the normal temperature of the human body ? How is it indicated in a clinical thermometer ?

23. Can a clinical thermometer be used to measure the temperature of boiling water ? Give reason for your answer.

24. Explain the term 'area of a surface'.

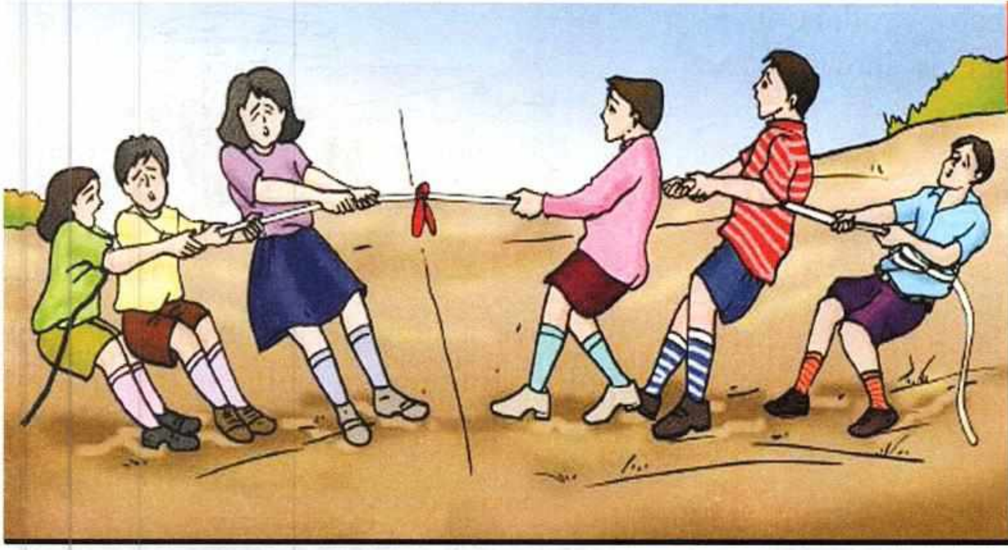
25. Name the S.I. unit of area and define it.

26. How are the units (i) square yard (ii) hectare (iii) km^2, (iv) cm^2 (v) mm^2 related to the S.I. unit of area ?

27. Explain how you will measure the area of (i) a square (b) a leaf ?

Project Work

- Use separate graph papers to find the area of (a) a square of each side 3 cm, (b) a rectangle of length 4 cm and breadth 3 cm and (c) a circle of radius 3 cm. Compare your results from area obtained after calculations using the standard formulae.



3 Force

Theme : This theme will enable children to understand the terms force and friction. The push or pull on an object is called force. A force can cause a stationary object to move and can change the direction of a moving object. When an inflated football is pressed from all sides its shape changes. When a ball is rolled down on a floor, it stops after some time. Children will understand why this happens because the force acting between the surface of the ball and the floor slows down the ball. This force is called Friction. Friction can be static, sliding or rolling. There are situations where friction is advantageous and situations where it is disadvantageous.

In this chapter you will learn

Force as a push or pull

Effects of force on

- Mass (No effect)
- Speed
- Direction (rest and motion)
- Change in shape and size
- Using real world examples only

Force of Friction

- Types – Rolling, Sliding and Static
- Advantages and Disadvantages

LEARNING OBJECTIVES

The children will be able to :

- define a force;
- explain that a force can change the state of motion;
- explain that a force can change the shape of an object;
- describe force of friction with examples from daily life;
- describe situations where static / sliding / rolling frictions are in play;
- explain advantage and disadvantage of force of friction in daily life situations.

FORCE AS PUSH AND PULL

We often use the word force in everyday life as push, pull, stretch and squeeze. Push and pull tend to move a body while stretch and squeeze tend to change the shape or size of the body. Following examples will make it clear.

A. Force as push :

1. To open a door, we push it.
2. To move a pile of rubbish, it is pushed by a broom.
3. To remove a pile of rubble (*i.e.* rough and broken pieces of stone), it is pushed by a bulldozer.

4. To move a trolley (or a baby stroller), it is pushed by the caretaker as shown in Fig. 3.1.

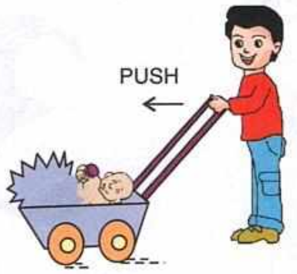


Fig. 3.1 Force as push to move the baby stroller

5. If a car does not start by its engine, we have to push it to move as shown in Fig. 3.2.

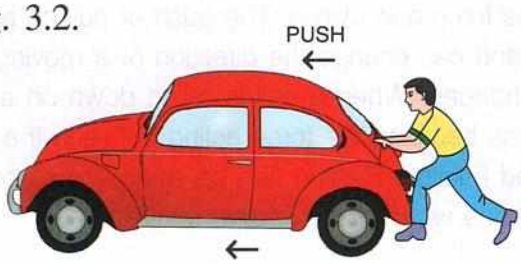


Fig. 3.2 Force as push to move a car

In the above examples, force is applied as a **push**.

B. Force as a pull :

1. To move a grass roller on a lawn, it is pulled by a gardener (Fig. 3.3).

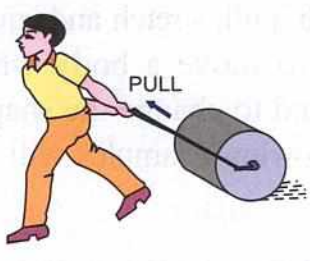


Fig. 3.3 Force as pull by the gardener to move the roller

2. To move a cart, it is pulled by a bull (Fig. 3.4).

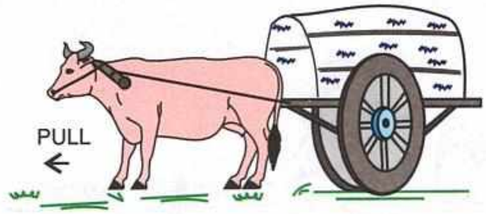


Fig. 3.4 Force as pull by a bull to move the cart

3. To move a luggage trolley, the bellboy applies force as a pull on the trolley (Fig. 3.5).

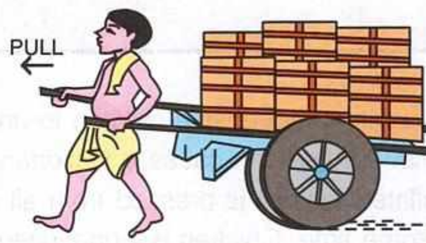


Fig. 3.5 Force as pull on a luggage trolley

4. We pull a door to open it.
5. A rickshaw man pulls on the rickshaw to move it (Fig. 3.6).

Fig. 3.6 Force as pull to move a rickshaw

In the above examples, force is applied as a **pull**.

Thus, movement of a body is obtained as a result of a push or a pull. This push or pull is termed as **force**.

Thus, force is a cause (a push or pull) which tends to result in the movement of a body.

C. Force as a stretch :

1. When a rubber string is stretched, its length increases.
2. On stretching a spring, it elongates.
3. On suspending a load at one end of a wire, keeping its other end fixed, the length of wire increases.

D. Force as a squeeze :

1. On squeezing a tube of gum or toothpaste, its shape changes.
2. If an inflated balloon is squeezed, its shape changes.
3. On squeezing an inflated football from all sides, its shape changes.

Thus, *a force applied as stretch or squeeze can cause a change in size and shape of an object.*

Do You Know ?

1. A body is said to be in the state of rest if it does not change its position with time with respect to its surroundings.
2. A body is said to be in the state of motion if it changes its position with time with respect to its surroundings.
3. If a force does not change the state of the body from rest to motion or from motion to rest, it is called a balanced force. But if a force changes the state of rest to motion or the state of motion to rest, it is called an unbalanced force.

EFFECTS OF A FORCE

When a force is applied on a body, it can have the following effects :

1. A force can move a body originally at rest.
2. A force can stop a moving body.
3. A force can make a moving body to move faster.
4. A force can slow down a moving body.
5. A force can change the direction of motion of a moving body.
6. A force can change the shape or size of a body.

1. A force can move a body originally at rest : When a force is applied on a body originally at rest, the body begins to move. *For example*, a car originally at rest when pushed, begins to move (Fig. 3.2). A grass roller when pulled begins to move (Fig. 3.3). A ball lying on the ground moves, when it is kicked.

2. A force can stop a moving body : When a force is applied on a moving body in a direction opposite to the direction of motion of the body, it can be made to stop. *For example*, a moving bicycle, bus or train is stopped by applying the brakes. The brakes act against the direction of motion of bicycle, bus or train. Thus, the brakes provide the stopping force. A moving cricket ball is stopped by the fielder when he catches it, by applying a force with his hands in a direction opposite to the motion of ball. (Fig. 3.7)

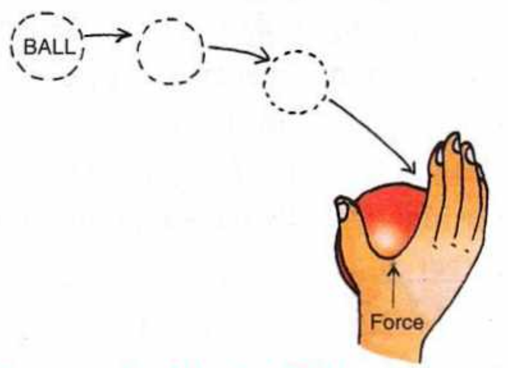


Fig. 3.7 Force applied by the fielder while catching a ball, stops the moving ball

3. **A force can make a moving body to move faster :** When a force is applied on a moving body in the direction in which it is moving, the body begins to move faster. *For example*, the speed of a bicycle increases, when more force is applied on the pedal by the cyclist. A swing moves faster when a push is given in the direction of the moving swing (Fig. 3.8).

Fig. 3.8 Force (push) on swing moves it faster

4. **A force can slow down a moving body :** When a force is applied on a moving body in a direction opposite to the direction of motion of the body, the body slows down or stops. *For example*, the speed of a moving vehicle is slowed down by applying brakes. The brakes provide a force in a direction opposite to the direction of motion. A swing can be slowed down if a person instead of pushing it, pulls the swing in the opposite direction.

5. **A force can change the direction of motion of a moving body :** If a force is applied on a moving body in a direction other than its direction of motion, the direction of motion of the body changes. *For example*, a player kicks a moving football to change its direction of motion (Fig 3.9), a player applies force with a hockey stick to change the direction of motion of the ball. Similarly, in tennis and badminton, the direction of motion of the ball or cock is changed by hitting it in the opposite direction.

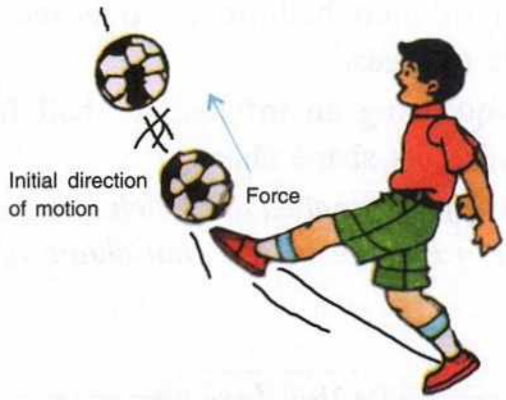


Fig. 3.9 Force changing the direction of motion of football

ACTIVITY 1

A force may change the direction of a moving object. Take a small piece of cardboard and hold it in between your two fingers. Release it gently so that it falls down. While it is falling, strike the cardboard with another finger. You will notice that the board does not fall along the same path but it falls somewhere else. This happens because force applied by push of the finger changes its direction.

6. **A force can change the shape or size of a body :** When a force is applied on a body which is not allowed to move, it gets deformed, *i.e.*, the shape or size of the body changes. *For example*, on squeezing a piece of rubber, its shape

changes (Fig. 3.4), on stretching a rubber string, its length increases.

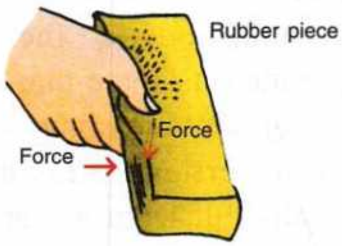


Fig. 3.10 A force (squeeze) on rubber piece changes its shape

If one end of a spring is tied to a hook and the other end is pulled down by suspending a body, its length increases (*i.e.* the size of spring changes) as shown in Fig. 3.3.

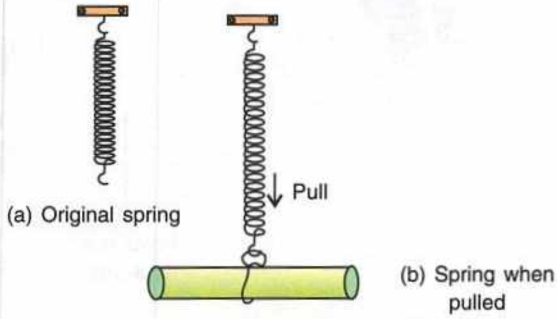


Fig. 3.11 On pulling a spring, its length increases

Do You Know ?

The increase in length of the spring in Fig. 3.11 is directly proportional to the weight of the body suspended from it. On this principle, a spring balance works which is used for the measurement of weight of a body.

From the above discussion, we can define force as follows :

A force is that cause which changes the state of a body (either the state of rest or the state of motion or the direction of motion) or changes the size or shape of the body.

Note : **1.** A force does not change the mass of the body on which it is applied.

2. We cannot see a force. However, we can see or feel the effect of a force.

3. A force is expressed by stating both its magnitude and direction.

4. Two forces acting on a body in the same direction get added to give the resultant force, whereas two forces acting on a body in opposite directions get subtracted to give the resultant force in the direction of bigger force (*i.e.* the force of large magnitude).

5. A body acted upon by two equal and opposite forces will have the resultant force zero. Such forces are called balanced forces.

6. The S.I. unit of force is newton (symbol N). Its gravitational units are kgf and gf where 1000 gf = 1 kgf and 1 kgf = 10 N (nearly).

KINDS OF FORCES

Depending upon the application of forces, they are classified in *two* categories :

1. Contact forces, and
2. Non contact forces

1. Contact forces : The force which acts on bodies by making an actual contact, is called contact force.

Examples :

(a) The muscular force applied as push and pull (Fig. 3.12).

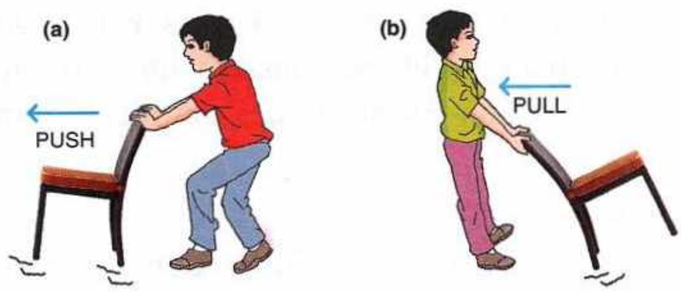


Fig. 3.12 Muscular force as a contact force

(b) The force of friction or frictional force exerted by a surface on a body in contact with it, in a direction opposite to the direction in which the body is moved on the surface (Fig. 3.13).

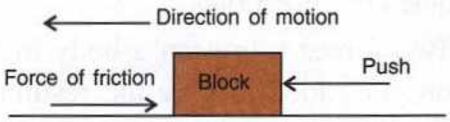


Fig. 3.13 Force of friction as a contact force

c) The force of tension in a string when a load is suspended from it (Fig. 3.14).

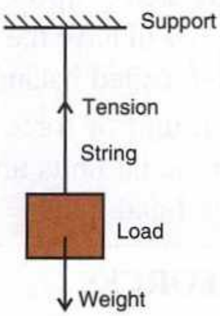


Fig. 3.14 Force of tension as a contact force

d) The force of reaction normal to the surface when a body is placed on a surface (Fig. 3.15).

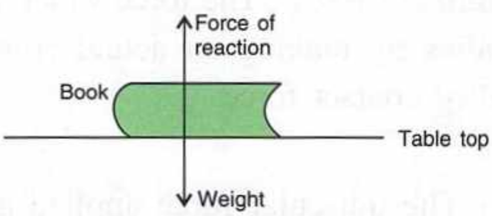


Fig. 3.15 The force of reaction as contact force

2. Non contact forces : Forces which act on bodies with no contact with them are called non-contact forces or forces from a distance.

Examples :

(a) **Gravitational force** between two bodies at a distance, such as the force of attraction between two heavenly bodies, the force of attraction on a body by earth, etc. The weight of a body is the force by which earth attracts that body, so the weight of a body is also called its force due to gravity. It is the force of gravity on a body due to which it tends to fall vertically downwards. The leaves and fruits fall from a tree downwards towards the ground, water in a river flows down stream, a ball thrown up goes to a height and then returns back on the ground (Fig. 3.16) are some examples of motion due to gravitational force.

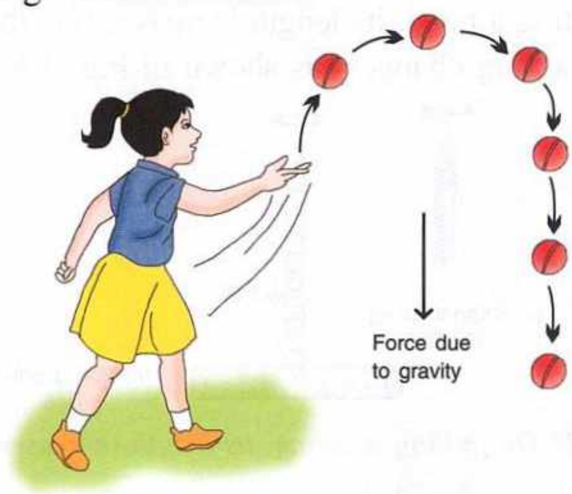


Fig. 3.16 Gravitational force on a ball

Do You Know ?

Weight, being a force, is expressed in gravitational unit kgf or gf whereas kg or g is the unit of mass.

(b) **Electrostatic force** between two charged bodies at a distance either repel or attract each other. Unlike charges attract while the like charges repel. If a plastic comb rubbed on dry hair is brought near small bits of paper, we find that the bits of paper begin to move towards the comb (Fig. 3.17) because

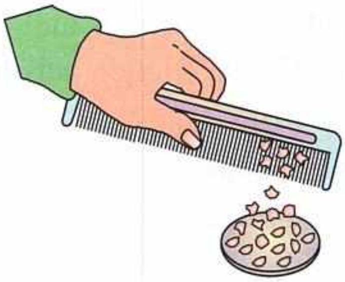


Fig. 3.17 : Electrostatic force of attraction makes the bits of paper move towards the comb

of electrostatic force of attraction between unlike charges.

(c) **Magnetic force** between the poles of two magnets at a distance. Like poles repel each other while the unlike poles attract each other (Fig. 3.18).

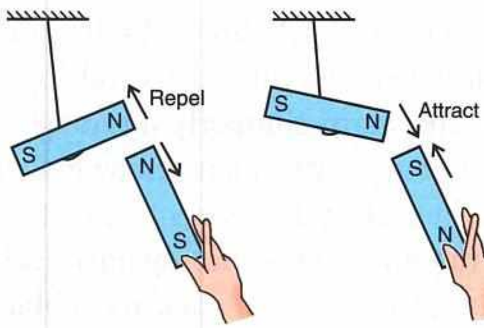


Fig. 3.18 Magnetic force between the poles of two bar magnets

Do You Know ?

1. Gravitational force is always attractive while the electrostatic and magnetic forces can be attractive as well as repulsive.
2. The magnitude of non-contact forces depends on the distance of separation. When distance of separation is doubled, the magnitude of force becomes one-fourth.

FORCE OF FRICTION

It is our common experience that if we stop pedalling our bicycle, it gradually slows down

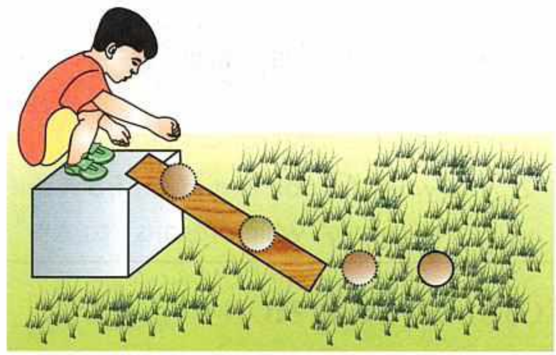


Fig. 3.19 The ball stops after rolling up to a certain distance

and ultimately it stops after travelling a certain distance. Similarly, if we roll a ball on a plane ground, it moves up to a certain distance and then stops. (Fig. 3.19). The question arises, why did the bicycle or ball stop ?

Reason : Since only a force can stop a moving body, so we can say that there must be a force acting on the bicycle or the ball which has stopped them.

The force which slows down the motion of a moving body in contact with the surface of another body, is called the frictional force or the force of friction. This force always opposes the motion. Fig. 3.20 shows that while pushing a heavy box, the force of friction opposes the motion and makes it difficult for us to push it.

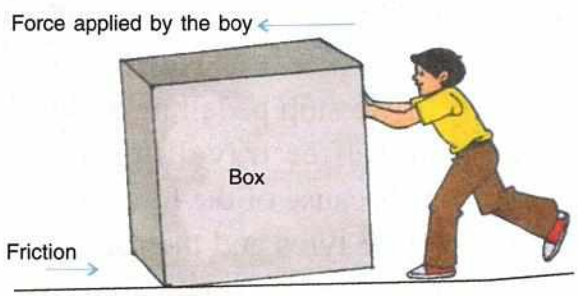


Fig. 3.20 Friction opposes motion

Thus we can define friction as follows :

Friction is the force that opposes the relative motion between the two surfaces in contact with each other.

