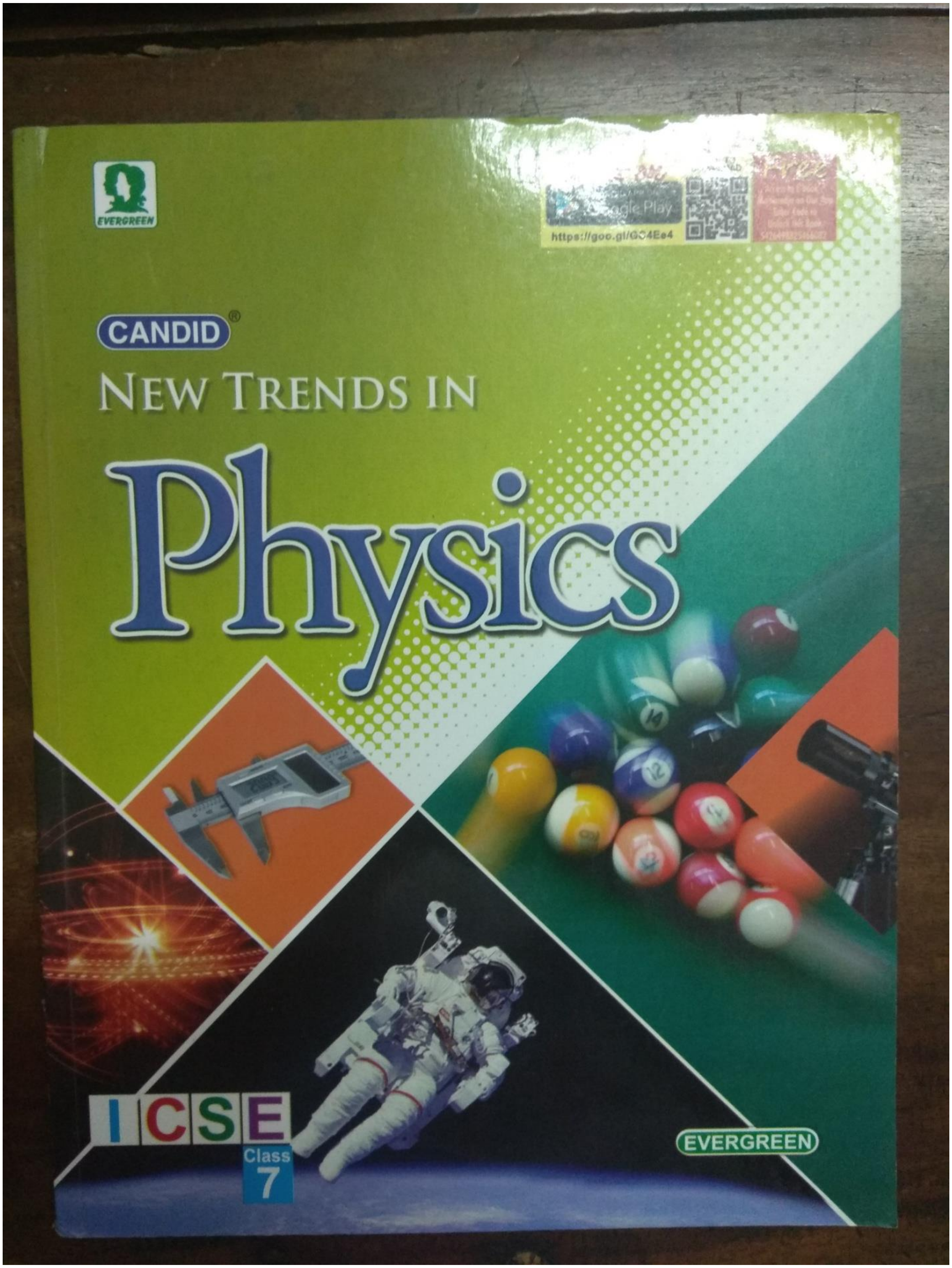
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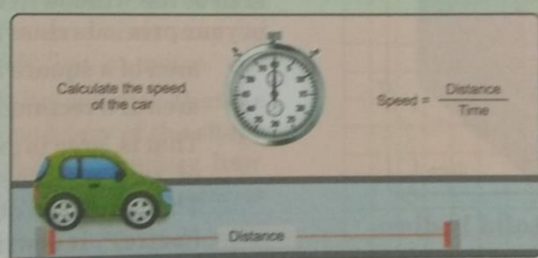
Contents

1

Physical Quantities and Measurement

Objectives

- Measurement of Volume (3D concept): Concept of unit volume
- Measurement of Area: Estimate the Area of irregular shape using Graph paper
- Measurement of Density of Regular Solids: Basic concept, Formula, simple numerical (SI units not required)
- Calculation of speed: Basic concept, formula, simple numerical (SI units not required)



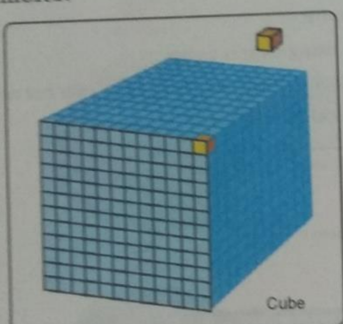
Calculation of speed.

Introduction

Measurement is one of the best tools which a scientist has. Suppose, if we are to report the result of a measurement to someone who wishes to reproduce these measurements, a standard must be defined. It would be meaningless if a visitor from outer space were to talk to us about a length of 8 "chinks" if we do not know the meaning of "chink". On the other hand, if someone familiar with our system reports than a wall is 2 metre high and our unit of length is 1 metre, we then know that the height of the wall is twice our fundamental unit of length. Likewise, if we are told that a person has a mass of 75 kilogram and our unit is defined as 1 kilogram, then our person is 75 times heavier than our fundamental unit of mass. Moreover, very accurate and precise measurements are required for the advancement of science. We have been able to put up satellites and even men on moon due to the exact knowledge of length and time, which we have obtained by, defining some standard units of measurement of mass, length and time.

1.1 MEASUREMENT OF VOLUME (3D CONCEPT)

What is Volume? We have learnt that matter occupies space. The volume of an object is the amount of space it occupies. For example, a brick occupies more space than a matchbox. It means a brick has more volume than a matchbox. Similarly, we see that a bucket will hold more water than a glass tumbler. In other words, we can say that the capacity of a bucket to hold water is greater than that of a glass tumbler. The space available in a container is called its capacity. So, we can conclude that the inner volume of a bucket is more than the inner volume of a glass tumbler.



Volume of regular solid bodies:

Cube and cuboid are examples of regular solids.

Volume of a cube = side × side × side = L^3

Volume of a cuboid

= length × breadth × height

= L × B × H

Concept of unit Volume:

When the sides are expressed in metres, then the volume will be in m^3. 1 $metre^3$ is a bigger unit but it is a standard unit of volume. The volume of smaller objects like the volume of the matchbox or the volume of a book is expressed in cm^3 or dm^3. You know that, cm^3 and dm^3 are related with m^3, let's see how!

$$1\ m^3 = 1\ m \times 1\ m \times 1\ m$$
$$= 100\ cm \times 100\ cm \times 100\ cm$$
$$= 1000000\ cm^3$$
$$= 10^6\ cm^3$$

Submultiples of unit of volume

$$1\ m^3 = 1000\ dm^3$$
$$1\ dm^3 = 1000\ cm^3$$
$$1\ cm^3 = 1000\ mm^3$$

When the volume of an object is small, it is convenient to express its volume in submultiples of m^3, such as, decimetre cube (dm^3) and centimetre cube (cm^3).