Do You Know ?

1. Friction is a force of contact.
2. The word friction is derived from the latin word "fricare" which means "to rub".

EFFECTS OF FRICTION

1. Friction opposes motion : We have read above that friction is a force which opposes motion. In daily life, we often have to move bodies from one place to another by pushing or pulling them. Suppose we want to push a box (Fig. 3.20). If we push the box with a little effort, we find that the box does not move. This means that there is some opposing force between the box and the ground which makes the box not to move. This opposing force is called the force of friction. Now if we push the box hard (*i.e.*, we apply more effort to push the box), the box starts moving. This happens because now the force applied has overcome the force of friction.

If we roll a ball on the ground, it gradually slows down and after travelling a certain distance, it stops. The reason is that the force of friction between the ball and the ground opposes the motion of the ball and brings it to stop.

Similarly, if we stop pedalling a bicycle, it slows down and after travelling a certain distance, it stops because of the force of friction between the bicycle tyres and the road. To start the bicycle, we have to exert a force on the pedal greater than the force of friction between the tyres and the road.

2. Friction always acts in a direction opposite to the direction of motion : If we move the box to the right, the friction acts towards the left [Fig. 3.21(a)] and if we move the box to the left, the friction acts towards the right [Fig. 3.21 (b)].

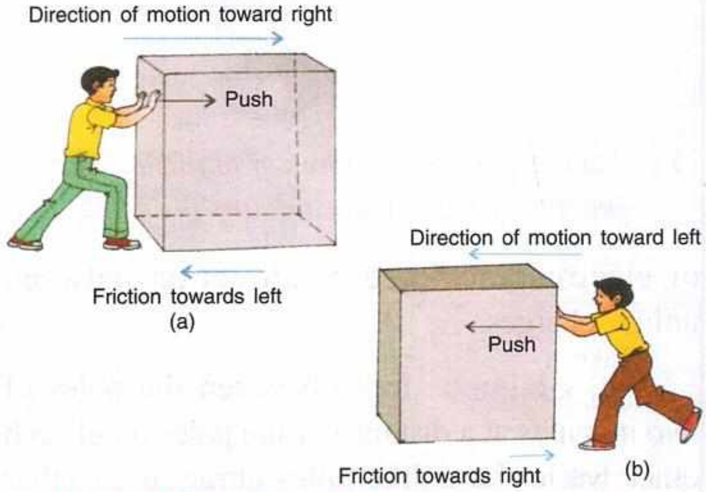


Fig. 3.21 Direction of friction is opposite to the direction of motion

3. Friction produces heat : It is our common experience that if we rub our palms, they become warm. Similarly it is due to friction that the moving parts of a machine get warm (or heated). In ancient days, people used to produce fire by rubbing two stones against each other. The lighting of a match stick by rubbing it on a rough surface, is also due to friction. Thus, friction produces heat.

4. Friction causes wear and tear : We have noticed in our daily life that the tyres of a bicycle, rickshaw, car and other vehicles gradually wear out when they are continuously used due to friction between the tyre and the ground. In machines, the moving parts gradually wear out when they are continuously used. Thus, friction causes wear and tear.

Do You Know ?

The force of friction arises because of the interlocking of the irregular projections on the two surfaces in contact.

Factors affecting the force of friction

1. **The smoothness of the surface :** The force of friction is more between rough surfaces and less between smooth surfaces. There will be no friction between two perfectly smooth surfaces. This is an ideal situation which is not practically possible.

ACTIVITY 2

Take a small ball. Roll the ball on a wooden surface. Note the distance which the ball covers on the wooden surface before it stops. Then roll the same ball on a glass surface. Again note the distance which the ball moves on the glass surface before it stops. You will notice that the distance moved on the wooden surface is less than the distance moved on the glass surface *i.e.* the friction on glass surface is less than that on the wooden surface. It is because the glass surface is smooth as compared to the wooden surface.

2. **The nature of medium (solid, liquid or gas) in which the body moves :** A solid, liquid or gas, all exert the force of friction on a moving body. The force of friction between a solid and another solid is more, it is less between a solid and a liquid and still less between a solid and a gas.

3. **The weight of the moving body on the surface :** Greater the weight of the moving body on a surface, more is the force of friction on the body by the surface (Fig. 3.22).

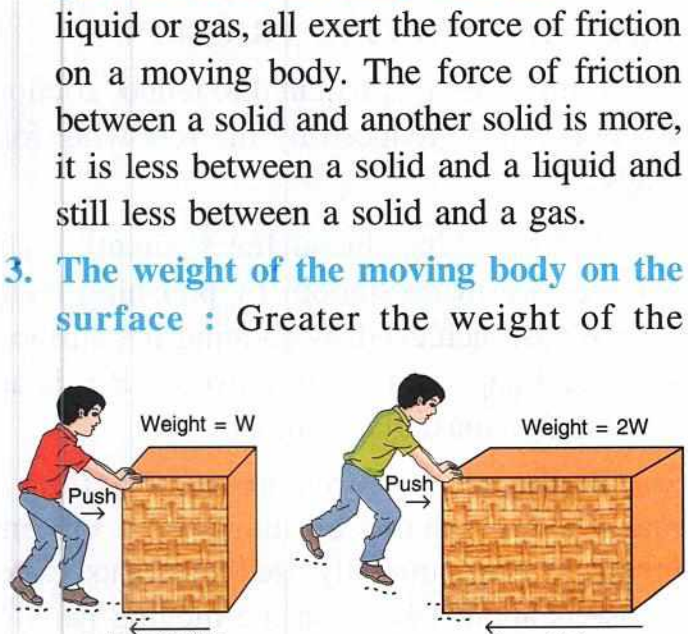


Fig. 3.22 More weight causes more friction

KINDS OF FRICTION

Friction is of *three* kinds :

1. Static friction,
2. Sliding friction, and
3. Rolling friction.

1. Static friction : Suppose we want to slide an object on a surface, we apply a force as push. If the force applied is less, the object does not move due to the force of friction on the object by the surface, opposing the motion. We then gradually increase the force applied on the object. The force of friction on the object also increases and the body does not move. If the applied force is increased further, a stage is reached when the force of friction becomes such that the net force on the object is zero and the object remains stationary, but it is just about to slide over the surface. At this stage, the force of friction acting on the object is called the static friction. Now if the applied force is slightly increased, the object begins to slide or roll on the surface. Thus, the maximum opposing force between the object and the surface in contact with it, so long as the object remains stationary even on applying the external force, is called the static friction. Thus, static friction is self adjusting.

Now once the body starts sliding on the surface, the applied force can be decreased to keep the body sliding on the surface.

2. Sliding friction : When the body begins to slide on a surface, the force exerted by the surface on the object is called the sliding friction. It is equal to the force required to keep the object in motion over the surface. The sliding friction is less than the static friction.

3. Rolling friction : When an object rolls over a surface, the force which opposes the rolling motion of the object is called the rolling friction. It is less than the sliding friction on a body of same mass. This is why to move heavy objects on the ground, rollers are used. In machines, generally the sliding motion of its parts is changed to the rolling motion by the use of ball bearings. *For example*, ball bearings are used between the hubs and axles of a ceiling fan and a bicycle. Vehicles like cars, trucks, scooters, bicycles, and luggage trolleys etc. are provided with wheels.

Do You Know ?

Static friction > sliding friction > rolling friction

ACTIVITY 3

1. Mount a pulley at the edge of a table as shown in Fig. 3.23. Place a wooden block provided with a hook, on the table. Tie one end of a string with the hook and pass its other end over the pulley with a pan. Now gradually increase the weights in the pan till the block just begins to slide on the table. Note the weight W_1.

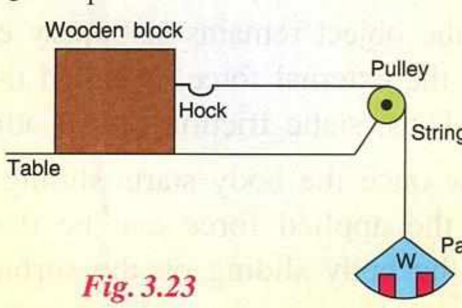


Fig. 3.23

2. When the block starts sliding on the table, gradually take out small weights from the pan till the block remains moving on the table such that it covers equal distances in equal intervals of time. Note the weight W_2 on the pan.

3. Now remove all the weights from the pan and place two rollers below the block on the table. Again gradually increase the weights on the pan till the rollers with the block begin to roll on the table. Note the weight W_3 on the pan.

4. Compare the values of W_1, W_2 and W_3.

You will notice that $W_1 > W_2 > W_3$. Here W_1 is the force of static friction (*i.e.* the maximum force applied on the block till it remains stationary). W_2 is the force of sliding friction (*i.e.* the force needed to keep the block moving with the same speed) and W_3 is the force of rolling friction.

DISADVANTAGES OF FRICTION

1. Friction opposes the motion of a body, so it decreases the efficiency (*i.e.*, more force is needed to move a body).
2. Friction causes wear and tear in the moving parts.
3. Friction produces heat.

WAYS OF REDUCING FRICTION

Sometimes it is required to reduce friction. Friction can be reduced by the following four ways :

1. By making the surfaces smooth : The surfaces are made smooth by polishing them. This is also achieved by rubbing the surfaces with sand paper and emry powder. Roads are cemented to make them smooth.

2. By use of lubricants : Friction in machines is reduced by lubrication. Oil and grease are the commonly used lubricants. Oil or grease is applied between the moving parts of the machine. This fills the fine pores or depressions in the surfaces and thus reduces friction. Sometimes, we use solid lubricants in the form of powders. We spread fine powder on the carom board to reduce friction between the coins and the board.

3. By the use of ball bearings : Rolling friction is much less than the sliding friction. Therefore, in place of wheels and axles, we use ball bearings to reduce friction.

4. By streamlining : Like solids, liquids and gases also offer friction to the bodies moving through them. Gases offer less friction than liquids, while liquids offer less friction than solids. The motion of a boat is slowed down by water. The motion of an aeroplane is slowed down by air. The friction experienced by a body moving in a liquid or a gas can be reduced by giving a special shape to the body. For this, the front portion of the body is made sharp or pointed as compared to its rear portion. This process of giving a shape with pointed ends is called streamlining.

If two arrows, one with a pointed or sharp tip and the other with a flat or blunt tip, are thrown into air (Fig. 3.24), we find that the arrow with the sharp tip covers a larger distance

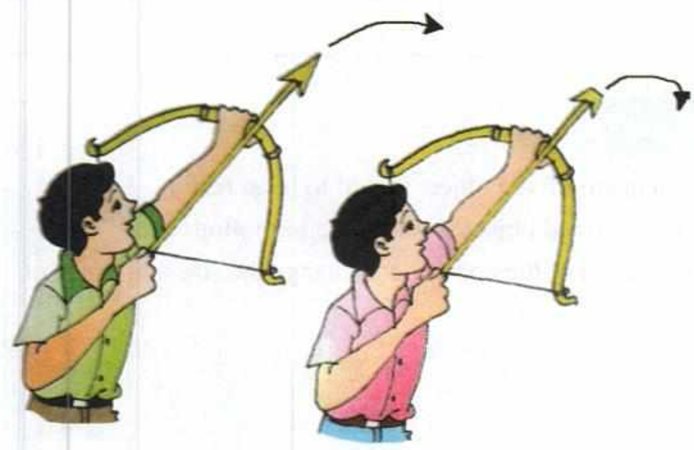


Fig. 3.24 The arrow with the sharp tip experiences less friction in air

in air than the arrow with a blunt tip. The reason is that the sharp arrow experiences less friction in air than the blunt arrow.

While diving, a swimmer lets his hands enter the water first, followed by his head and body, so as to reduce the friction between himself and water. The shape of a boat, car, aeroplane, train, etc. is designed to be streamlined. In nature, the shapes of fish and birds are streamlined so that they can easily move in water or air (Fig. 3.25).

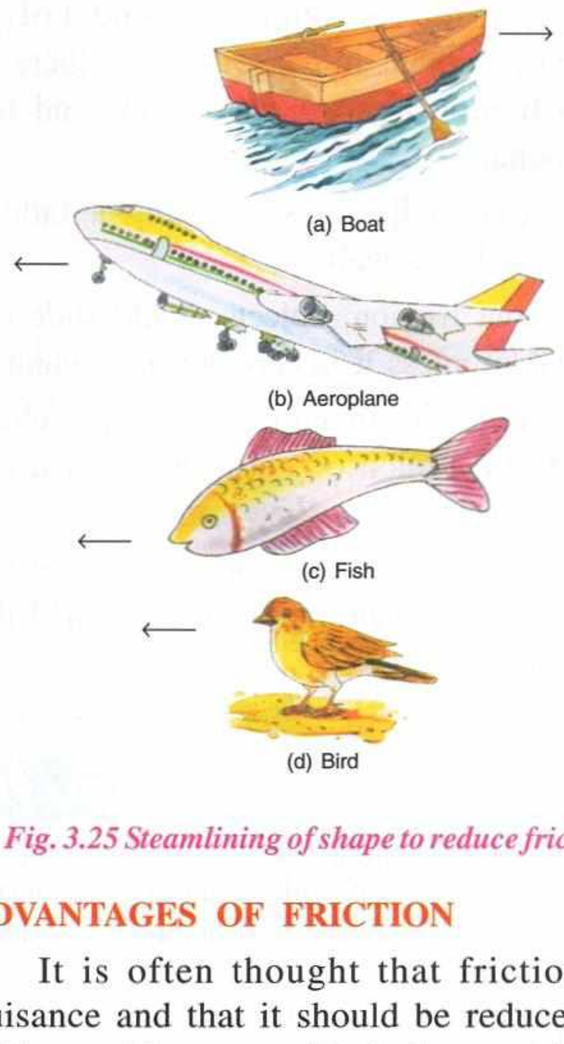


Fig. 3.25 Steamlining of shape to reduce friction

ADVANTAGES OF FRICTION

It is often thought that friction is a nuisance and that it should be reduced to a minimum. However, a frictionless world would not at all be convenient. Most of our daily activities of life depend on the existence of friction. Some such examples are given below :

1. In absence of friction, we would not be able to walk on road. It is the reaction of the force of friction which makes us move ahead.
2. When the road becomes wet after rain, friction is reduced and hence, the road becomes slippery.
3. We slip on icy roads or polished smooth surfaces.
4. The wheels of vehicles would fail to rotate without moving ahead if there is no friction between the wheels and the ground.
5. Friction helps in supporting a ladder inclined to a wall.
6. Without friction, objects would slide off a table unless it is perfectly horizontal.
7. It would be difficult to sit on a chair without friction or brush our teeth using a tooth brush.
8. Brakes in a vehicle work because of the friction between the brake-lining and the drum of the wheel.
9. Friction is necessary to light a match-stick.
10. It is due to friction that we can write on a board by a chalk.

The above examples show that some friction is necessary for our daily activities.

WAYS OF INCREASING FRICTION

We have seen that friction is necessary to some extent. Friction can be increased by the following three ways :

1. **By making the surfaces rough :** Rough surfaces have a better grip on each other, so sometimes sand is sprinkled on surfaces to make them rough.
2. **By using dry surfaces :** Dry surfaces have more friction while wet surfaces have less friction, so surfaces are dried.
3. **By increasing the weight :** By increasing the weight of the moving body, friction increases which develops a better grip between the body and the surface on which the body moves.

RECAPITULATION

- A body not changing its position with time with respect to a nearby fixed object is said to be at rest.
- A body changing its position with time with respect to a nearby fixed object is said to be in motion.
- Force is a push or pull which can change the state of rest or motion of the body or can change the size and shape of the body (*i.e.* it can deform a body).
- A force applied on a body can
  (a) move it if it is not in motion
  (b) stop it if it is moving
  (c) increase or decrease its speed

(d) change its direction of motion

(e) change its shape or size

- A force has no effect on mass of the body on which it is applied.
- Force is defined as that cause which changes the state of rest or the state of motion of a body and can also deform it.
- A force has both magnitude and direction.
- When two forces act in opposite directions, the net force is equal to the difference of these forces, in the direction of the bigger force.
- When two forces act on a body which are equal in magnitude, but opposite in direction, the net force on the body is zero.
- Forces are of *two* types : (1) contact forces and (2) non-contact forces (or forces at a distance).
- Contact forces are (i) the muscular force applied as push or pull, (ii) force of friction (iii) the force of reaction normal to the surface and (iv) the force of tension in a string pulled by a load.
- Non-contact forces are (i) gravitational force (ii) electrostatic force and (iii) magnetic force
- The weight of a body is the force with which the earth pulls the body.
- The gravitational unit of weight (or force) is kgf and not kg which is the unit of mass.
- Friction is a force that opposes motion.
- Friction always acts in a direction opposite to the direction of motion.
- The cause of friction is the interlocking of the irregular projections on the two surfaces in contact.
- The force of friction depends on :

  (a) the smoothness (or roughness) of the surfaces in contact, and

  (b) the weight of the sliding (or rolling) body.
- The force of friction does not depend on the area of the surfaces in contact.
- The disadvantages of friction are :

  (a) Friction opposes motion

  (b) Friction produces heat

  (c) Friction causes wear and tear

  (d) Friction reduces efficiency
- Friction can be reduced by

  (a) making the surfaces smooth

  (b) the use of lubricants

  (c) the use of ball bearings

  (d) streamlining the shape of the moving body.
- The maximum force exerted by a surface on a body so long as it remains stationary is called the force of static friction.
- The minimum force required to keep the body moving over a surface such that it moves equal distances in equal intervals of time is called the force of sliding friction.
- The minimum force required to roll a body on a surface is called the force of rolling friction.
- Rolling friction is less than the sliding friction and sliding friction is less than the static friction.
- Friction is advantageous to us in almost all activities of our life.

TEST YOURSELF

A. Objective Questions

1. Write *true* or *false* for each statement :
   (a) The frictional force acts in the direction of motion of body.
   (b) The unit of weight is kilogram.
   (c) A force can change the direction of motion of a moving body.
   (d) A force increases the mass of the body when applied on it.
   (e) The force of friction is always disadvantageous.
   (f) The sliding friction is more than the rolling friction.
   (g) Liquids offer more friction than the gases.
   (h) A wet oily road offers more friction than a dry rough road.

   Ans: True: (c), (f), (g)
   False: (a), (b), (d), (e), (h)

2. Fill in the blanks :
   (a) Force is applied as .... or ....
   (b) On squeezing a gum tube, its .... changes.
   (c) On pulling a string, its................ increases.
   (d) A moving football when kicked, its .... changes.
   (e) On applying brakes on a moving car, its speed ....
   (f) We use ball bearings to .... the friction.
   (g) Friction .... motion.
   (h) Lubricants are used to.................. friction.
   (i) Friction causes .... of moving parts of a machine.

   Ans: (a) push, pull (b) shape (c) length (d) direction of motion (e) slows down (f) reduce (g) opposes (h) reduce (i) wear and tear

3. Match the following columns :

Column A	Column B
(a) Non contact force	(i) repel
(b) Like poles	(ii) kg
(c) Contact force	(iii) Gravitational force
(d) Mass	(iv) wear and tear
(e) Weight	(v) force of friction
(f) Friction	(vi) kgf

Ans: (a)-(iii), (b)-(i), (c)-(v), (d)-(ii), (e)-(vi), (f)-(iv)

4. Select the correct alternative :
   (i) A body falls downwards because of
   (a) electrical force
   (b) gravitational force
   (c) mechanical force
   (d) magnetic force.
   (ii) A force does not change
   (a) mass
   (b) length
   (c) shape
   (d) state of motion.
   (iii) A force to be expressed correctly requires
   (a) only the magnitude
   (b) only the direction
   (c) both the magnitude and direction
   (d) none of the above.
   (iv) Friction
   (a) promotes motion
   (b) opposes motion
   (c) acts in the direction of motion
   (d) is always a nuisance.
   (v) Friction is reduced by
   (a) making the surfaces wet
   (b) making the surfaces dry
   (c) making the surfaces rough
   (d) sprinkling sand on the surface.
   (vi) Friction
   (a) causes wear and tear
   (b) produces heat
   (c) stops a moving body
   (d) has all the above disadvantages.

(vii) Friction is increased if
   (a) an oil is sprayed
   (b) the surfaces are made wet
   (c) the surfaces are made dry
   (d) the surfaces are polished.

Ans: (i)-(b), (ii)-(a), (iii)-(c), (iv)-(b), (v)-(a), (vi)-(d), (vii)-(c)

B. Short/Long Answer Questions

1. Name the term used for the push or pull.
2. Give one example each of a force as (i) a push, (ii) a pull, (iii) a stretch and (iv) a squeeze.
3. Explain the meaning of the term force.
4. What effect can a force have on a stationary body ?
5. What effects can a force have on a moving body ?
6. What effect can a force produce on a body which is not allowed to move ?
7. Give *one* example each to indicate that the application of a force
   (a) produces motion
   (b) stops motion
   (c) slows down motion
   (d) changes the direction of motion
   (e) deforms a body.
8. State the effect produced by a force in the following cases :
   (a) The sling of a rubber catapult is stretched
   (b) A man pushes a heavy cart
   (c) A player uses his stick to deflect the ball
   (d) A cyclist applies brakes
   (e) A spring is compressed.
9. Name the two kinds of forces in nature.
10. Name the type of force which acts in the following cases :
   (a) A coolie lifts a luggage
   (b) A bicycle comes to rest slowly when the cyclist stops pedalling
   (c) A stone falls from a roof
   (d) A comb rubbed with silk attracts bits of paper
   (e) A string hangs with a load
   (f) A horse moves a cart
   (g) A magnet attracts an iron pin
   (h) A boy opens a door
   (i) An apple falls from a tree
   (j) A man rows a boat.
11. What do you mean by the gravitational force ? Give an example to illustrate it.
12. Define the term "weight of a body".
13. What do you understand by the term friction ?
14. Give an example to illustrate the existence of force of friction.
15. What is the cause of friction ?
16. State *two* factors which directly affect the force of friction.
17. In which case will there be more friction between a truck and the road : when the truck is empty or when it is loaded ? **Ans:** When it is loaded
18. Which offers more friction on a body : a glass surface or a wooden surface ? **Ans:** A wooden surface
19. Name the *three* kinds of friction.
20. List *three* disadvantages of friction.
21. When you apply the brakes, a bicycle stops and the rims of its wheels become hot. Explain the reason.
22. The eraser gets smaller and smaller as you use it more and more. Explain the reason.
23. List *three* ways of reducing friction.
24. It is difficult to open an inkpot with greasy or oily hands. Explain.
25. It is difficult to walk on a wet road. Explain.
26. Give *three* examples to illustrate that friction is a necessary evil.
27. Define (i) static friction (ii) sliding friction and (iii) rolling friction.
28. Arrange the following in descending order of magnitude : (i) static friction (ii) sliding friction and (iii) rolling friction ?
29. A body needs a force F_1 just to start motion on a surface, a force F_2 to continue its motion and a force F_3 to roll on the surface. What is (i) the static friction (ii) sliding friction and (iii) rolling friction ? State whether F_2 is equal, less than or greater than (i) F_1 and (ii) F_3.
30. Friction is a necessity and also acts as an evil. Explain.

4 Simple Machines

Theme : The ability to do work is called energy. Machines help us to do work. For example, a bottle opener is a machine. A needle, a door knob are also machines. Some machines are more complex than others. A simple machine changes the direction or the magnitude of force applied. The six simple machines are the lever, the pulley, the wheel-and-axle, the inclined plane, the wedge and the screw. The factor by which a machine multiplies the force applied is called 'mechanical advantage'. On the basis of location of fulcrum (the pivot point), the load and the effort, levers be classified into three types or orders. The aim of this theme is to enable children to know and understand about different types of machines and levers.

In this chapter you will learn

Simple Machines

- Basic Concept
- Mechanical Advantage
- Types of Simple Machines
  - Lever - Wheel and axle - Pulley
  - Inclined plane - Wedge - Screw
- Different Orders of Levers
- Numericals based on mechanical advantage or leverage.
  Load × Load arm = Effort × Effort arm

LEARNING OBJECTIVES

The children will be able to :

- define what is a machine;
- describe six simple machines with examples from daily life;
- describe different types of levers;
- define mechanical advantage of a lever;
- solve problems based on formula for mechanical advantage of a lever.

WORK AND ENERGY

Work : In chapter 3, we have read that a force can move a stationary body. In Physics, work is said to be done only when the body moves on applying a force. No work is done if there is no motion produced in the body even when a force acts on it. Thus,

Work is said to be done if the force applied on the body moves it. If no motion or change in position takes place, no work is said to be done.

For example, a cyclist pedalling a cycle does work, a horse pulling a cart does work, an engine pulling a train does work, a coolie lifting a box does work, a boy going upstairs does work, a boy lifting a book does work. However, a person does no work if there is no motion even if a force is applied. *For example*, a boy pushing a heavy stone does no work if the stone does not move. Similarly, a coolie does no work while standing with a heavy box on his head, as there is no motion.

Energy : A body capable of doing work is said to possess energy. Energy is needed to do work. Actually, energy and work are related to each other. We define energy as follows :

The energy of a body is its capacity (or ability) to do work.

Note : The S.I. unit for both work and energy is joule (symbol J).

Do You Know ?

Work done by a force on a body is measured as :

Work done = force × distance moved by the body in the direction of force.

MACHINES

A machine is a device which helps us to do work more easily by applying less force and spending less energy.

Examples :

1. Suppose the lid of a tin container is tightly closed and you want to open it. First try to open the lid with your finger nails. You will find that you are unable to open it. Then take a spoon and insert the front end of the spoon between the lid and the edge of the tin, and then push the other end of the spoon (Fig. 4.1). You will find that the lid gets opened. Thus, the spoon here is used to serve as a machine in opening the lid.

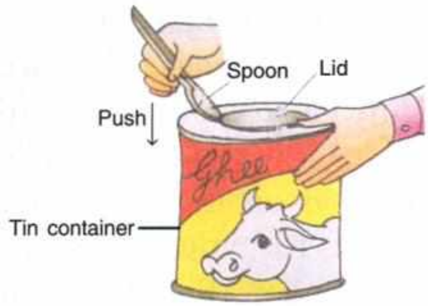


Fig. 4.1 Opening the lid of a tin container using a spoon

2. Suppose you are to open a tight nut. You will find it difficult to open it with your fingers. But if you use a spanner as shown in Fig. 4.2, to open it, you will find it easier to open the nut.

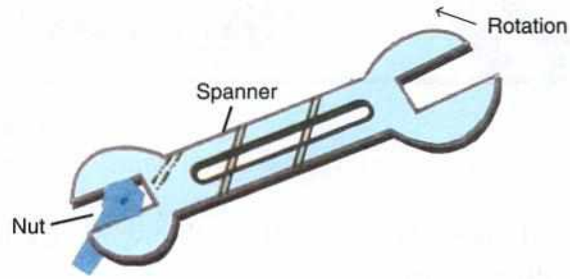


Fig. 4.2 A spanner is used to open a tight nut

3. It is difficult to remove a tightly fitted cork from a bottle. But if you use a cork opener and insert its tip in the cork and then pull it as shown in Fig. 4.3, the cork easily comes out of the bottle.

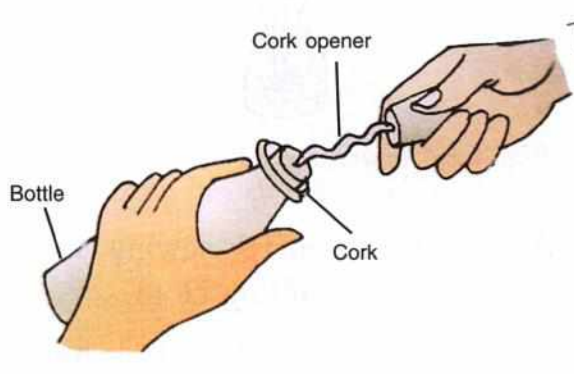


Fig. 4.3 Opening a tightly fitted cork from a bottle using a cork opener

4. Suppose you are to move a heavy load from one place to another. You will find it very difficult to move it by lifting or pushing it. But if you take a trolley and place the load on it, then it becomes much easier for you to move it by pushing the trolley (Fig. 4.4). You must have seen coolies using the trolley to carry heavy loads at the railway station or airport.

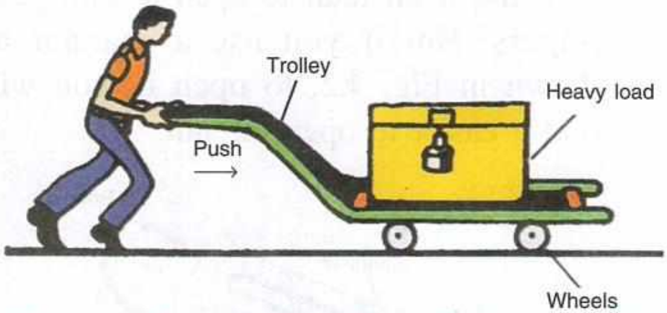


Fig. 4.4 A boy carrying a heavy load on a trolley

5. In factories, a crane is used to lift heavy equipments.

6. A bottle opener is used to open the lid of a soft drink bottle (Fig. 4.5).

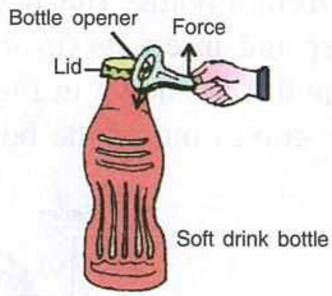


Fig. 4.5 A bottle opener used to open the lid of a soft drink bottle

7. A needle is used for sewing and a pair of scissors for cutting cloth.

8. A door knob is used to lock and unlock a door.

9. A pulley is used to pull a bucket of water from a well.

10. An iron bar (also called a crow bar) is used to shift a heavy stone by pushing it.

In the above examples, the simple tools such as a spoon, a wrench, a bottle opener, a trolley, a crow bar, a needle, a pair of scissors, a door knob, a pulley, a screw driver etc. are some of the examples to show that a machine makes a difficult work easy.

However, some machines are simple and others may be complex using several moving parts run by an engine or electricity. Such complicated machines are generally used in factories.

PRINCIPLE OF A MACHINE

A machine does not work by itself. When energy is supplied to it (or work is done on it), it does some useful work. To do work on a machine, a force is applied. This applied force is called the **effort** (symbol E). As a result of this force, the machine lifts or moves an object called the **load** (symbol L) in order to do work.

EFFICIENCY OF A MACHINE

The efficiency of a machine is the ratio of the useful work done by the machine to the work put into the machine by the effort. Thus,

$$\text{Efficiency} = \frac{\text{Useful work done by the machine on the load}}{\text{Work done on the machine by the effort}}$$

Or in other words,

$$\text{Efficiency} = \frac{\text{Work output on load}}{\text{Work input by effort}}$$

IDEAL (OR PERFECT) MACHINE

A machine in which no part of the work

done on the machine is wasted, is called an ideal or perfect machine. Thus, for an ideal machine, the work output is equal to the work input, *i.e.*, the efficiency of an ideal machine is 1 (or 100 per cent). However, practically there is no perfect or ideal machine.

ACTUAL MACHINE

In practice, however, no machine is perfect because some part of the work done on a machine is always used up (or wasted) in overcoming the friction between the moving parts of the machine. Therefore, the work output of a machine is always less than the work input. In other words, the efficiency of an actual machine is always less than 1 (or less than 100 percent). If a machine is 80% efficient, it means that 80% of the work input to the machine is obtained as the useful work output. The remaining 20% of the work input has been wasted in overcoming friction.

FUNCTIONS OF A SIMPLE MACHINE

In most of the machines, the load is greater than the effort. However, in some machines, the load is equal to the effort or less than the effort but in such cases, the load moves a greater distance than the effort, or the effort acts in a desired direction or at a convenient point which makes the job easy. Thus, a machine has the following *four* functions :

1. It decreases the magnitude of the force required, *i.e.* the effort is less than the load.

   Examples : A jack is used to lift a car, a bar is used to push a heavy stone, a spade is used to turn the soil. In these examples, the effort needed is much less than the load.

2. It increases the distance moved by the load.

   Example : In a pair of scissors, its arms move longer on cloth (or paper) than its handle while in use.

3. It changes the direction of effort in a convenient direction.

   Example : To lift up a bucket of water from a well, we need to apply the effort upwards which is a difficult task. But by the use of a pulley, effort is not only applied downwards but we also use our own weight as an effort to pull up the bucket of water.

4. It changes the point of application of effort to a convenient point.

   Example : In a bicycle the rear wheel is jointed with the help of a chain to a toothed wheel attached with a pedal. The rear wheel is rotated by applying the effort on the pedal.

Thus, we can define a machine as follows :

A machine is a device which enables us (i) to exert a force (called the load) greater than the force (called the effort) applied to it or (ii) to apply a force at a convenient point or (iii) to apply a force in a desired direction, or (iv) to move the load longer than the effort.

Following are the *six* simple machines which we generally use in our daily life :

1. The lever *e.g.* mango cutter, beam balance, a pair of scissors, etc.
2. The pulley *e.g.* water well, crane, etc.
3. The wheel and axle *e.g.* door knob, steering wheel, etc.

4. The inclined plane *e.g.* staircase, ramp, etc.
5. The wedge *e.g.* needle, axe, etc.
6. The screw *e.g.* bolt, jar lid, drill, etc.

MECHANICAL ADVANTAGE

The factor by which a machine multiplies the force applied (*i.e.* effort) is called the **mechanical advantage** of that machine. It is the ratio of the load to the effort. In other words,

$$\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}}$$

Smaller the effort required for a certain load, the greater is the mechanical advantage of the machine. It can have a value greater than 1, 1 or less than 1. If the mechanical advantage of a machine is greater than 1 (*i.e.* effort < load), the machine is called a **force multiplier**.

LEVERS

A lever is a simple machine which we most commonly use in our daily life. In its simplest form, *a lever is a rod which can turn about a fixed point called the fulcrum.*

PRINCIPLE OF A LEVER

Fig. 4.6 shows a rod *AB* which can turn about a point *F*. The rod *AB* thus behaves as a lever. The fulcrum of the lever is *F*.

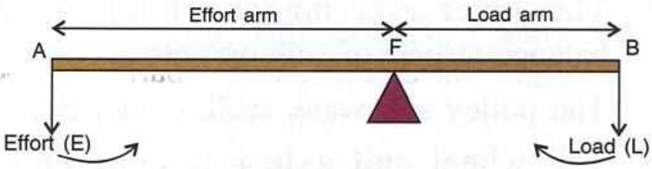


Fig. 4.6 Principle of a lever

If an effort *E* is applied at one point *A* on the lever and load *L* is exerted at another point *B*, the distance *FB* of load from the fulcrum *F* is called the **load arm** and the distance *FA* of effort from the fulcrum F is called the **effort arm**. When the lever is in balanced position (*i.e.* horizontal), it is found that

Load × Load arm = Effort × Effort arm

Or $L \times FB = E \times FA$

Mechanical advantage of lever

$$= \frac{\text{Load } L}{\text{Effort } E}$$

$$= \frac{\text{Effort arm } FA}{\text{Load arm } FB}$$

Thus, *the mechanical advantage of a lever is equal to the ratio of the effort arm to the load arm.* This is called the principle of a lever.

If load arm is greater than the effort arm, mechanical advantage is less than 1.

If load arm is equal to the effort arm, the mechanical advantage is equal to 1.

If load arm is smaller than the effort arm, mechanical advantage is greater than 1.

CLASSES (OR ORDERS) OF LEVERS

Levers are divided into *three* classes (or orders) depending on the position of the fulcrum, effort and load. They are

(1) class I (2) class II, and (3) class III

1. Levers of Class I

The levers in which the fulcrum is in between the load and the effort are called levers of class I (Fig. 4.7).

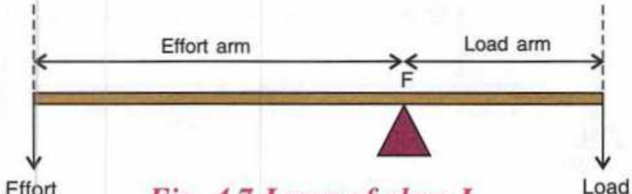


Fig. 4.7 Lever of class I

Generally, the effort arm of levers of class I is longer than the load arm, therefore, the mechanical advantage of class I levers is greater than 1. However, if the effort arm is equal to the load arm, the mechanical advantage is equal to 1. But if the effort arm is shorter than the load arm, its mechanical advantage is less than 1. Thus, *the mechanical advantage of levers of class I can be greater than 1, equal to 1 or less than 1.*

Examples : Some examples of class I levers are : a see-saw, a pair of scissors, a pair of pliers, crow bar, common balance, spoon opening the lid of a tin can, handle of a hand pump, the oar rowing a boat etc. Fig. 4.8 shows few levers of class I type.

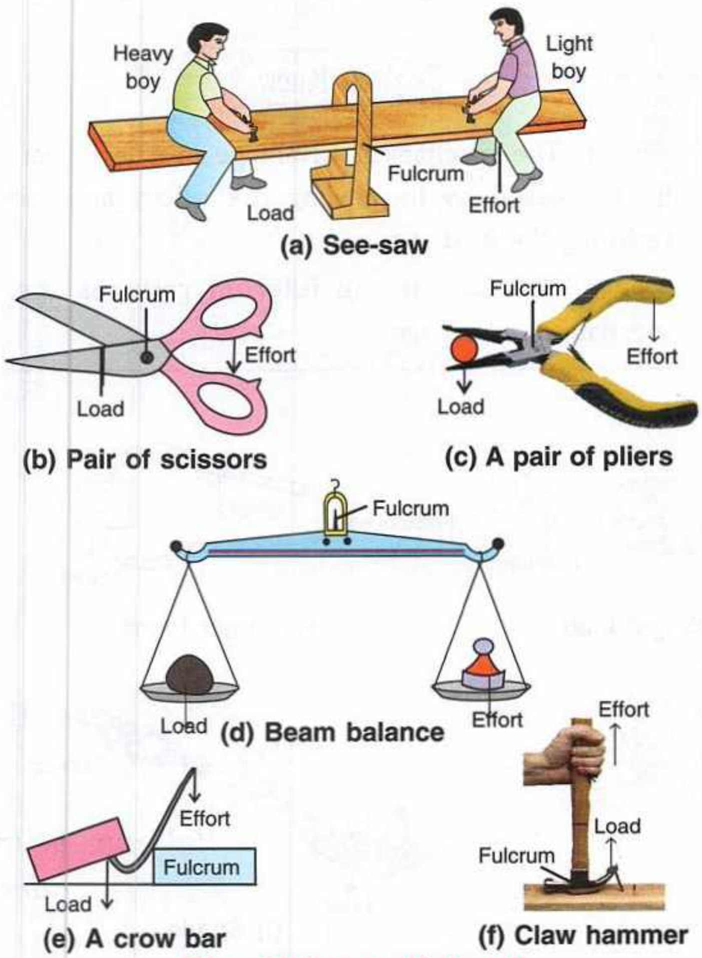


Fig. 4.8 Levers of class I

Note : **1.** The shears of a pair of pliers are shorter while that of a pair of scissors are longer. Thus, the load arm of pliers is shorter than the effort arm, so its mechanical advantage is more than 1, while the load arm of a pair of scissors is longer than the effort arm, so its mechanical advantage is less than 1.

2. In a beam balance, the effort arm is equal to the load arm, so its mechanical advantage is equal to 1.

2. Levers of class II

The levers in which the load is in between the fulcrum and the effort are called levers of class II (Fig. 4.9).

In class II levers, the fulcrum is at one end and the load is closer to the fulcrum. Thus, the effort arm is always longer than the load arm. Hence, **the mechanical advantage of class II levers is always more than 1.**

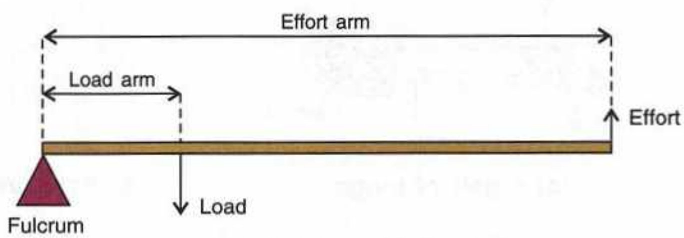
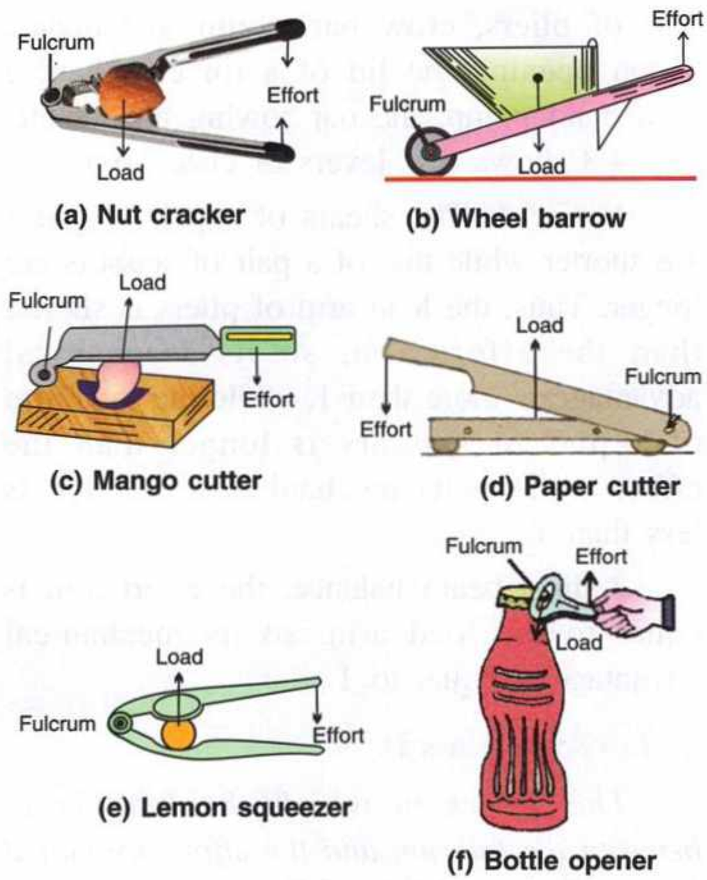


Fig. 4.9 A lever of class II

Examples : Few examples of levers of class II are: nut cracker, wheel barrow, paper cutter, mango cutter, lemon squeezer, bottle opener etc. Fig. 4.10 shows few levers of class II type.



(a) Nut cracker (b) Wheel barrow

(c) Mango cutter (d) Paper cutter

(e) Lemon squeezer (f) Bottle opener

Fig. 4.10 Levers of class II

3. Levers of class III

The levers in which the effort is in between the fulcrum and the load are called levers of class III (Fig. 4.11).