1.2 MEASUREMENT OF AREA

Surface area is defined as the measure of the surface of an object.

Therefore, more the surface of the object, the more will be its area. Hence, surface area of a door is certainly more than the surface area of the window. You have already learnt in your previous class that :

- area of a square is : side × side.
- area of a rectangle is : length × breadth. That is, area is expressed as the product of two lengths (length × length). Therefore, the standard unit of area is $(metre)^2$. It is written as m^2.
- **Small areas are expressed as :** In our daily life, the area of a book, a newspaper or a handkerchief is expressed in cm^2. To express the area of still smaller objects like microchips, the convenient unit is mm^2.
- **Large areas are expressed as:** To express larger areas such as the area of a town or city, area of a big plot of land, area of a country etc., the convenient units are 'are' and 'hectare'.

$$1\ m^2 = 10000\ cm^2$$
$$1\ cm^2 = 100\ mm^2$$
$$1\ \text{are (read as air)} = 100\ m^2$$

1 hectare = 100 are

= 10000 m^2

1 km^2 = 1000 m × 1000 m

= 1000000 m^2

Very big areas are expressed as square kilometres.

For irregular polygons (geometric shapes with straight edges) the most accurate way to compute the area is to partition the shape into triangles, then add up the areas of those smaller triangles.

For irregular shapes with curved edges, there are more crude ways to approximate the area, yet the results can still be quite accurate. The method described below requires only graph paper and two coloured pencils.

First, copy the irregular shape onto a grid. Essentially, you will approximate the area of the irregular shape by estimating how many squares the shape covers on the grid paper. Make a note of the size or scaled size of each square. For example, a grid unit may be 1 square centimetre, inch, foot, or metre.

Next, colour all of the squares that lie completely within the boundary of the shape and contain no part of the boundary line. Count them, and call the number of interior squares 'C'.

Use a different colour to fill in the squares that contain the border of the shape. Only colour in a square if the boundary line goes through the square. Count them, and call the number of perimeter squares 'P'.

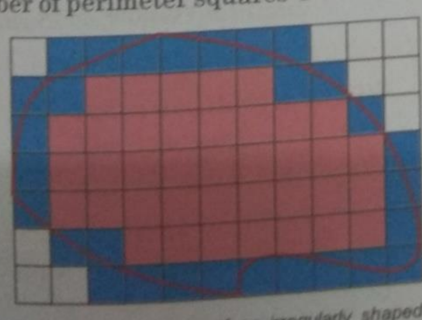


Fig. 1.1 *Estimating the area of an irregularly shaped body*

Now, use the formula

Area = C + (0.5) × P

to approximate the area of the shape.

The finer the grid, *i.e.*, the smaller the squares, the more accurate the estimate. Use this trick if you need to estimate the area of an irregularly shaped garden, pool, or piece of land.

Example 1 : Suppose the number of interior squares is 38, and the number of boundary squares is 29. Using the approximation formula, we estimate the total area of the shape to be

38 + (0.5) × (29) = 52.5

Example 2 : Let us find the area of a Maple leaf, which has been used to demonstrate the use of grid paper in measuring surface. Let us trace the maple leaf onto 1 cm grid paper as shown in the figure 1.2.

Fig. 1.2 *Finding the area of maple leaf.*

For each calculated surface area, whole squares located within the leaf area drawing were identified first and multiplied by the appropriate area of each grid size 1 cm^2. Squares which included part of the leaf surface are added up, then divided by 2 since only part of the surface was included within the square. Note: As the grid size gets smaller, a better estimate of the true leaf surface area is determined. Grid size can be decreased until it becomes too difficult to see the squares.

Using different grid sizes is a great lead-in to a discussion of accuracy and precision in surface area measurement.