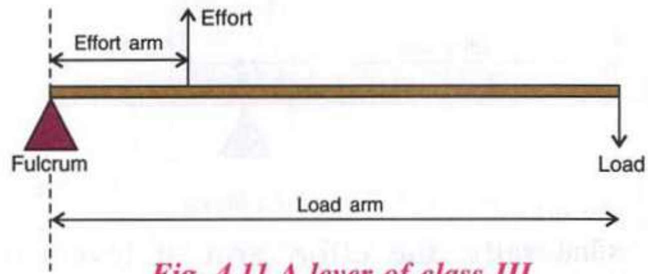


Fig. 4.11 A lever of class III

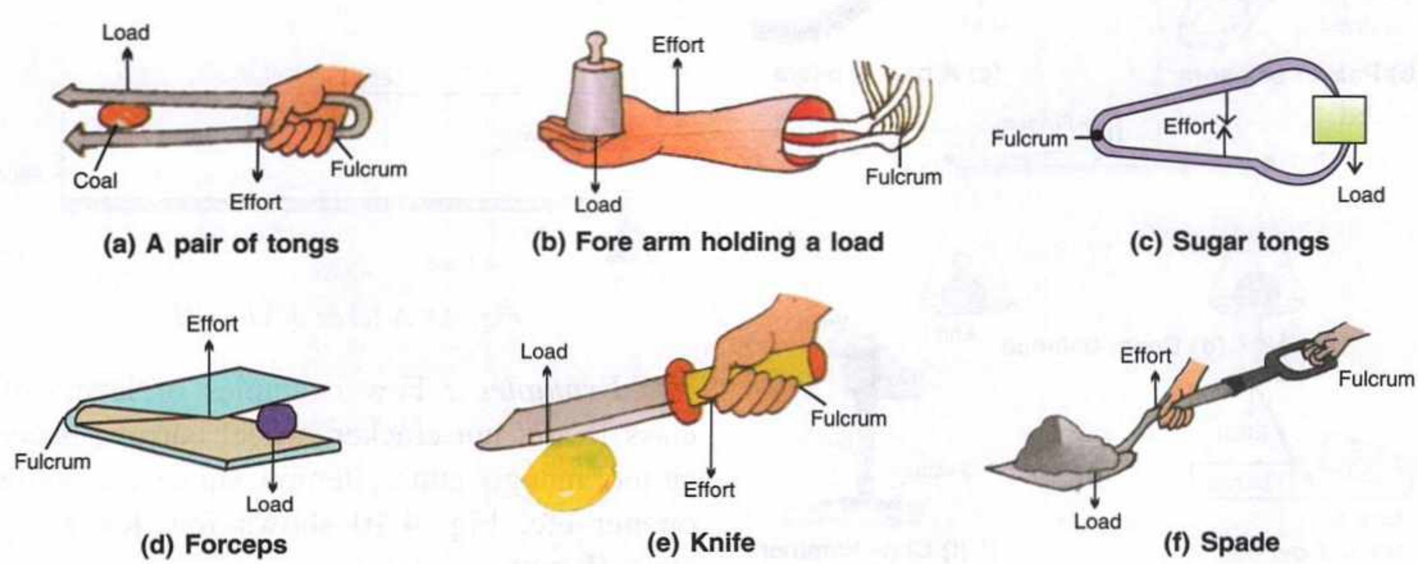
In class III levers, the fulcrum is at one end and the effort is close to the fulcrum, thus the effort arm is always shorter than the load arm. Hence, **the mechanical advantage of class III levers is always less than 1.**

Examples : Some examples of levers of class III are : a pair of tongs, sugar tongs, knife, forceps, forearm of a person holding a load, spade for lifting soil or coal etc. Fig. 4.11 shows few levers of class III type.

Do You Know ?

1. The mechanical advantage of a lever can be increased by increasing the effort arm or reducing the load arm.

2. Friction at the fulcrum reduces the mechanical advantage.



(a) A pair of tongs (b) Fore arm holding a load (c) Sugar tongs

(d) Forceps (e) Knife (f) Spade

Fig. 4.12 Lever of class III

Distinction between the three classes of levers

CLASS I	CLASS II	CLASS III
1. It has the fulcrum between the load and the effort.	1. It has the load between the fulcrum and the effort.	1. It has the effort between the fulcrum and the load.
2. The effort arm can be shorter, equal to or longer than the load arm.	2. The effort arm is always longer than the load arm.	2. The effort arm is always shorter than the load arm.
3. The mechanical advantage can be less than, equal to or greater than 1.	3. The mechanical advantage is always greater than 1.	3. The mechanical advantage is always less than 1.
4. The load and the effort both are in the same direction.	4. The load and the effort are in opposite directions.	4. The load and the effort are in opposite directions.

PULLEY

A pulley is used for lifting up a load such s a bucket full of water from a well, a heavy aterial in a factory, a car engine in a garage tc. by applying the effort downwards.

A pulley is a simple machine by which he direction of effort is changed to raise up a load.

A pulley consists of a circular disc made of a metal or wood. The disc can rotate about n axle passing through its centre. The disc as a groove along its rim through which a tring or rope can pass around. The ends of he axle are supported on a frame which is alled the block. The block of the pulley is ttached to a fixed support. Fig. 4.13 shows pulley arrangement.

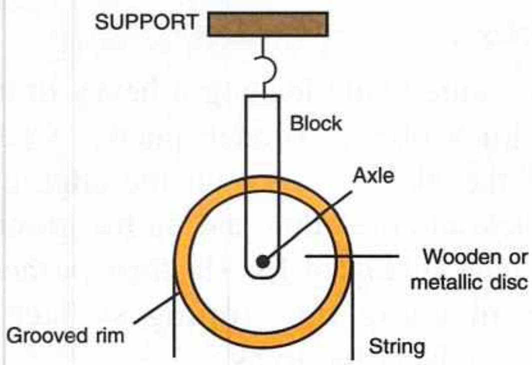


Fig. 4.13 A pulley arrangment

To raise a load, the load is attached to one end of the string and the effort is applied at the other end by pulling it in downward direction as shown in Fig. 4.14.

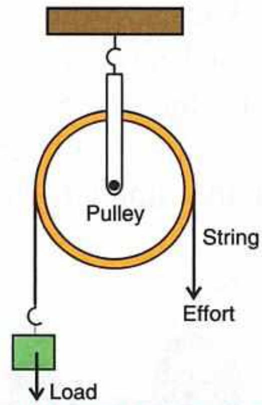


Fig. 4.14 A pulley used in raising a load

MECHANICAL ADVANTAGE OF THE PULLEY

In an ideal pulley, the effort applied is equal to the load to be lifted.

i.e., Effort = Load

$$\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}} = 1$$

In an actual pulley, due to friction, the mechanical advantage is less than 1 (*i.e.* the effort is more than the load).

The reason why we use the pulley when its mechanical advantage is equal to 1 or less than 1 is that the pulley allows us to apply the effort downwards *i.e.* in a convenient direction. To raise a load directly upwards is difficult, but with the help of a pulley, the effort can be applied in the downward direction which helps to move the load upwards. One can also hang onto it and make use of his own weight in order to apply the effort.

WHEEL AND AXLE

A wheel and axle is also a simple machine. It consists of either a wheel attached to an axle or two wheels of different diameters attached together as shown in Fig. 4.15. The wheel is the circular object which is capable of rotating on its axis. As the wheel rotates, the axle also rotates with it and advances linearly. If there are two wheels, the effort is applied on the bigger wheel (called wheel) and load is attached with the smaller wheel (called the axle).

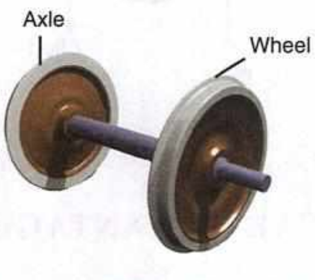


Fig. 4.15 Wheel and axle

The use of wheel and axle provides linear motion by the rotation of wheel and so it reduces the friction (because rolling friction is less than the sliding friction).

Examples : Steering wheel of a car, bicycle pedal, door knob, screw driver, water tap etc. Fig. 4.16 shows some such tools.

Fig. 4.16 Tools with wheel and axle

INCLINED PLANE

An inclined plane is a slanting wooden plank or a sloping surface. It is a simple machine which is used to move a load up with a less effort. Fig 4.17 shows an inclined plane.

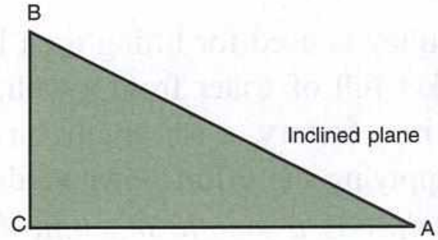


Fig. 4.17 Inclined plane

The effort required to push a load up an inclined plane is less than the load. Thus, **the mechanical advantage of an inclined plane is always greater than 1**. For greater mechanical advantage (or less effort) the length of slope *AB* must be much more than its vertical height *CB*. In other words, mechanical advantage is more when the slope is smaller and less steep as the effort needed to push the load up is less.

Examples :

1. A coolie while loading a heavy drum on a truck uses a wooden plank. One end of the plank is kept on the edge of the truck and the other end on the ground as shown in Fig. 4.18. He then pushes the drum along the sloping surface and places it on the truck.

Fig. 4.18 An inclined plane used by a coolie to load a truck with drums

2. A ramp (or inclined plane) is provided in a building which helps people in keeping their scooters, motor cycles or bicycles inside the building by pushing it along the ramp.
3. Hospitals and huge buildings are provided with ramps which help nurses to move up the patients on a stretcher or to carry heavy equipments.
4. Staircases in our homes are also made as inclined planes.
5. The roads on a hill are made inclined with a small slope.

WEDGE

A wedge is a simple machine having a sharp edge which is formed by putting two inclined planes together as shown in Fig. 4.19.

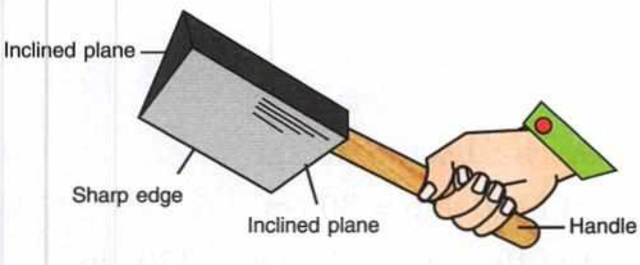


Fig. 4.19 A wedge

A heavy wedge with a sharp edge is easy to drive into the log and split it into two pieces.

Examples : Knife, axe, plough, nail, saw, needle etc. are some examples of wedge, some of these are shown in Fig. 4.20.

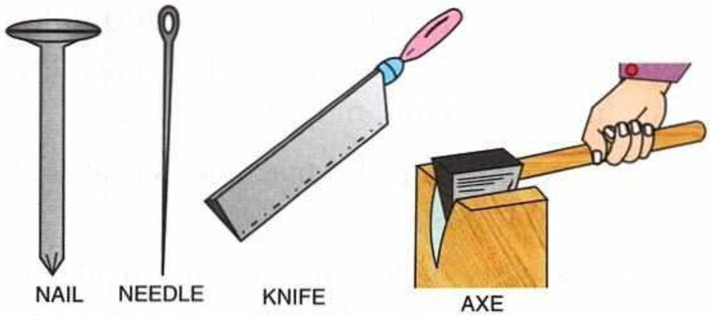


Fig. 4.20 Some tools with wedge

SCREW

A screw is a simple machine which appears like an inclined plane wound around a rod with a pointed tip. Hence, it appears like a nail with grooves on its circular curved surface. A screw is made by cutting the spiral grooves on the surface of a metal rod. The spiral grooves so formed are called the **threads** of the screw. Fig. 4.21 shows a screw. The one end of the rod is made narrow (or pointed) which is called the **tip** of the screw. The other end is made flat which is called the **head** of the screw. A narrow slit is made in the head of the screw so as to turn the screw with the help of a screw driver.

Fig. 4.21 A screw

It is difficult to drive a screw into the wood by hammering it on its head. But it can easily be driven into the wood by turning it with a screw driver because the screw then works as an inclined plane. Thus, a screw is simply a modified form of an inclined plane.

CARE OF MACHINES

We all use several kinds of machines in our daily life. They are used for our convenience. Therefore, we should take proper care of the machines. For this, the following precautions must be followed :

1. We should keep the machines clean and free from dust.
2. If the parts of the machine are made of iron, they can rust. To prevent them from rusting, such parts must be painted.
3. Friction causes wear and tear of the moving parts of a machine. To reduce friction, these parts must be properly lubricated from time to time.

Such care of machines increases their life and efficiency.

SOLVED EXAMPLES

1. A machine requires an effort of 10 kgf for a load of 50 kgf. Find its mechanical advantage.

Given : Load = 50 kgf, Effort = 10 kgf

$$\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}} = \frac{50\,\text{kgf}}{10\,\text{kgf}} = 5$$

2. Calculate the mechanical advantage of a lever in which the effort arm is 60 cm and the load arm is 4 cm.

Given : Effort arm = 60 cm,
Load arm = 4 cm

$$\text{Mechanical advantage} = \frac{\text{Effort arm}}{\text{Load arm}} = \frac{60\,\text{cm}}{4\,\text{cm}} = 15$$

3. A machine of mechanical advantage 6 is used for a load of 120 kgf. Find the required effort.

Given : Mechanical advantage = 6,
Load = 120 kgf

$$\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}}$$

$$\text{Effort} = \frac{\text{Load}}{\text{Mechanical advantage}} = \frac{120\,\text{kgf}}{6} = 20\ \text{kgf}.$$

4. A lever of length 1.20 m has a load of 50 kgf at a distance of 30 cm from one end and fulcrum is at the end of shorter arm. The effort is applied at the end of the longer arm. Draw a diagram and find :

(a) the length of load arm
(b) the length of effort arm
(c) the mechanical advantage, and
(d) the effort required.

Name the class of lever.

The diagram is shown in Fig. 4.22.

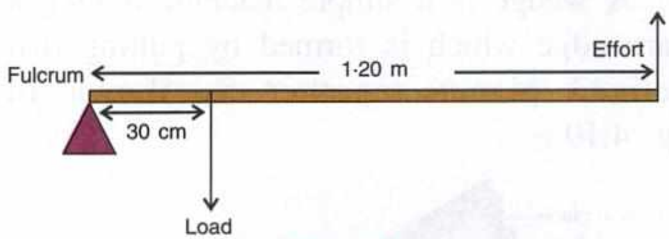


Fig. 4.22

Given : Load = 50 kgf

(a) Load arm = 30 cm

(b) Effort arm = 1·20 m = 120 cm

$$\text{(c) Mechanical advantage} = \frac{\text{Effort arm}}{\text{Load arm}} = \frac{120\,\text{cm}}{30\,\text{cm}} = 4$$

(d) By definition,

$$\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}}$$

$$\therefore\ 4 = \frac{50\ \text{kgf}}{\text{Effort}}$$

$$\text{Effort} = \frac{50\ \text{kgf}}{4} = 12{\cdot}5\ \text{kgf}$$

The lever is of class II type.

RECAPITULATION

- Work is said to be done when a force applied on a body moves it. If the body does not move on applying a force on it, no work is done by the force.
- The capacity of doing work is called energy.
- A machine is a device which helps us to do a job more easily.
- A machine enables us (i) to apply an effort less than the load, (ii) to move the load longer than the effort, (iii) to apply the effort in a convenient direction and (iv) to apply the effort at a convenient point.
- Some machines are simple and some are complex.
- The mechanical advantage of a machine is the ratio of the load to the effort, *i.e.*,

$$\text{Mechanical advantage} = \frac{\text{Load}}{\text{Effort}}$$

- Smaller the effort required for a certain load, greater is the mechanical advantage of the machine.
- The efficiency of a machine is the ratio of the useful work done on the load by the machine to the work put into the machine by the effort, *i.e.*

$$\text{Efficiency} = \frac{\text{Work output}}{\text{Work input}}$$

- The efficiency of an ideal or perfect machine is 1 (or 100 per cent).
- The efficiency of an actual machine is less than 1 because some part of the work put into the machine is wasted in overcoming the friction between the moving parts of the machine.
- A lever is a simple machine which we most commonly use in our daily life. It is a rod which can turn about a fixed point called the fulcrum.
- The mechanical advantage of a lever is equal to the ratio of the effort arm to the load arm, *i.e.*

$$\text{Mechanical advantage of a lever} = \frac{\text{Effort arm}}{\text{Load arm}}$$

- The levers are of three kinds :

  Class I levers which have fulcrum in between the load and the effort.

  Class II levers which have load in between the fulcrum and the effort.

  Class III levers which have effort in between the fulcrum and the load.
- The mechanical advantage of class I levers can be 1, more than 1 or less than 1.
- The mechanical advantage of class II levers is always more than 1.
- The mechanical advantage of class III levers is always less than 1.

- A pulley is a simple machine which is used for raising a load up by applying the effort downwards.
- The mechanical advantage of an ideal pulley is 1. In an actual pulley, due to friction, the mechanical advantage is less than 1 (*i.e.* the effort is more than the load).
- The pulley allows us to apply the effort downwards which is a convenient direction.
- The wheel and axle is a simple machine having a wheel and an axle. The linear motion of axle is obtained by rotating the wheel so as to reduce friction. *Examples :* Steering wheel, screw driver, water tap etc.
- An inclined plane is a simple machine which is used to move a load up with a less effort. It is a sloping (or slanting) surface.
- Less the slope of the inclined plane, less is the effort needed to push a load up.
- The mechanical advantage of an inclined plane is greater than 1 (*i.e.* less effort is required to push a heavy load up an inclined plane).
- A wedge is a sharp edge formed by joining two inclined planes together. *Examples :* nail, knife, axe, plough etc.
- A screw is a modified form of an inclined plane.
- A screw jack is a simple machine having a combination of a screw and a lever. It is used to lift heavy vehicles such as cars, trucks, buses etc.
- Machines are used for our convenience. Therefore, we should take proper care of a machine by painting its iron parts to avoid their rusting, lubricating its moving parts to reduce friction, etc. This increases the life span of the machine.

TEST YOURSELF

A. Objective Questions

1. State whether the following statements are *true* or *false* :
   (a) A boy does work while pushing a wall.
   (b) A machine performs work by itself.
   (c) In an ideal machine, work done on load is equal to the work done by effort.
   (d) All levers are force multipliers.
   (e) A pulley changes the direction of force.
   (f) An inclined plane always has the mechanical advantage more than 1.

   Ans: True (c), (e), (f) **False** (a), (b), (d)

2. Fill in the blanks :
   (a) The useful work done by an actual machine is always .... than the work done on the machine.
   (b) In class II levers, the .... is in between fulcrum and ....
   (c) The mechanical advantage of class .... lever is always less than 1.
   (d) A pulley is used to change ....
   (e) Mechanical advantage of an inclined plane is always ....

   Ans: (a) less (b) load, effort (c) III (d) the direction of effort (e) greater than 1

3. Match the following columns :

Column A	Column B
(a) Needle	(i) class II lever
(b) Door knob	(ii) inclined plane
(c) Ramp	(iii) class I lever
(d) Lemon crusher	(iv) wheel and axle
(e) See-saw	(v) wedge

   Ans: (a)-(v), (b)-(iv), (c)-(ii), (d)-(i), (e)-(iii)

4. Select the correct alternatives :
   (a) For an ideal machine, the efficiency is
   (i) greater than unity

(ii) less than unity

(iii) equal to unity

(iv) depends on the value of load

(b) Mechanical advantage of a machine is defined as :

(i) Load × Effort (ii) $\frac{\text{Load}}{\text{Effort}}$

(iii) Load + Effort (iv) $\frac{\text{Effort}}{\text{Load}}$

(c) The mechanical advantage of a lever is equal to :

(i) $\frac{\text{Load arm}}{\text{Effort arm}}$ (ii) $\frac{\text{Effort arm}}{\text{Load arm}}$

(iii) Load arm + Effort arm

(iv) Load arm – Effort arm

(d) A pulley is used because it

(i) has the mechanical advantage greater than one

(ii) has 100% efficiency

(iii) helps to apply the force in a convenient direction

(iv) requires more effort to raise a less load.

(e) Wheel is used with axle because

(i) sliding friction is less than the rolling friction

(ii) rolling friction is less than the sliding friction

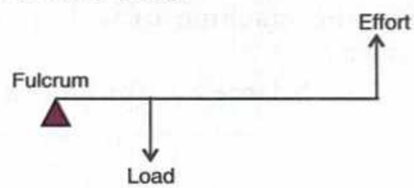
(iii) they work as the inclined plane

(iv) they help us to change the direction of force.

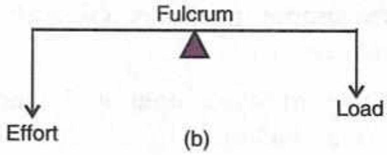
Ans: (a)-(iii), (b)-(ii), (c)-(ii), (d)-(iii), (e)-(ii)

B. Short/Long Answer Questions

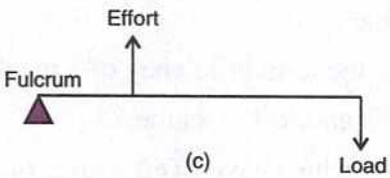
1. When is work said to be done by a force ?
2. What is energy ?
3. What do you understand by a machine ?
4. What is the principle on which a machine works ?
5. State *two* functions of a machine.
6. Name *six* simple machines. Give an example of each machine.
7. Define the term 'work input' and 'work output' in relation to a machine.
8. Explain the term mechanical advantage of a machine.
9. Define the term efficiency of a machine.
10. What is an ideal machine ?
11. Can a machine have an efficiency of 100 % ? Give a reason to support your answer.
12. 'A machine is 75% efficient'. What do you understand by this statement ?
13. What is a lever ?
14. Describe *three* orders of levers giving an example of each. Draw neat diagrams showing the positions of fulcrum, load and effort in each kind of lever.
15. What do you mean by the mechanical advantage of a lever ?
16. Which class of lever has the mechanical advantage always more than 1 ? Give an example.
17. Which class of lever has the mechanical advantage always less than 1 ? Give an example.
18. Give *one* example of class I lever in each case where the mechanical advantage is
    (i) more than 1 (ii) equal to 1 (iii) less than 1.
19. Name the class to which the following levers belong :
    (a) A pair of scissors, (b) a lemon squeezer,
    (c) a nut cracker, (d) a pair of sugar tongs,
    (e) a beam balance, (f) an oar rowing a boat,
    (g) a wheel barrow, (h) a see-saw,
    (i) a pair of pliers, (j) a crowbar.
20. The diagram given below shows the three kinds of levers. Name the class of each lever and give one example of each class.



(a)



(b)

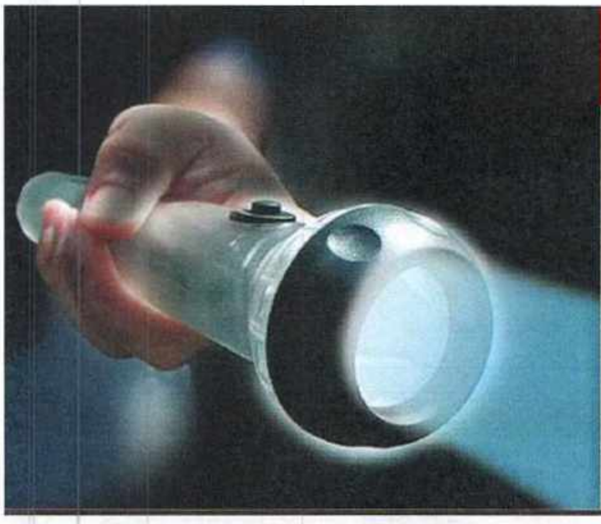


(c)

21. Draw diagrams to illustrate the positions of fulcrum, load and effort, in each of the following:
    (a) a see-saw (b) a beam balance
    (c) a nut cracker (d) a pair of forceps
22. How can you increase the mechanical advantage of a lever ?
23. How does the friction at the fulcrum affect the mechanical advantage of a lever ?
24. State three differences between the three classes of levers.
25. What is a pulley ?
26. What is the mechanical advantage of an ideal pulley ?
27. The mechanical advantage of an actual pulley is less than 1. Give a reason. What is the justification for using the pulley then ?
28. Draw a neat labelled diagram showing a pulley being used to lift a load. How are load and effort related in an ideal situation ?
29. What is an inclined plane ? What is its mechanical advantage ? Give two examples where it is used.
30. What is a screw ? Give *two* examples.
31. What is wheel and axle ? Give *two* examples.
32. How does a wheel help in moving the axle ?
33. What is a wedge? Give *two* examples.
34. Name the machine to which the following belong :
    (a) Beam balance (b) Lemon crusher
    (c) Sugar tongs (d) Ramp
    (e) Door knob (f) Needle
35. What care would you take to increase the life span of a machine which you use ?
36. Select the correct statement :
    (a) A wheel barrow is a lever of class I.
    (b) The efficiency of a machine is always 100%.
    (c) Friction in moving parts of a machine reduces its efficiency.
    (d) No lever has the mechanical advantage greater than 1.
    (e) It is easier to lift a load vertically up than to push it along an inclined plane.
    (f) A screw is made by two inclined planes placed together. **Ans:** (c)

C. Numericals :

1. In a machine an effort of 10 kgf is applied to lift a load of 100 kgf. What is its mechanical advantage? **Ans:** 10
2. The mechanical advantage of a machine is 5. How much load it can exert for the effort of 2 kgf ? **Ans:** 10 kgf
3. The mechanical advantage of a machine is 2. It is used to raise a load of 15 kgf. What effort is needed ? **Ans:** 7·5 kgf
4. A lever of length 100 cm has effort of 15 kgf at a distance of 40 cm from the fulcrum at one end. What load can be applied at its other end ? **Ans:** 6 kgf
5. In a lever, fulcrum is at one end at a distance of 30 cm from the load and effort is at the other end at a distance of 90 cm from the load. Find :
    (a) the length of load arm,
    (b) the length of effort arm, and
    (c) the mechanical advantage of the lever.
    Ans: (a) 30 cm, (b) 120 cm, (c) 4



5

Light

Theme : Light is an important element that helps in making objects visible and travels in a straight line. When light falls on an object it casts a shadow. The earth and the moon and, in fact, planets cast their shadows in space. Sometimes, on a full- moon day, the moon passes through the shadow of the earth. The earth casts two shadows that fall on the moon during a lunar eclipse. The umbra is a full dark shadow. The penumbra is a partial outer shadow.

In this chapter you will learn :

Rectilinear propagation of light

Applications of rectilinear propagation of light

Pinhole camera

- Principle and Working
- Factors on which the size of the image produced depends on.

Shadows

- Umbra
- Penumbra
- Natural Shadows – Eclipses

LEARNING OBJECTIVES

The children will be able to :

- give examples of evidence that light travels in straight lines;
- describe principle, construction and working of a pinhole camera;
- explain the factors on which the size of the image in a pinhole camera depends upon;
- explain the formation of shadows;
- explain the occurrence of lunar eclipse;
- explain the term umbra and penumbra.

LIGHT

We are aware of the importance of light. We can see objects around us when there is light, while nothing is seen in the dark. If we enter a dark room, we cannot see anything. But if we switch on a torch, or switch on a bulb, or light a match stick, or light a candle, we are able to see the things around us. In the daylight, we do not require anything else to see the objects around us.

An object becomes visible to us when the light after striking the object gets reflected and reaches our eyes. Light itself is not visible, but light makes objects visible to us. Light is therefore a vital and useful requirement of our life. We define light as follows :

Light is a form of energy that affects our eyes to produce the sensation of vision.

Do You Know ?

1. Light travels in straight lines in form of rays.

2. Light travels with the maximum speed equal to 3×10^8 metre per second in air or vacuum.

SOURCES OF LIGHT

We have *two* types of sources of light :

(1) natural sources of light and

(2) artificial sources of light.

1. **Natural sources of light :** The sun is the main natural source of light. On earth, we receive light mainly from the sun. During the day, we see all the things around us because of sunlight. The other natural sources of light are the innumerable stars that we see in the sky at night. Since they are very far from us, we receive very little light from them.

   A firefly (or *jugnu*) emits light naturally due to certain chemicals present in its body. However, the light we receive from it is very faint and we can't see much just by its light.

   Note : The moon is not a natural source of light.

2. **Artificial sources of light :** At night when we do not receive light from the natural source (*i.e.* the sun), we use artificial sources of light. Some of the common artificial sources of light are : fire, a glowing electric bulb, electric tubelight, a burning candle, a kerosene lamp, a torch, heated bodies, etc. Some of these are shown in Fig. 5.1.

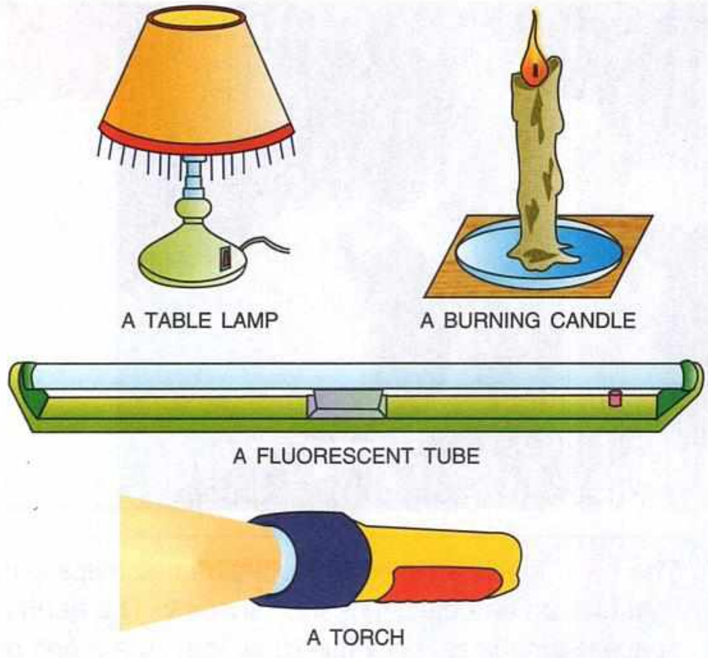


Fig. 5.1 Some artificial sources of light

Do You Know ?

There is brightness all around us even if the sunlight does not directly reach us. The reason is that the light given out by the sun spreads in all directions by the particles (or molecules) of the atmospheric air. This process is called the scattering of light. It is the scattered light which reaches all places around us even when no direct light from sun reaches there. This scattered sunlight makes objects visible to us.

LUMINOUS AND NON-LUMINOUS BODIES

1. **Luminous bodies :** The bodies which emit their own light are called luminous bodies. They shine and glow by their own light. A luminous body provides us light. The sun, the stars, a burning candle, an electric lamp, a torch, an electric tube light, a kerosene lamp, all are luminous bodies.

2. **Non-luminous bodies :** The bodies which do not emit light by their own, but become visible (or they shine) by the light falling on them from some luminous body, are called non-luminous bodies. The moon, earth, a table, a book, a chair etc. are non-luminous bodies. A non-luminous body becomes visible when light from a luminous body falls on it and after striking it, light reaches our eyes. Fig. 5.2 shows how a non-luminous body (say, a book) becomes visible when light from a torch reaches our eyes after striking the book.

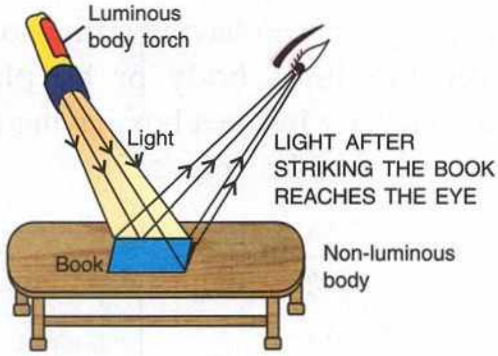


Fig. 5.2 Visibility of a non-luminous body (book)

ACTIVITY 1

1. Take a rectangular cardboard box (may be a shoes box) and cut a peeping window on one of its smaller faces. Place few objects such as pen, pencils, geometry box, pocket diary etc. inside the box. Cover the box as well as your head with a piece of thick black cloth. Peep into the box through the window. You will not be able to see anything.

2. Now place a lighted torch inside the box, and peep into the box again. Now you will be able to see the torch as well as the other things in the box.

Thus, a luminous object (such as torch) can be directly seen but non-luminous objects are seen only when light falls on them.

3. **Seeing the moon :** We see the moon shining at night. But moon is not a luminous body, it is non-luminous. It has no light of its own. The moon receives light from the sun. This sunlight after striking the moon reaches us on earth, due to which it is seen shining. Fig. 5.3 illustrates how the moon becomes visible to an observer on earth when sunlight reaches him after striking the moon.

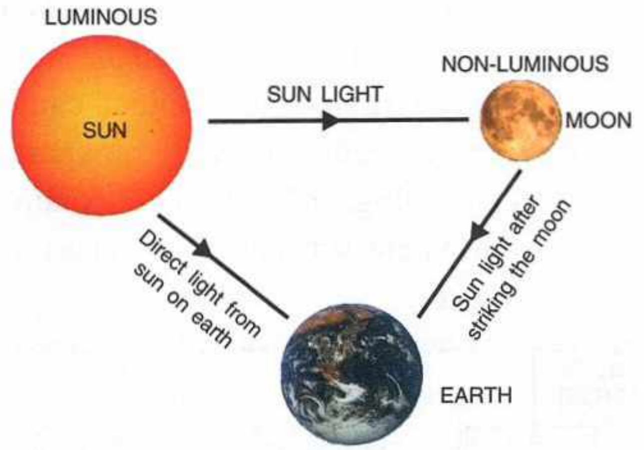


Fig. 5.3 Visibility of moon to an observer on earth

Do You Know ?

Light does not require any medium for its propagation. It can travel through a vacuum. However if there is any medium, it can travel through it also. Light reaches earth from the sun after travelling through vacuum and then through air.

SOME IMPORTANT TERMS

A. Transparent, Translucent and Opaque substances

When light falls on a substance, *three* cases can arise :

(i) The light passes completely through the substance.

(ii) The light passes partially through the substance.

(iii) The light does not pass through the substance.

Depending upon the behaviour of the substances towards light, they are of three kinds :

1. Transparent substance,
2. Translucent substance, and
3. Opaque substance

1. Transparent Substance : A *substance is said to be transparent if light passes through it easily*. The object can be distinctly seen across a transparent substance [Fig. 5.4 (a)]. The examples of transparent substances are glass, air, water, etc.

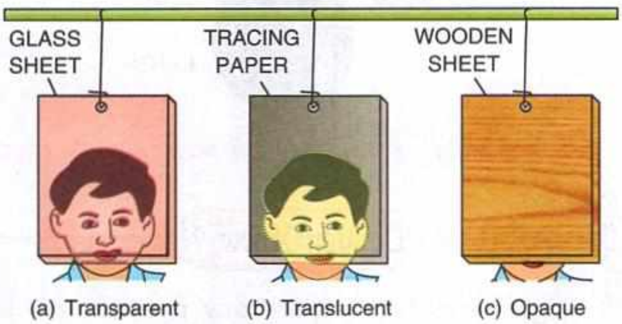


Fig. 5.4 Different kinds of substances

2. Translucent substance : *A substance is said to be translucent if it allows only a part of light to pass through it*. The details of an object cannot be distinctly seen through a translucent substance, but only a faint impression is seen [Fig. 5.4 (b)]. Ground glass, tracing paper, waxed paper, greased paper, etc. are some examples of translucent substances.

3. Opaque substance : *A substance is said to be opaque if it does not allow any light to pass through it*. We cannot see the objects through an opaque substance [Fig. 5.4 (c)]. Wooden screen, metallic sheets, black paper, etc. are examples of opaque substances.

Thus, if light travels in a medium, the medium must be transparent.

B. Extended and a point source of light

A luminous body such as torch, electric lamp or burning candle emits light and it is called an extended source of light.

A point source of light is obtained either by placing a screen having a fine hole, in front of the luminous body or by placing the luminous body inside a box having a fine hole on one of its sides (Fig. 5.5).

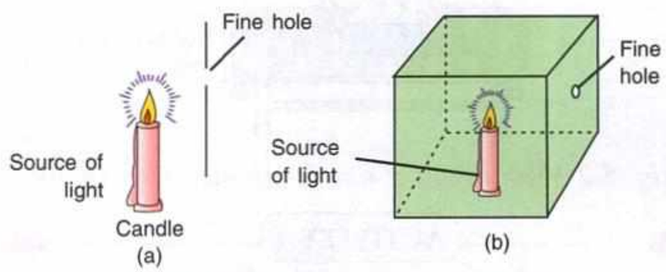


Fig. 5.5 A point source of light

C. A ray and a beam of light

The light given out by a point source spreads in all directions, moving in straight lines. The light travelling in any one direction in a straight line is called **a ray of light**. A ray of light is represented by a straight line bearing an arrow as shown in Fig. 5.6. The tip of the

Fig. 5.6 A ray of light

arrow indicates the direction in which light is moving.

A group of light rays given out from a source is called **a beam of light**. Fig. 5.7 shows a beam of light given out from a point source of light.

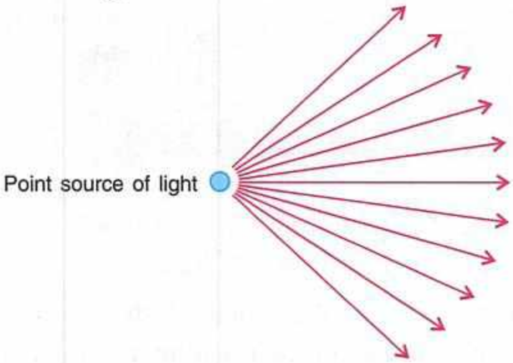


Fig. 5.7 A beam of light from a point source of light

The beam of light can be of *three* kinds :

(a) A parallel beam,

(b) A divergent beam, and

(c) A convergent beam.

(a) The beam of light from a source at a very far distance has light rays parallel to each other. It is called a parallel beam of light (Fig. 5.8).

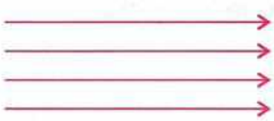


Fig. 5.8 A parallel beam of light from a distant source

(b) The beam of light given out from a point source at a finite distance spreads out in different directions (*i.e.* it diverges) as shown in Fig. 5.7. It is called a divergent beam of light.

(c) The beam of light coming towards a point (*i.e.* converging to a point) is called a convergent beam of light (Fig. 5.9).

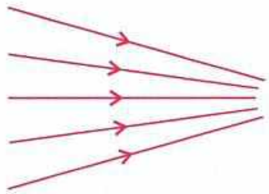


Fig. 5.9 A convergent beam of light

RECTILINEAR PROPAGATION OF LIGHT

It is our common experience that if we close all the windows and doors of our room to make it completely dark and then look at the light entering into the room through a narrow opening (or hole) as shown in Fig. 5.10, we observe the paths of illuminated dust particles which show that the path of light is nearly **straight**.

Now if we take a thread and stretch it along the path of light ray, with the help of a friend, it is noted that the thread coinciding the path of the light ray becomes illuminated. This shows that light travels in a straight line path. The motion of light in a straight line path is called the rectilinear propagation of light.

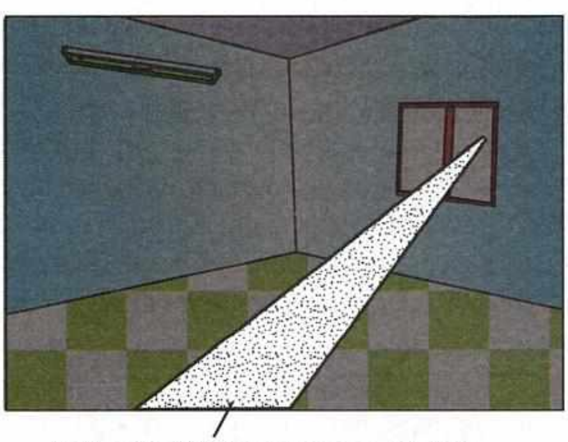


Fig. 5.10 Rectilinear propagation of light

ACTIVITY 2

Place a lighted candle on a table. Take a drinking straw. Close one eye and look at the candle flame through the straw from the other eye. The flame is clearly visible [Fig. 5.11 (a)].

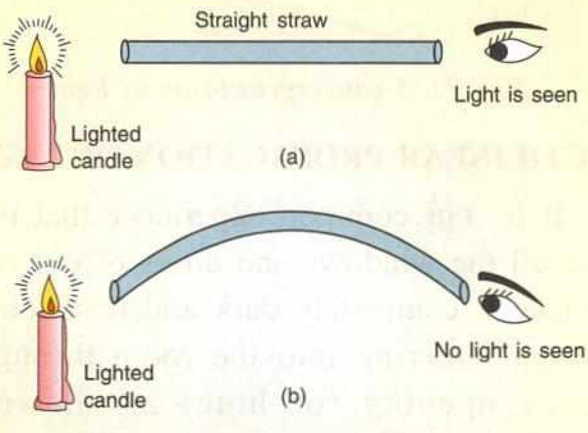


Fig. 5.11 To show the rectilinear propagation of light

Now bend the straw in the middle and again look at the candle flame through the straw [Fig. 5.11 (b)]. The flame is not visible now. The reason is that light travels in a straight line path. When the straw is bent, the light of the candle flame does not reach our eye.

Conclusion : Light travels in a straight line path.

ACTIVITY 3

Take three square cardboards A, B and C each of side about 5 cm. Take a pin and make a small hole in each cardboard at the same height. Suspend the cardboard pieces by separate threads vertically from a support such that each hole is at the same height, as shown in Fig. 5.12 (a). Pass a string through the holes and pull it taut. This makes the three holes to be in a straight line. Now take out the string.

Place a lighted candle near one of the cardboards (say A). Look at the candle flame from the other side of the cardboard C. The candle flame is clearly visible [Fig. 5.12 (a)].

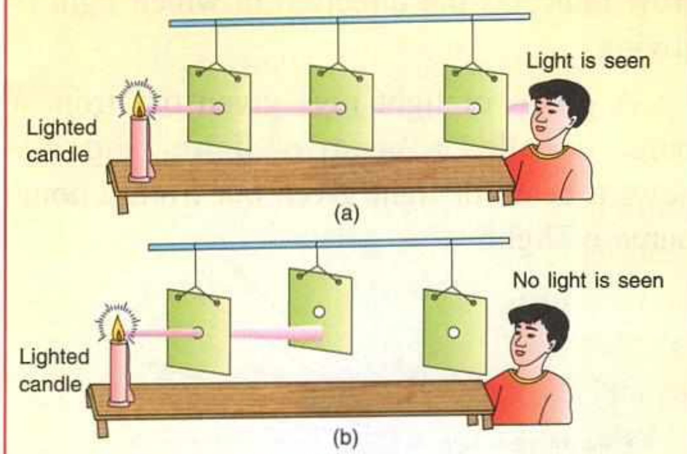


Fig. 5.12 To show the rectilinear propagation of light

Now slightly displace one of the cardboards (say B) so that the holes no longer remain in a straight line [Fig. 5.12 (b)]. Again look at the candle flame from the other side of the cardboard C. You do not see the candle flame. The reason is that light travels in a straight line and now the holes in the cardboards A, B and C are not in a straight line. Therefore, the flame is not visible.