Now, area of the maple leaf is

$$49 \text{ squares} = 49 \times 1\ \text{cm}^2 = 49\ \text{cm}^2$$

$$41/2 \text{ squares} = 41/2 \times 1\ \text{cm}^2 = 20.5\ \text{cm}^2$$

Hence, estimated area of maple leaf

$$= 49 + 20.5 = 69.5\ \text{cm}^2$$

1.3 MEASUREMENT OF DENSITY OF REGULAR SOLIDS

Density is defined as the ratio of the mass of a body to its volume. Mathematically, it is represented as

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{V}$$

Density is represented by D.

The density of a pure substance varies little from sample to sample and is often considered a characteristic property of the substance. Most substances undergo expansion when heated and, therefore, have lower densities at higher temperatures. Many substances, especially gases, can be compressed into a smaller volume by increasing the pressure acting on them. For these reasons, the temperature and pressure at which the density of a substance is measured are usually specified. The density of a gas is often converted mathematically to what it would be at a standard temperature and pressure. Water is unusual in that it expands, and thus decreases in density, as it is cooled below 3.98°C (its temperature of maximum density). It has a density of 1 g cm^{-3} or 1000 kg m^{-3} at 3.98°C. Density often is taken as an indication of how "heavy" a substance is. Iron is denser than cork, since a given volume of iron is more massive (and weighs more) than the same volume of cork. It is often said that iron is "heavier" than cork, although a large volume of cork obviously can be more massive and thus be heavier (*i.e.*, weigh more) than a small volume of iron.

Units of Density

In SI, density is measured in kilogram per cubic metre (kg m^{-3}). In CGS, density is measured in gram per cubic centimetre (g cm^{-3}). These two units are related as

$$1\ \text{g cm}^{-3} = 1000\ \text{kg m}^{-3}$$

Finding Density of a Regular Solid

In order to calculate density, you have to know two measurements: the mass and the volume of the object.

To determine the mass of an object, you use a triple beam or electronic balance. Mass is expressed in gram. If the object is a regular shaped object, such as a cube, you can determine the volume mathematically using the formula for volume, then density of the solid is given by

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

SAMPLE PROBLEMS

E1. *You have a rock with a volume of 15 cm^3 and a mass of 45 g. What is its density?*

Soln. Given, M = 45 g, V = 15 cm^3

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{45\ \text{g}}{15\ \text{cm}^3}$$

$$= 3\ \text{g cm}^{-3}$$

E2. *If 96.5 g of gold has a volume of 5 cm^3, what is the density of gold?*

Soln. Given, M = 96.5 g, V = 5 cm^3

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{96.5\ \text{g}}{5\ \text{cm}^3}$$

$$= 19.3\ \text{g cm}^{-3}$$

E3. ***If the density of a diamond is $3.5\ g\ cm^{-3}$, what would be the mass of a diamond whose volume is $0.5\ cm^3$?***

Soln. Given, $D = 3.5\ g\ cm^{-3}$, $V = 5\ cm^3$

$$M = D \times V$$

$$M = 3.5\ g\ cm^{-3} \times 0.5\ cm^3$$

$$M = 1.8\ g$$

E.4. ***If a 96.5 g piece of aluminium has a density of $2.7\ g\ cm^{-3}$, what is its volume?***

Soln. Given, $M = 96.5\ g$, $D = 2.7\ g\ cm^{-3}$

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}} = \frac{96.5\ g}{2.7\ g\ cm^{-3}}$$

$$= 35.7\ cm^3$$

1.4 CALCULATION OF SPEED

In our daily life, we come across scenarios, which give us a concept of 'fast' and 'slow' motion. For example, let us consider the motion of a cycle and a car. We observe that the car travels faster than the cycle. In turn, we move slower than the cycle. How do we compare these motions? How do we calculate exactly how fast the cycle and the car travel? There is often a need to measure how much distance a body can cover in a given period of time. This is how the term speed came into existence, which is the measurement of the distance covered per unit time.

We know that speed is given by the formula:

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

It can be inferred from the above formula that to find out the speed of a body, we need to keep track of the distance covered by it and the time taken for the journey.