Conclusion : Light travels in a straight line path.

Do You Know ?

Light travels in one second, a distance equal to 3×10^8 metre in air, $2{\cdot}25 \times 10^8$ metre in water and 2×10^8 metre in glass.

APPLICATIONS OF RECTILINEAR PROPAGATION OF LIGHT

Now we shall discuss the following *three* applications of rectilinear propagation of light :

(1) Pin hole camera,

(2) Formation of shadows, and

(3) Eclipses.

PIN HOLE CAMERA

Pin hole camera is a simple application of the rectilinear propagation of light.

To construct a pin hole camera : Take an ordinary cardboard box (or a tin can) either cylindrical or rectangular. Make a small pin hole near the centre of one face of the box (or can). Remove the opposite face of the box (or can) and fix a tracing paper (or wax paper) in its place, using a rubber band (or some thread). Now a pin hole camera is ready for use. Fig. 5.13 shows a pin hole camera.

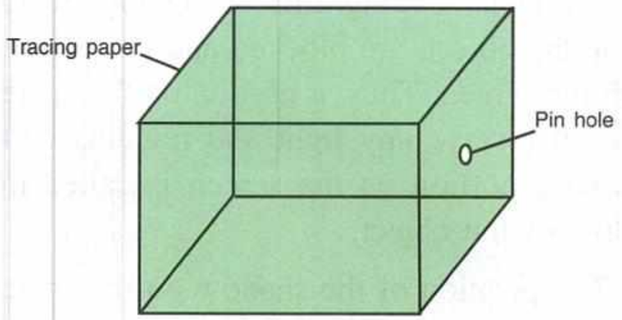


Fig. 5.13 Pin hole camera

Do You Know ?

The pin hole camera was invented in the eleventh century by an Arabic scientist, so as to see the solar eclipse without directly looking towards the sun.

Working and formation of image : If a luminous object AB, such as a lighted candle, is placed in front of the pin hole, an inverted picture A′B′ of the candle is obtained on the tracing paper. This picture A′B′ is called the image. The image obtained is upside down (*i.e.* inverted). The reason is that light travels in a straight line path. Hence, light from the upper point A of the candle passes through the pin hole and strikes the tracing paper at A′. Similarly, light from the lower point B of the candle passes through the pin hole and strikes the tracing paper (or screen) at B′. Light rays from all the other points between A and B, on passing through the pin hole strike the tracing paper in between A′ and B′. As a result, an inverted image of the candle is seen on the tracing paper. Fig. 5.14 shows the simple ray diagram for the formation of image.

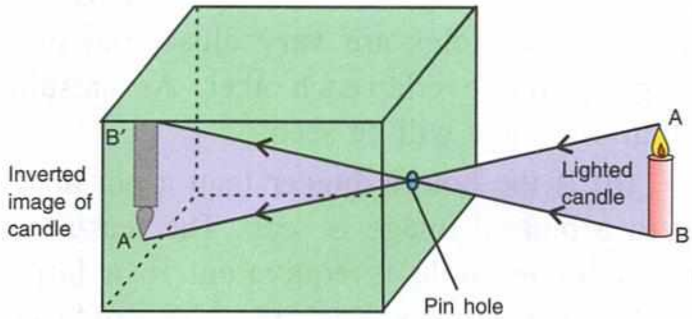


Fig. 5.14 Ray diagram for formation of image in a pinhole camera

Factors affecting the size of the image :

The size of an image depends on the following *two* factors :

(1) The distance of screen (*i.e.* tracing paper) from the pin hole, and

(2) The distance of object (*i.e.* candle) in front of the pin hole.

(1) Effect of distance of screen from the pin hole on the size of image : On increasing the distance of screen (*i.e.* tracing paper) from the pin hole, the size of image also increases.

(2) Effect of the distance of object from the pin hole on the size of image : If the object is moved away from the pin hole (*i.e.* the distance of object from the pin hole is increased), the size of the image decreases.

Actually,

$$\frac{\text{The size of image}}{\text{The size of object}} = \frac{\text{Distance of screen from the pin hole}}{\text{Distance of object from the pin hole}}$$

Note : (a) If another pin hole is made near the first pin hole, two images are formed on the screen, one due to each of the two pin holes. If the holes are very close, the two images tend to overlap each other. As a result, a blurred image will be seen.

(b) If the hole is bigger than a pin hole, again a blurred image is seen. The reason is that a bigger hole is equivalent to a large number of pin holes. Each pin hole produces one image. These images overlap each other resulting in a blurred image.

(c) If a photographic film is placed in the place of the tracing paper, a photograph can be obtained.

Characteristics of the image formed by the pin hole camera

1. It is real *i.e.* it is formed on the screen.
2. It is inverted or upside down.
3. It is generally smaller in size than the object (because the object is far away from the pin hole than the screen).

Do You Know ?

1. The image obtained on the screen of a pin hole camera is temporary.
2. The image does not show the details of the object.
3. A pin hole camera can not be used to see the motion of a moving object.

SHADOW

We have read that an opaque object does not allow light to pass through it. It completely obstructs the light. If an opaque object is placed in front of a point source of light, it obstructs the passage of light and produces a dark patch on a screen placed behind the object. This dark patch is called the **shadow** of the opaque object.

The shadow is similar in shape to the object but it may or may not be of equal size. The shadow is formed because light from the source travels in straight lines. The rays which fall on the object, are blocked and they do not reach the screen. Thus, a portion on the screen does not receive any light and remains dark. This dark portion on the screen is called the shadow of the object.

The position of the shadow on the screen is obtained by drawing straight lines from the source to the screen touching the edges of the object.

For a point source of light, the shadow of an opaque object on the screen is completely dark. It is called the **umbra**. But with an extended source, the shadow of an opaque object on the screen is dark at the centre which is surrounded by some brightness (or dim light). The dark portion of shadow is called **umbra** while the surrounding portion of less brightness is called **penumbra**. Thus, a shadow can have two portions : (1) umbra, and (2) penumbra

(1) Umbra : It is the portion of shadow where no light reaches from the source of light due to the opaque object. It is completely dark.

(2) **Penumbra :** It is the portion of shadow where a portion of light from the source of light reaches the shadow even in the presence of the opaque object in between them. It is not completely dark, but is dim (or less bright).

Now we shall consider the cases of formation of (i) umbra alone, and (ii) umbra and penumbra both.

Case (i): Formation of umbra alone :

Umbra alone is obtained on the screen when the opaque object is illuminated by a point source of light. Take a piece of cardboard. Make a small hole in it and put a lighted candle or an electric lamp behind it. Place a screen in front of the cardboard at some distance from it. Now place an opaque object AB (say a coin) in between the hole and the screen as shown in Fig. 5.15.

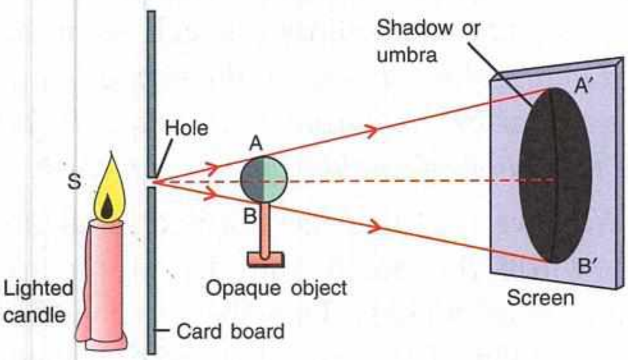


Fig. 5.15 Shadow (or umbra) due to a point source

You will see a circular dark patch A′B′ on the screen. This dark patch is well defined (*i.e.* it has sharp edges) and it is uniformly dark since this part of the screen does not get any light from the source. The part of the screen which does not receive any light from the source is called an umbra. Thus, an umbra is formed due to a point source of light.

In this case, the size of shadow is always bigger than the size of the opaque object.

If you move the screen towards the object, you will notice that the size of the shadow decreases. But if you move the screen away from the object, the shadow increases in size.

Case (ii) : Formation of umbra and penumbra both :

Umbra and penumbra both are obtained on the screen when the opaque object is illuminated by an extended source of light such as a burning candle or a glowing torch. Take a burning candle or a glowing torch PQ. Place a screen at some distance in front of it. Now place an opaque object AB in between the source of light and the screen. The size of the object AB is of same size or bigger than that of the source PQ. You will see that the shadow formed on the screen is not well defined and it is not equally dark everywhere. There is an inner dark circle CD surrounded by a partially dark circle EF as shown in Fig. 5.16.

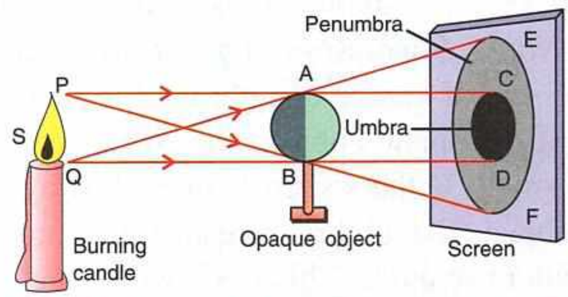


Fig. 5.16 Shadow (umbra and penumbra both) due to an extended source of light

It is clear from Fig. 5.16 that the portion CF of the screen does not receive any light from the point P on the top of the candle flame. Similarly, the portion DE of the screen does not receive any light from the point Q on the bottom of the candle flame. Thus, the portion CD, which is common to both CF and DE does not receive any light from any point of the candle flame. This portion of the shadow is completely dark and is called the umbra.

The rest of the portion between C and E does not receive light from the point Q of the candle flame, but receives light from the point P of the candle flame. Similarly, the portion between D and F does not receive light from the point Q of the candle flame but receives light from the point P. Thus, the portion of the shadow surrounding the umbra is not completely dark because it receives some light from some part of the candle flame. This partially dark portion of the shadow is called the **penumbra**.

Thus, umbra and penumbra both are formed in the shadow. It is because of penumbra that the shadow is not well defined (*i.e.* the edges of the shadow are not sharp). The umbra is bigger in size than the object if the object is bigger than the source and it is of same size as the object if the object is of the size same as the source. If you move the screen away from the object, you will notice that the size of both the umbra and penumbra increases.

Note : **Formation of penumbra only —** If the size of source of light is bigger than the size of the opaque object, the size of umbra is very small. If the screen is moved away from the object, the umbra vanishes and only the penumbra remains. This is shown in Fig. 5.17.

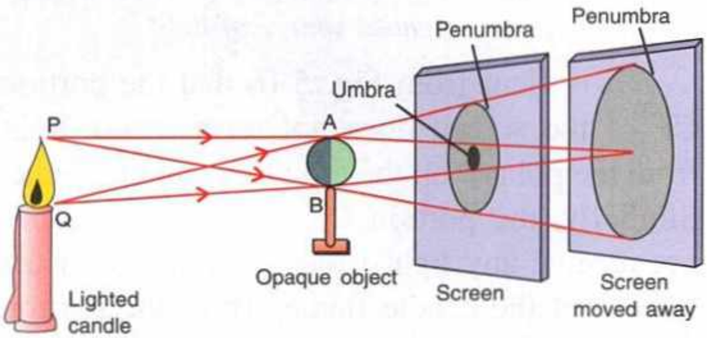


Fig. 5.17 Formation of only penumbra as the shadow due to an extended source of light of size bigger than the opaque object

Examples : 1. If we place a sewing needle in front of an electric bulb, we do not see its shadow on the wall.

2. We do not see the shadow of a kite or a bird flying high up in air because in their shadow, the umbra is absent and the penumbra is too large and too faint that it is not visible as the distance of screen (*i.e.* earth) is very large from the object (*i.e.* kite or bird).

Do You Know ?

Image is formed in front of an object when light reaches an object, but shadow is formed behind the object when light is obstructed by the object.

ECLIPSES

Eclipses are examples of formation of shadows in nature. There are *two* kinds of eclipses : (1) Lunar eclipse (the eclipse of the moon), and (2) solar eclipse (the eclipse of the sun). *Lunar eclipse is due to the formation of shadow of earth on moon and solar eclipse is due to the formation of shadow of moon on earth.*

We have read that the sun is a luminous body, while the earth and the moon are non-luminous bodies. They become visible when the light of the sun after striking them

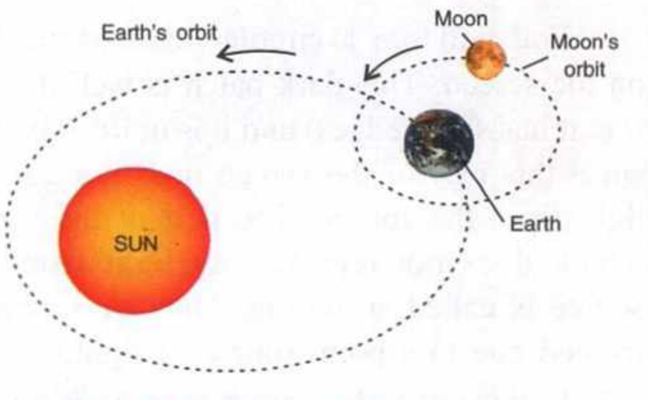


Fig. 5.18 Earth's and Moon's orbits

reaches us. The earth moves around the sun, while the moon moves around the earth as shown in Fig. 5.18.

The sun is bigger in size than the earth and the earth is bigger in size than the moon. At times, the sun, the earth and the moon come in a straight line. The earth or the moon whichever comes in between, casts its shadow on the other and causes an eclipse.

1. Lunar eclipse : On a certain full moon night, when the earth comes in between the sun and the moon, the earth casts its shadow on the moon. The part of the moon which lies within the umbra of earth, will not be visible from the earth. Thus, the lunar eclipse takes place (Fig. 5.19).

If the sun, the earth and the moon are in a straight line, the whole moon is in the umbra of the earth. It causes total lunar eclipse. But if they are slightly out of line, only a part of the moon is in the penumbra of the earth and a partial lunar eclipse occurs.

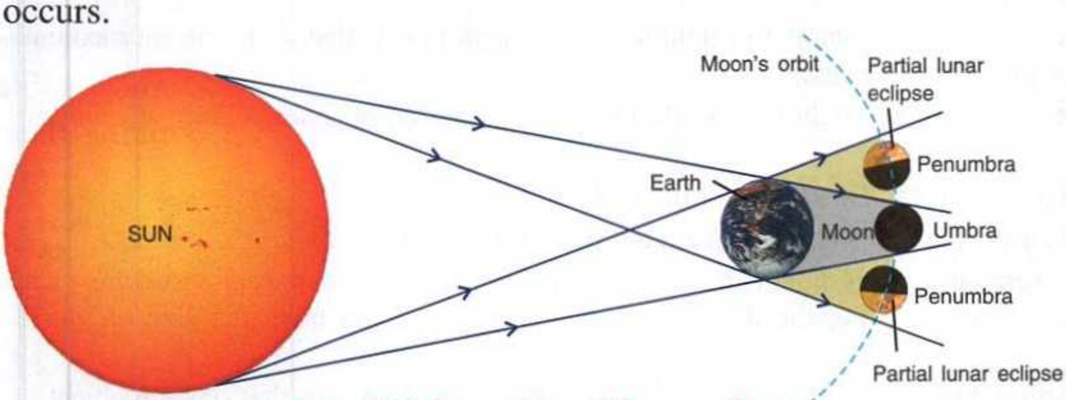


Fig. 5.19 Formation of lunar eclipse

2. Solar eclipse : On a certain new moon's day, when the moon comes in between the sun and the earth, the moon casts its shadow on the earth (Fig. 5.20).

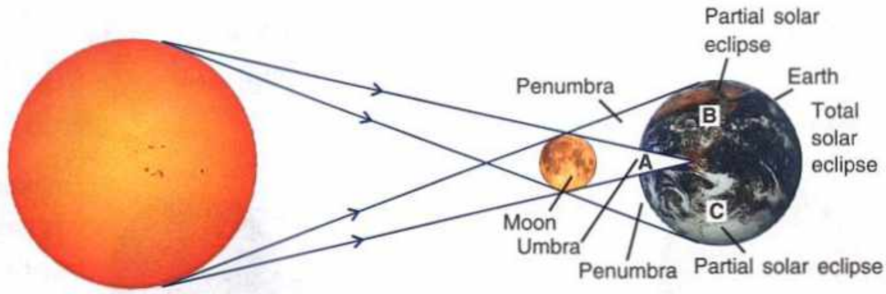


Fig. 5.20 Formation of solar eclipse

From the part A on the earth which lies in the umbra of the moon, the sun is not visible. Thus, total solar eclipse occurs for the part A on the earth. To the people in this part A on the earth, the sun appears as a black circular disc with a ring of light as shown in Fig. 5.21.


Fig. 5.21 Appearence of total solar eclipse

But for the part B or C on the earth which lies in the penumbra of the moon, the solar eclipse is partial.

An annular solar eclipse occurs when only the tip of the umbra of the moon falls on the earth at a point D. From the point D, the sun will appear to be completely obstructed by the moon, only the outer rim of the sun, called corona, is then visible for a very short time which is known as the diamond ring. The formation of annular solar eclipse is shown in Fig. 5.22.

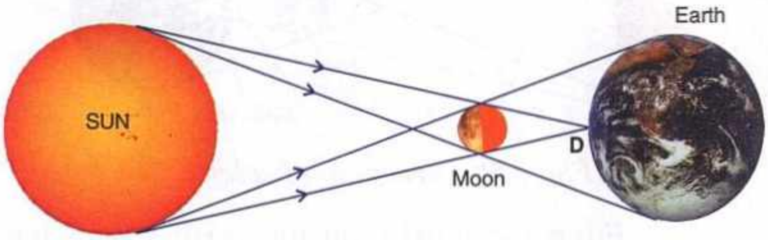


Fig. 5.22 Formation of annular solar eclipse

Do You Know ?

1. No eclipse should be seen with the naked eye because direct rays from the sun may harm the eyes. To see an eclipse, a card board with a pin hole must be placed before a wall or screen and the image of eclipse formed on the wall (or screen) must be seen through the hole.

2. In fact all planets and satellites cast their shadows in space.

RECAPITULATION

- Light itself is not visible, but in the presence of light other objects become visible.
- Light is defined as a form of energy which produces the sensation of vision in the eyes.
- Two types of sources of light are:
  (1) Natural sources such as sun, stars and jugnu.
  (2) Artificial sources such as fire, electric lamp, electric tube light, a burning candle, a kerosene lamp, heated bodies, etc.
- The bodies which themselves emit light are called luminous bodies. *Examples:* torch, electric lamp, electric tube light, burning candle, kerosene lamp, sun, stars. Jugnu etc.
- The bodies which do not emit light by their own, but they shine because of the light falling on them from a luminous body, are called non-luminous bodies. *Examples:* moon, earth, table, book, chair etc.
- A medium which allows the passage of light through it easily, is called a transparent medium. *Examples:* glass, air, water etc.
- A medium which allows only a small amount of light to pass through it, is called a translucent medium. *Examples:* ground glass, tracing paper etc.
- A medium which does not allow any light to pass through it, is called an opaque medium. *Examples:* wood, metals etc.
- Light travels in a straight line path. This is called the rectilinear propagation of light.
- The pin hole camera is a simple application of the rectilinear propagation of light.
- The image (or picture) formed in a pin hole camera is upside down (*i.e.* inverted, real, temporary and smaller than the object). On increasing the distance of screen from the pin hole, the size of image increases.
- The shadow of an opaque object is the dark patch obtained on the screen when that opaque object is placed in the path of light.
- Shadow is formed because light travels in a straight line path.
- Shadow is similar in shape as that of the object.
- The part of the shadow where no light reaches from the source is completely dark and is called the umbra.

- The part of the shadow where light reaches from only a portion of the source is partially dark and is called the penumbra.
- There is only umbra in the shadow of an opaque object due to a point source. The umbra is bigger in size than that of the object. The umbra increases in size if the screen is moved away from the object.
- The shadow of an opaque object due to a light source smaller than the object contains an umbra surrounded by a penumbra. The umbra is bigger in size than that of the object. Both the umbra and penumbra increase in size as the screen is moved away from the source.
- The shadow of an opaque object due to a light source bigger than the object contains an umbra (which is much smaller in size than the object) surrounded by a penumbra. The umbra diminishes while the penumbra increases in size if the screen is moved away from the object.
- Lunar and solar eclipses are examples of formation of shadows in nature.
- A lunar eclipse is caused on a certain full moon night when the earth comes in between the sun and the moon and the earth casts its shadow on the moon.
- A solar eclipse is caused on a certain new moon's day when the moon comes in between the sun and the earth and the moon casts its shadow on the earth.

TEST YOURSELF

A. Short Answer Questions :

1. Write *true* or *false* for each statement :
   (a) The moon is a natural source of light.
   (b) The moon is self luminous.
   (c) We can see an object through an opaque medium.
   (d) Light passes through glass.
   (e) Light travels in a straight line path.
   (f) Image formed in a pin hole camera is real.
   (g) The image in a pin hole camera gets blurred if the hole is made bigger.
   (h) A shadow is formed because light travels in a straight line path.
   (i) Solar eclipse occurs when the sun comes in between the earth and the moon.
   (j) If the shadow of earth falls on the moon, the eclipse is called lunar eclipse.

   Ans: True (d), (e), (f), (g), (h), (j)
   False (a), (b), (c), (i)

2. Fill in the blanks :
   (a) Light gives us the sensation of ....
   (b) The sun is a .... source of light.
   (c) A medium through which light cannot pass is called the ....
   (d) A medium which allows light to pass through it easily is called the ....
   (e) Moon is a .... body.
   (f) Light travels in a .... path.
   (g) In a pin hole camera, the image formed is ....
   (h) The darkest portion of a shadow is called the ....
   (i) The less dark portion of a shadow is called the ....
   (j) Lunar eclipse occurs when the .... comes in between the .... and the sun.

   Ans: (a) vision (b) natural (c) opaque medium (d) transparent medium (e) non-luminous (f) straight line (g) inverted and real (h) umbra (i) penumbra (j) earth, moon

3. Match the following columns :

Column A	Column B
(a) Wooden block	(i) new moon's day
(b) Sun	(ii) rectilinear propagation of light
(c) Umbra	(iii) opaque body
(d) Eclipse	(iv) luminous body
(e) Solar eclipse	(v) complete dark part

   Ans: (a)-(iii), (b)-(iv), (c)-(v), (d)-(ii), (e)-(i)

4. Select the correct alternative :
   (i) The natural source of light is
   (a) candle flame (b) electric lamp
   (c) sun (d) kerosene lamp
   (ii) The formation of inverted image in a pin hole camera shows that
   (a) light enables us to see
   (b) light travels in a straight line path
   (c) light can pass through the pin hole
   (d) light does not pass through the pin hole
   (iii) The luminous body is
   (a) a lighted bulb (b) earth
   (c) noon (d) table
   (iv) Umbra is a region of
   (a) complete darkness
   (b) partial darkness
   (c) complete brightness
   (d) partial brightness
   (v) Penumbra is a region of
   (a) complete darkness
   (b) complete brightness
   (c) partial brightness
   (d) none of the above
   (vi) Solar eclipse occurs on
   (a) every new moon's day
   (b) certain new moon's day
   (c) every full moon's day
   (d) certain full moon's day
   (vii) Lunar eclipse occurs on
   (a) every full moon's night
   (b) certain full moon's night
   (c) every new moon's day
   (d) certain new moon's day

Ans: (i) c, (ii) b, (iii) a, (iv) a, (v) c, (vi) b, (vii) b

B. Short/Long Answer Questions :

1. What is light ? Define it.
2. How does light make an object visible ?
3. Name *two* natural sources of light.
4. List *two* artificial sources of light.
5. Differentiate between luminous and non-luminous bodies. Give *two* examples of each.
6. Is the moon a luminous object ?
7. What do we call a body that shines on its own ?
8. What do we call an electric bulb producing light ?
9. What is a transparent medium ? Give *two* examples.
10. Explain the difference between a transparent, a translucent and an opaque medium. Give *two* examples of each.
11. What do we call a substance through which we cannot see light ? Give an example of such a substance.
12. What do we call a substance through which light passes ? Give an example of such a substance.
13. Can a transparent medium form an image? Explain your answer.
14. How can you obtain a point source of light ?
15. Define the terms: a ray of light and a beam of light.
16. What do you mean by 'rectilinear propagation of light' ?
17. Describe an experiment to show that light travels in a straight line path.
18. In which of the following two arrangements (a) and (b) shown in Fig. 5.23, you can see the light of the bulb ? Explain your answer.

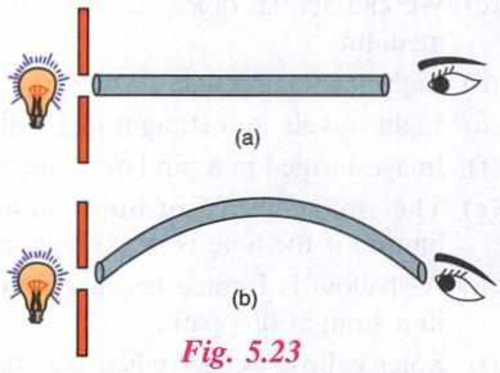


Fig. 5.23

19. Name a simple application of the rectilinear propagation of light.
20. What is a pin hole camera? Draw a neat and labelled diagram to show the formation of image of a lighted candle by it.
21. Explain the formation of image of a luminous object in a pin hole camera with the aid of a neat diagram.
22. State *two* factors which affect the size of image formed in a pin hole camera.
23. Is the image obtained in a pin hole camera erect or inverted ? Give reason for your answer.

24. How is the image affected in a pin hole camera when another fine hole is made near the first pin hole ?

25. State the effect on the image in a pin hole camera if :
    (a) the hole is made bigger.
    (b) the luminous object is moved towards the pin hole.
    (c) the length of the pin hole camera is increased (*i.e.* the screen is moved away from the pin hole).

26. What is a shadow? Give a reason for its formation.

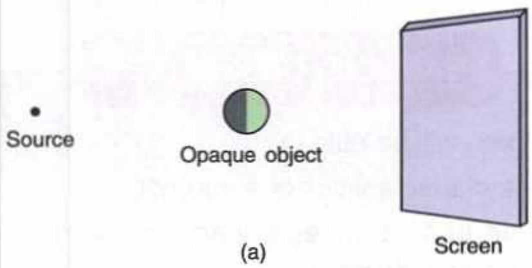
27. Draw a ray diagram to show the formation of shadow of an opaque object by a point source of light. How is the size of shadow affected if the screen is moved away from the object ?

28. State *two* differences between an umbra and a penumbra.

29. Draw a ray diagram to show the formation of umbra alone.

30. Draw a ray diagram to show the formation of umbra and penumbra both. Label the parts umbra and penumbra in your diagram.

31. In each of the following diagrams, draw rays to form umbra and penumbra on the screen.



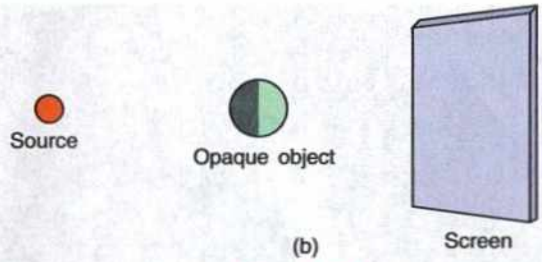


Fig. 5.24

32. State the conditions when only the penumbra of an opaque object is obtained on the screen.

33. Why is it that the birds flying in the sky do not cast their shadows on the earth ?

34. Why are shadows at noon shorter than in the morning or in the evening ?

35. What is an eclipse? Name the *two* types of eclipses.

36. When does a lunar eclipse take place ? Does it occur on every full moon's night ?

37. Draw a diagram to show the formation of lunar eclipse.

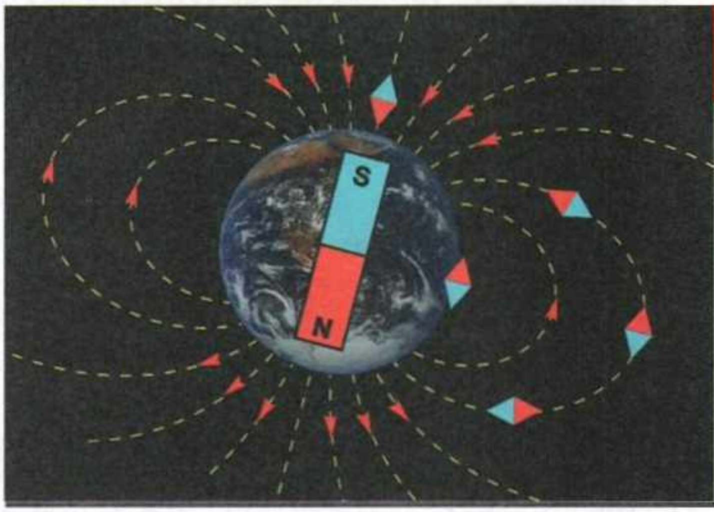
38. When does a solar eclipse take place ? Does it occur on every new moon's day ?

39. Draw a diagram to show the formation of solar eclipse.

40. What is annular solar eclipse ? Draw a labelled diagram to show its formation.

Project Work

- List at least *three* luminous and *five* non-luminous objects at your home.
- Take a shoe box and a sheet of tracing paper. Use them to construct a pin hole camera.



6 Magnetism

Theme : Substances that have property of attracting iron are called magnets. The materials that get attracted towards a magnet are known as magnetic materials. *For example*, iron, nickel and cobalt. Materials that are not attracted towards a magnet are non-magnetic - *for example*, glass, plastic, wood. When a magnet is suspended freely, it always rests in the same direction. The end of the magnet that points towards north is called North pole. The end that points towards south is called South pole. This property of magnets helps us to find directions. Opposite poles of two magnets attract each other and similar poles repel one another. Each magnet is surrounded by a magnetic field. Permanent magnets retain their magnetism for a long time. Temporary magnets behave like a magnet only till they are under influence of a magnetic field. When an electric current flows through a coil of wire, the coil behaves like a magnet. This type of magnet is called electromagnet. Electromagnets are useful because their strength can be varied and they can be turned off and on, as desired.

In this chapter you will learn :

- Magnetic and non-magnetic substances.
- Characteristics of a magnet.
- Properties of magnets
- Magnetic field around a magnet.
- Earth's magnetic field.
- Making of magnets
- Permanent and temporary magnets and their uses
- Electromagnets and
- Choice of material for the core of electromagnet
- Care and storage of magnets
- Demagnetization by heating, hammering and electricity.

LEARNING OBJECTIVES

The children will be able to :

- state characteristics of a magnet;
- distinguish between magnetic and non-magnetic substances;
- state the properties of magnets;
- recognise the magnetic field around a magnet;
- recognise the Earth's magnetic field;
- describe different ways to make a magnet;
- distinguish permanent and temporary magnets;
- make a simple electromagnet;
- list precautions for care and storage of magnets;
- discuss loss of magnetic property due to heating, hammering and electricity.

DISCOVERY OF MAGNETS

The substances which have the property of attracting iron, are called **magnets**. The first magnets were found from a naturally occurring mineral of iron called **magnetite** around 800 B.C. There is a story about a shepherd named **Magnes** whose shoe nails and iron hook of his stick were stuck to a rock containing magnetite. The rock was later found to attract iron pieces and was called magnet. The word magnet originated from the name of town **Magnesia**, a district in Asia Minor where large deposits of magnetite were found.

Later on it was found that the piece of magnetite when suspended freely, always rests in a fixed direction and therefore it can be used to indicate a direction correctly. Hence it was also called the **lodestone**.

NATURAL MAGNETS

The ore of magnetite (or lodestone) found in nature are called **natural magnets**. They are found in irregular and odd shapes. They are weak in strength, so they are not of much use. For practical uses, artificial magnets are made.

ARTIFICIAL MAGNETS

The magnets that are made by us are called **artificial magnets**. They are made of iron or steel in various shapes and sizes as required for the use. These magnets are strong. Some such magnets are (a) bar magnet, (b) cylindrical magnet, (c) U-shaped magnet, (d) horse shoe magnet, (e) magnetic needle and (f) compass. They are shown in Fig. 6.1.

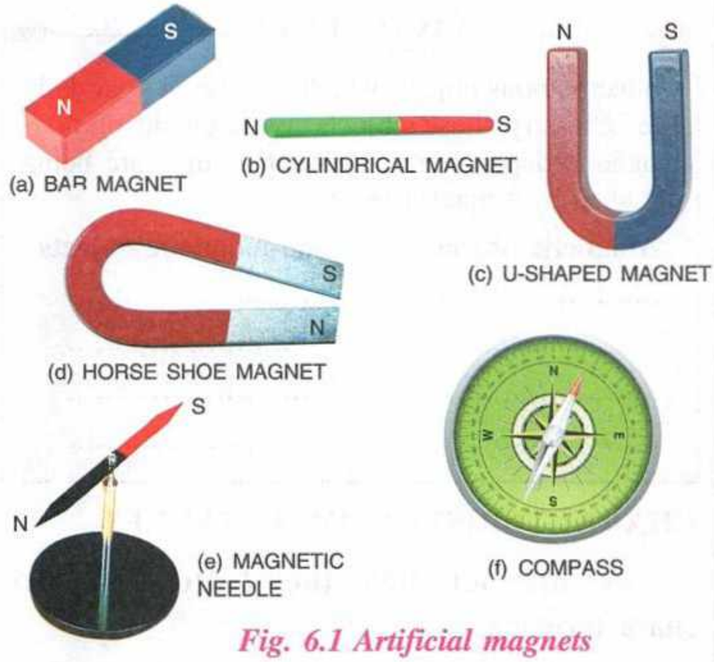


Fig. 6.1 Artificial magnets

Do You Know ?

Magnetic compass is used to find the geographic directions at a place because its needle rests in geographic north-south direction.

MAGNETIC AND NON-MAGNETIC SUBSTANCES

The substances that get attracted by a magnet are called ***magnetic substances***. Iron, steel, cobalt and nickel are magnetic substances. Magnetic substances are also known as ferromagnetic substances. The substances that do not get attracted by a magnet are called **non-magnetic substances**, *e.g.*, wood, plastic, copper, paper, aluminium, rubber, stone, sand, ceramics, glass, bismuth, gold, silver, brass, *etc*.

Do You Know ?

Iron, cobalt and nickel are ferromagnetic substances, *i.e.* these metals can easily be converted into magnets and can be demagnetised quite easily as well.

ACTIVITY 1

Collect various objects which you use in your daily life. Classify these objects as magnetic or non-magnetic depending upon whether they are being attracted by a magnet or not.

Magnetic objects	Non-magnetic objects
....	....
....	....
....	....
....	....

CHARACTERISTICS OF A MAGNET

A magnet has the following *two* characteristics :

1. When a magnet is suspended freely, it always rests in a specific (north-south) direction.
2. It attracts small pieces of iron.

1. When a magnet is suspended freely, it always rests in a specific direction

Suspend a bar magnet with a silk thread from a wooden stand as shown in Fig. 6.2. The magnet swings for some time and then eventually comes to rest in a particular direction *i.e.*, **north-south direction**. If we disturb the magnet a little, the magnet again comes to rest in the north-south direction.

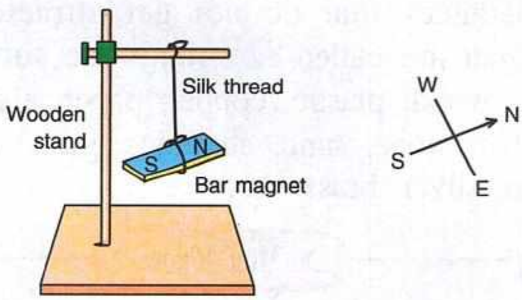


Fig. 6.2 A freely suspended magnet rests in north-south direction

The end of the magnet which points towards the north is called the north seeking pole or simply the **north pole** and the end which points towards the south is called the south seeking pole or simply the **south pole**. The north and south poles are marked by the letters N and S respectively. Sometimes a red dot is etched on the magnet at the north pole.

This characteristic of magnet helps us to use it to find geographic directions.

2. A magnet attracts small pieces of iron

If a bar magnet is brought near small iron nails, it is observed that most of the nails cling near the ends of the magnet and very few nails cling near the middle as shown in Fig. 6.3 This shows that the property of attraction is not same every where along the length of the magnet, but it is maximum near the ends and very little in the middle of the magnet.

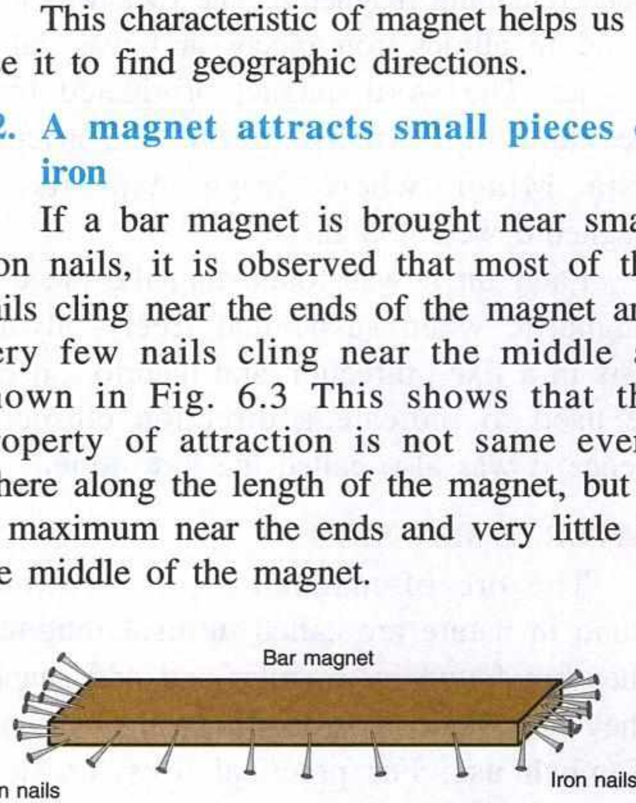


Fig. 6.3 Attraction is maximum near the ends of the magnet

The ends of the magnet where the attraction property is maximum are called the **magnetic poles** of the magnet.

Do You Know ?

The poles of the magnet are not situated exactly at the ends, but they are located slightly inside. The two poles of the magnet are the north and south poles.

PROPERTIES OF MAGNETS

(1) Like poles repel and unlike poles attract

Two like poles (both north poles or both south poles) repel each other. Two unlike poles (one north pole and the other south pole) attract each other.

ACTIVITY 2

(1) Take two bar magnets A and B. Suspend one magnet A with a silk thread from a support so that it is free to swing. The magnet will come to rest in the north-south direction. The north pole of the magnet is in the north direction and the south pole of the magnet is in the south direction.

(2) Now holding the other magnet B in your hand, bring its north pole near the north pole of the suspended magnet A (such that the two magnets do not touch each other) as shown in Fig. 6.4. You will observe that the suspended magnet A moves away from the magnet B. This shows that like poles repel each other.

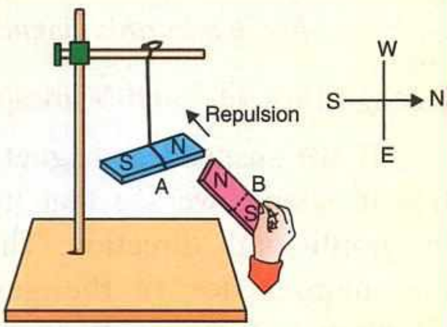


Fig. 6.4 Like poles of magnets repel each other

Now bring the south pole of the magnet B near the north pole of the suspended magnet A as shown in Fig. 6.5, without touching it. You will observe that the magnet A moves towards the magnet B. This shows that unlike poles attract each other.

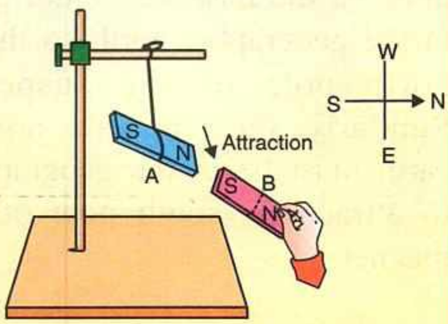


Fig. 6.5 Unlike poles of magnets attract each other

Do You Know ?

(1) When a piece of iron is brought near one end of a magnet, an opposite pole is induced on the near face of the iron piece. It gets attracted towards the magnet due to attraction between unlike poles.

(2) Earth itself behaves like a magnet with its magnetic north in geographic south and magnetic south in geographic north. When a magnet is freely suspended, due to attraction between unlike poles, the north pole of the suspended magnet rests in geographic north where there is the magnetic south pole of earth's magnet.

(2) Poles exist in pairs

Magnetic poles always exist in pairs. It is not possible to separate the two poles of a magnet.

If a bar magnet shown in Fig. 6.6 (a) is broken at the middle in two parts, each part is found to be a magnet. Each part has the property to attract small iron pieces. Each part rests in the north-south direction when suspened freely. This shows that new poles are formed at the broken ends [Fig. 6.6 (b)].

If these pieces are broken again and again, each part is still found to be a complete magnet. Each part has both the poles (N pole and S pole) as shown in Fig. 6.6 (c). Thus, the two poles of a magnet exist simultaneously.

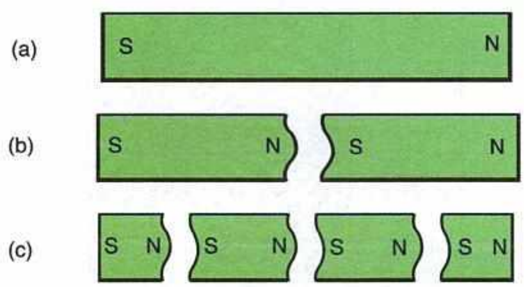


Fig. 6.6 Poles exist in pairs

From the above discussion, we conclude that a magnet has the following *four* properties :

1. A magnet attracts small pieces of iron.
2. A magnet always rests in the north-south direction if it is suspended so as to swing freely.
3. Like poles repel each other and unlike poles attract each other.
4. Poles exist in pairs.

MAGNETIC FIELD AROUND A MAGNET

The space around a magnet in which if a magnetic substance such as small pieces of iron, are placed, they get attracted towards the magnet, is called a magnetic field.

At each place in absence of any magnet, the needle of a magnetic compass always rests in the geographic north-south direction. But if the magnetic compass is placed near a magnet, its needle swings and then rests in some other direction. As the position of magnetic compass is changed, the direction in which its needle rests, also changes.

Recognition of the magnetic field around a magnet : If a magnet is placed below a sheet of stiff paper and some iron filings are spread on it, then on tapping the sheet gently, the iron filings are found to arrange themselves in a definite pattern as shown in Fig. 6.7.

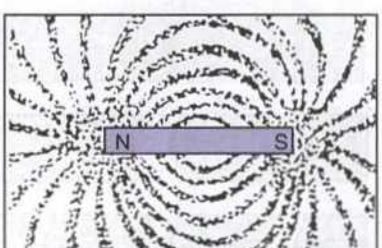


Fig. 6.7 Arrangement of iron filings on a paper sheet above a magnet

The pattern of iron filings represent th magnetic field of the magnet. Its direction i from north pole of magnet to its south pole The magnetic field is not unform. It is stron near the magnet while weak at a distanc from the magnet.

EARTH'S MAGNETIC FIELD

The earth itself behaves like a magne and it has a magnetic field around it. In limited space, the magnetic field of earth i same everywhere (*i.e.*, it is uniform) and i in direction, from geographic south to north.

Fig. 6.8 shows the pattern of earth' magnetic field.

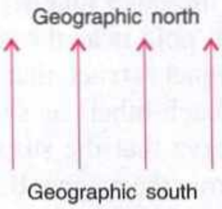


Fig. 6.8 Earth's magnetic field

Recognition of earth's magnetic field

If we suspend a magnet such that it is free to swing, we see that it always rests i the north-south direction. The north pole o the magnet lies in the geographic nort direction and the south pole of the magne lies in the geographic south direction.

The reason is that like poles repel and unlike poles attract. Therefore, ther must be the magnetic south pole of the eart in the geographic north so that it attracts the north pole of the suspended magnet Similarly, the magnetic north pole of th earth must be in the geographic south so a to attract the south pole of the suspendec magnet.

ACTIVITY 3

Take a soft iron bar. Place it in the north-south direction under the ground. After some days, you will find that the iron bar behaves as a magnet. The end which is towards the geographic north becomes the north pole and the end towards the geographic south becomes the south pole.

Conclusion : The earth has a magnetic field. It behaves like a magnet. There must be the magnetic north pole of the earth in the geographic south and the magnetic south pole in the geographic north.

Do You Know ?

Although earth behaves like a huge magnet, there is no magnet inside the earth.

MAKING A MAGNET

A given piece of iron in the form of a needle or a bar can be made a magnet by the following *four* methods :

1. By magnetic induction method,
2. By single touch method,
3. By double touch method, and
4. By electrical method.

1. By magnetic induction method

When a piece of iron is placed nearby (or brought near) a magnet, it acts as a magnet *i.e.*, it acquires the properties of a magnet temporarily. But as soon as the magnet is removed, the iron piece no longer remains a magnet. This process is called **magnetic induction**.

To make an iron nail a magnet by magnetic induction, we proceed as follows :

(i) Take a long nail. Put it on the arm of a stand passing through a cork as shown in Fig. 6.9. Spread some iron pins on the base of the stand. You will find that the pins do not move towards the nail.

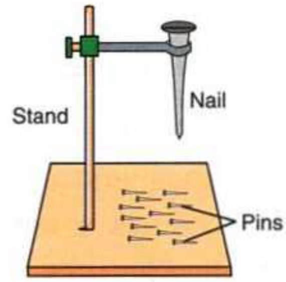


Fig. 6.9 No pin clings to the nail

(ii) Now bring one pole (say north pole) of a magnet A near the head of the nail as shown in Fig. 6.10. You will notice that now some pins begin to cling to the nail. This shows that in the presence of the magnet, the nail has become a magnet.

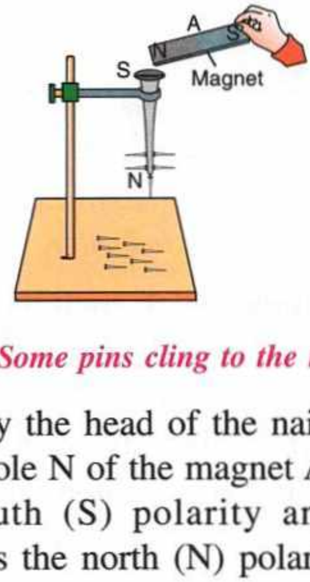


Fig. 6.10 Some pins cling to the nail

Actually the head of the nail near the north pole N of the magnet A acquires the south (S) polarity and its tip acquires the north (N) polarity.

(iii) Then remove the magnet A as shown in Fig 6.11. You will see that all the pins fall down. This shows that on removing the magnet A, the nail loses its magnetic property.

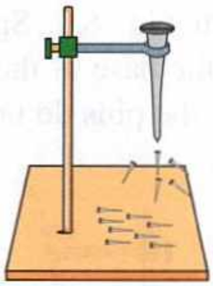


Fig. 6.11 On removal of the magnet, pins fall down

Thus by magnetic induction, the nail or bar becomes a temporary magnet only in the presence of an external magnet.

Polarities produced by magnetic induction

When a magnet NS is placed near an iron piece AB, the iron piece behaves like a magnet and the end A of the iron piece near the north (N) pole of the magnet becomes a south (S) pole while the far end B becomes a north (N) pole as shown in Fig. 6.12

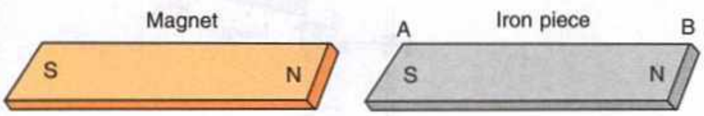


Fig. 6.12 Polarities produced by magnetic induction

2. By single touch method

Place an iron bar (or the needle) AB on a table. Take a bar magnet NS and place it almost vertical with its north pole (N) on the end A of the bar, as shown in Fig. 6.13.

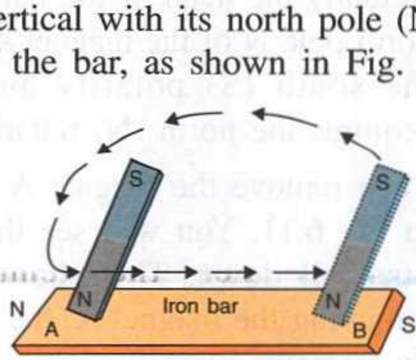


Fig. 6.13 Single touch method

Move the magnet along the iron bar till the other end B is reached, as shown in Fig. 6.13 by dotted lines.

Lift the magnet at the end B and again place it on the first end A as shown by the arrows in the diagram. Again stroke the bar. **Repeat the process about 20 times**. Then turn the iron bar AB upside down. Again stroke it with the magnet about 20 times. The bar now becomes a magnet.

The end touched last has the polarity opposite to that of the striking pole. Thus, the end B of the bar becomes the south pole (S) and the end A becomes the north pole (N).

3. By double touch method

Take two magnets P and Q and place them vertically at the centre of the iron bar AB with their opposite poles on one side. Keep a cork in between the two poles. Move the two magnets together with the cork on the bar towards the right till the end B is reached. Then without raising the magnets, move them backwards to the end A of the bar. This movement is shown in Fig. 6.14 by the arrows.

Repeat the process about 20 times. Then turn the bar AB upside down and repeat the same process about 20 times. The bar now becomes a magnet.

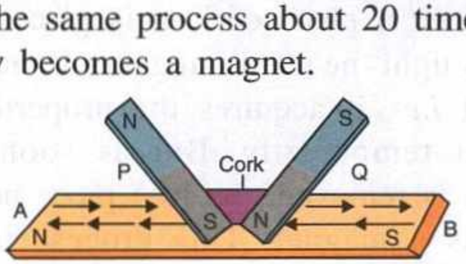


Fig. 6.14 Double touch method

The end A of the bar where the south pole (S) of the magnet P leaves, becomes the north pole (N) and the end B of the bar where the north pole (N) of the magnet Q leaves, becomes the south pole (S).

4. **By electrical method**

Take the given iron bar AB. Wound everal turns of insulated copper wire over he bar. Connect the ends of the wire to a attery through a switch as shown in Fig. 15. Press the switch to pass current. After ome time, the bar AB becomes a magnet.

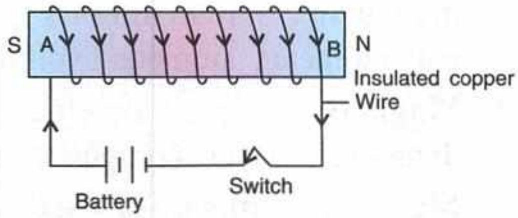


Fig. 6.15 Electrical method

The end A of the bar at which the rrent enters the coil in clockwise direction comes the south pole (S) and the end B f the bar becomes the north pole (N).

The polarity at the ends of the bar can e reversed by reversing the direction of urrent in the coil.

As the current in coil is switched off, he iron bar loses its magnetic properties. hus, the iron bar magnet so formed by the lectrical method is a **temporary magnet**.

Temporary and permanent magnets

Temporary magnet : A magnet which oon loses it magnetic properties is called a emporary magnet. *For example*, an iron iece in presence of an external magnet ecomes a temporary magnet by magnetic nduction.

A soft iron bar (or needle) becomes a emporary magnet when current is passed in coil wound around the given bar (or eedle). A temporary magnet is generally ade of soft iron.

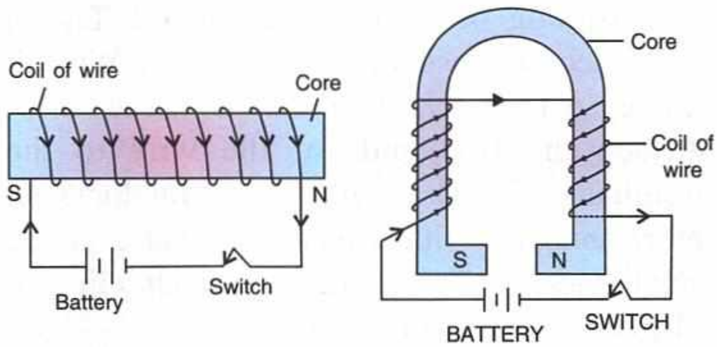
Permanent magnet : A magnet which does not lose its magnetic properties, is called a permanent magnet. It is made up of steel.

Differences between temporary and permanent magnets

Temporary magnet	Permanent magnet
1. It is made of soft iron.	1. It is made of steel.
2. It shows magnetic properties so long as the current passes in the coil wound around it.	2. It shows magnetic properties even after current is stopped through the coil wound around it.
3. Its magnetic strength can be changed.	3. Its magnetic strength can not be changed.
4. Its polarity can be changed by reversing the direction of current.	4. Its polarity can not be changed
5. It is easily demagnetised.	5. It is not easily demagnetised.

ELECTROMAGNETS

An electromagnet is a current carrying coil with a core in it. The core can be a soft iron in the shape of a bar or a horse-shoe as shown in Fig. 6.16 (a) and (b) respectively.



(a) Bar electromagnet (b) Horse-shoe electromagnet

Fig. 6.16 Electromagnets

Choice of the material of core of the electromagnet : For the temporary electromagnet the material of core is soft iron while for the permanent electromagnet, the material of core is steel.

Remember

1. An electromagnet is made by passing electric current.
2. A coil carrying current produces a magnetic field around it.
3. The end of the electromagnet from where the current enters in clockwise direction becomes the South pole (S), and the end from where the current enters in anti-clockwise direction becomes the North pole (N).

Strength of the electromagnet : The strength of the electromagnet can be increased:

(i) by increasing the current in the coil, and

(ii) by increasing the total number of turns of the coil.

Do You Know ?

A Danish physicist Hans Christian Oersted was the first scientist to find the connection between electricity and magnetism. In 1820, he discovered that a current carrying wire creates a magnetic field around it.

Making of an electromagnet : Take a long piece of insulated copper wire. Wrap it around a long screw as shown in Fig. 6.17. Attach the free ends of the wire to the terminals of a dry cell. Now you have an electromagnet with which you can pick up small pieces of iron such as paper clips or allpins of iron. However, if two or three cells are joined in series to increase the current in the coil, the electromagnet will show stronger magnetic attraction.

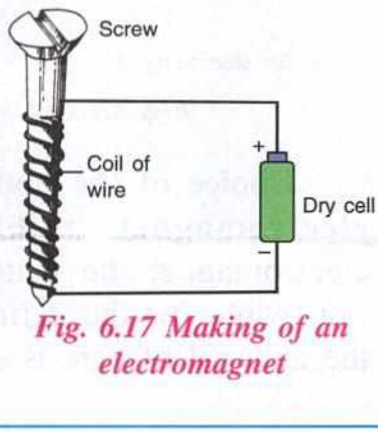


Fig. 6.17 Making of an electromagnet

USES OF MAGNETS

1. Temporary electromagnets are used i devices such as electric bells, telephon receiver, loud speaker, magnetic toys et
2. Strong electromagnets are used fo loading and unloading scraps of iron.
3. Permanent magnets are used in electri measuring instruments such a galvanometer, ammeter, voltmeter, etc.
4. Magnets are used in electric motor dynamo, speaker, computer, etc.
5. Magnetic compass is used to find th geographic direction at a place by sailor or pilots.

CARE AND STORAGE OF MAGNETS

A magnet has a tendency to lose it magnetic properties. Therefore, care is take not to leave a magnet all alone.

To store magnets, magnetic keepers a used. **The magnetic keepers are pieces o soft iron.**

Fig. 6.18 shows a pair of bar magnets and B kept with opposite polarities facing c one side and the soft iron pieces P and Q their ends with a piece of wood in betwee the two magnets A and B.

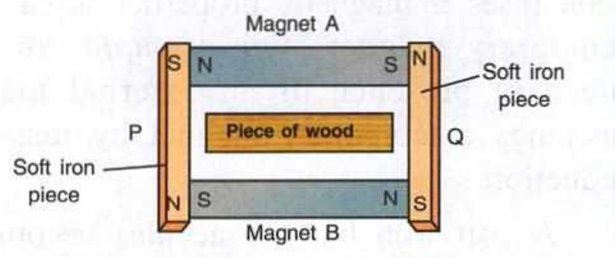


Fig. 6.18 Two magnets with magnetic keepers

By magnetic induction, opposite polaritie are developed at the ends of each soft iro piece and a close cycle is formed. This prevent the loss of magnetism of magnets.

For a horse shoe magnet only one ·iece P of soft iron is needed as shown in ·ig 6.19.

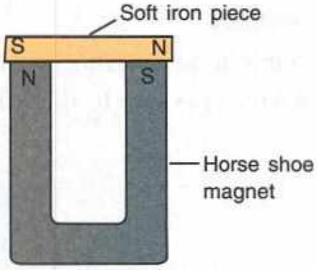


Fig. 6.19 Horse shoe magnet with a magnetic keeper

DEMAGNETISATION OF A MAGNET

A magnet can be demagnetised, (*i.e.* the magnetic properties of a magnet can be destroyed) by the following *five* ways :

1. By rough handling.
2. By hammering the magnet repeatedly.
3. By dropping the magnet repeatedly on a hard surface.
4. By heating the magnet to a high temperature.
5. By passing alternating current through a coil around the magnet keeping it in east-west direction.

RECAPITULATION

- A substance which can attract iron is called a magnet.
- The first natural magnet was discovered in Magnesia, a town in Greece. When it is freely suspended, it always rests in a definite direction, so it was also called lodestone.
- Artificial magnets are made of iron or steel. They are made of different shapes, namely the bar magnet, cylindrical magnet, U-shaped magnet, horse-shoe magnet, magnetic needle and compass.
- The materials which are attracted by a magnet are called magnetic materials. *Examples* : iron, steel, cobalt, nickel.
- The materials which are not attracted by a magnet are called non-magnetic materials. *Examples* : paper, wood, brass, plastic, copper, aluminium, etc.
- A magnet has two poles, a north and a south pole.
- A magnet has the following properties :
  - (i) A magnet attracts small pieces of iron.
  - (ii) A magnet always rests in the north-south direction, if it is free to swing.
  - (iii) Like poles repel each other and unlike poles attract each other.
  - (iv) Poles always exist in pairs, they cannot be isolated.
- The magnetic field around a magnet is the space in which a magnetic substance such as small iron piece experiences a force of attraction.
- The earth itself behaves like a magnet. It has its own magnetic field.
- The magnetic south of the earth is near the geographic north and the magnetic north of the earth is near the geographic south.
- Magnetic induction is the process in which a piece of iron temporarily behaves like a magnet in the presence of another magnet.
- When a magnet is placed near an iron piece, the iron piece behaves like a magnet. The end of the iron piece near the north pole of the magnet becomes a south pole while the far end becomes a north pole.

- It is because of magnetic induction that a magnet attracts a piece of iron.
- An iron piece can be made into a magnet by any of the following methods :
  (i) Magnetic induction (ii) Single touch method
  (iii) Double touch method (iv) Electrical method
- In the single touch method, we need a single magnet, but in the double touch method we need two magnets. In these methods, the end touched last by the magnet has the polarity opposite to that of the striking pole.
- Powerful magnets are made by the electrical method.
- Temporary magnets are made of soft iron.
- Permanent magnets are made of steel.
- Electromagnets are used in devices like electric bell, magnetic toys, telephone etc.
- Permanent magnets are used in devices like galvanometer, ammeter, voltmeter etc.
- A magnet can be destroyed by rough handling, by dropping it several times, by hammering it repeatedly and by heating it.
- Magnets are used to separate iron and steel from their mixture with non-magnetic substances.
- Magnets are used in many electrical appliances such as electric bell, loud-speaker, etc.
- A magnetic compass is used by sailors and navigators to find the north-south direction.
- Magnetic keepers are used to store magnets.
- Magnetic keepers are small pieces of soft iron.

TEST YOURSELF

A. Objective Questions

1. Write *true* or *false* for each statement.
   (a) Artificial magnets are weaker than natural magnets.
   (b) Poles of a magnet cannot be separated.
   (c) A magnet can attract only a magnetic substance.
   (d) A magnet has no effect when it is heated to a high temperature.
   (e) Permanent magnets get easily demagnetised.
   (f) Magnetic poles occur in pairs.
   (g) Single touch method is better than the electrical method for making a magnet.
   (h) Magnetic keeper is a wooden piece.
   (i) Copper cannot be magnetised.
   Ans. : True (b), (c), (f), (i)
   False (a), (d), (e), (g), (h)

2. Fill in the blanks :
   (a) Temporary magnets are usually made up of ....
   (b) Rough handling destroys the .... properties of a magnet.
   (c) Like poles .... each other.
   (d) A freely suspended magnet points in th .... direction.
   (e) In a magnet, ... have the maximu.. attractive property.
   (f) A magnet has .... poles.
   Ans. : (a) soft iron, (b) magnetic, (c) repel (d) north-south, (e) ends, (f) tw

3. Match the following columns :

Column A	Column B
(a) Steel	(i) to store magnets
(b) Soft iron	(ii) temporary magnet
(c) Used in electric bell	(iii) permanent magnet
(d) Magnetic keepers	(iv) electromagnet

   Ans. : (a)-(iii), (b)-(ii), (c)-(iv), (d)-(i)

4. Select the correct answer :
   (a) If we suspend a magnet freely, it will settle in
   (i) east-west direction

(ii) north-south direction
(iii) north-east direction
(iv) east-south direction

(b) Making a magnetic substance a magnet by bringing it closer to another magnet without touching it, is
(i) magnetic induction method
(ii) single touch method
(iii) double touch method
(iv) electrical method

(c) An example of natural magnet is
(i) iron (ii) steel
(iii) lodestone (iv) none of above

(d) The artificial magnet used to detect direction in the laboratory is
(i) U-shaped magnet
(ii) horse shoe magnet
(iii) electromagnet
(iv) magnetic compass

Ans. : (a) (ii), (b) (i), (c) (iii), (d) (iv)

B. Short/Long Answer Questions :

1. What is a magnet ?
2. What are magnetic and non-magnetic substances? Give *two* examples of each.
3. What are natural and artificial magnets ?
4. How is an artificial magnet prepared from a natural magnet ?
5. State *two* ways of magnetising an iron piece.
6. How can magnetic properties of a magnet be destroyed ?
7. Why does a freely suspended magnet always rest in north-south direction ?
8. Draw diagrams of artificial magnets of *four* different shapes.
9. Why are artificial magnets preferred over the natural magnets ?
10. Describe an experiment to show that the maximum attractive property is at the poles of a magnet.
11. State four important properties of a bar magnet.
12. Explain the attractive property of a magnet with the help of an experiment.
13. Describe a method by which an iron bar can be made a magnet.
14. How are the magnets kept safely ? What is the role of keepers in storing magnets ?
15. Define the term magnetic field of a magnet. How will you recognise it experimentally ?
16. How will you make a bar of iron an electromagnet ? Draw a diagram showing the polarities of an electromagnet.
17. State *two* ways of increasing the strength of an electromagnet.
18. Suppose you are given a long bar magnet and you are asked to break it into *four* small magnets. Draw diagrams showing the polarities of each broken part.
19. State *three* important uses of a magnet.
20. What is magnetic induction ? Explain with the help of a diagram.
21. In which direction does a suspended bar magnet come to rest ? Give reason.
22. State *three* differences between temporary and permanent magnets.
23. State *three* ways of demagnetising a magnet.
24. Suggest *one* way to recognise the magnetic field of the earth.
25. Name the material of core of an electromagnet for (a) temporary magnet (b) permanent magnet.
26. You are given an iron nail, a torch cell and a long piece of insulated copper wire. With the help of a labelled neat diagram, describe in steps how you will make the nail, an electromagnet.
27. Describe an experiment to illustrate that like poles repel while unlike poles attract.
28. What are magnetic keepers ? Name its material.
29. How are the north and south poles of a magnet located ? Explain.