Units of Speed

The SI unit for the measurement of distance and time are metre and second respectively. So the SI unit for speed is metre per second.

However, for measuring larger amounts of time we have units like minutes and hours. Similarly, we often use kilometre and miles for larger distances. Depending on the usage, we use several units for speed. Some of them are:

metre per second ($m\ s^{-1}$)

kilometre per hour ($km\ h^{-1}$ or kmph)

miles per hour (mph)

SAMPLE PROBLEMS

E5. ***A boy walks at a speed of 4 kmph. How much time does he take to walk a distance of 20 km?***

Soln. Given, speed = 4 kmph,

distance = 20 km, time = ?

Time = Distance/Speed = 20/4

= 5 hours.

E6. ***A cyclist covers a distance of 15 miles in 2 hours. Calculate his speed.***

Soln. Given, distance = 15 km,

time = 2 hours, speed = ?

Speed = Distance/Time = 15/2

= 7.5 kmph.

E7. ***A car takes 4 hours to cover a distance, if it travels at a speed of 40 kmph. What should be its speed to cover the same distance in 1.5 hours?***

Soln. Given, time = 4 hours,

speed = 40 kmph

Therefore,

distance covered = 4 × 40 = 160 km

Now,

Speed required to cover the same distance in 1.5 hours

= Distance/Time = 160/1.5

= 106.66 kmph

Let's See it Again

1. The volume of an object is the amount of space it occupies.
2. Space available in a container is called its capacity.
3. When the volume of an object is small, it is convenient to express its volume in submultiples of m^3, such as, decimetre cube (dm^3) and centimetre cube (cm^3).
4. Surface area is defined as the measure of the surface of an object.
5. Surface area is defined as the measure of the surface of an object.
6. For irregular polygons (geometric shapes with straight edges), the most accurate way to compute the area is to partition the shape into triangles, then add up the areas of those smaller triangles.
7. Density is defined as the ratio of the mass of a body to its volume.
8. The density of a pure substance varies little from sample to sample and is often considered a characteristic property of the substance.
9. Water is unusual in that it expands, and thus decreases in density, as it is cooled below 3.98°C (its temperature of maximum density).

Exercises

A. SHORT ANSWER TYPE QUESTIONS

1. Which of the following is the standard unit of length?
   (*a*) metre (*b*) millimetre (*c*) decimetre (*d*) centimetre.
2. What is volume?
3. Write the relationship between the following units :
   (*i*) hectare and $metre^2$ (*ii*) $metre^3$ and cm^3 (*iii*) $metre^3$ and litre (*iv*) cm^3 and mL (*v*) 'are' and $metre^2$
4. What is the unit of volume?
5. What is the unit used to measure small area?
6. In which unit is large area measured?
7. Which two factors are to be specified to measure density?
8. How do you find density of a regular solid?
9. How can you find the speed of a body?

B. LONG ANSWER TYPE QUESTIONS

1. Describe a method to approximate the area of an irregular body.

C. PICK THE CORRECT ONE

1. Hectare is a unit of :
   (*a*) area (*b*) volume (*c*) length (*d*) none of these

2. 'Are' is a unit of :
   (a) area (b) volume (c) length (d) none of these
3. Which one of the following is not used for the measurement of volume?
   (a) burette (b) beam balance (c) graduated cylinder (d) tumbler measure

D. FILL IN THE BLANKS

1. The standard unit of volume is ....
2. Area of an regular surface is measured by ....
3. Are is a unit for the measurement of ....
4. Volume of a cube is ....
5. Volume of a cuboid is ....

E. DEFINE THE FOLLOWING TERMS

1. Volume
2. Area
3. Density
4. Speed

F. MARK THE STATEMENT AS TRUE OR FALSE

1. Volume of a solid is expressed in mL.
2. Volume of a cube is expressed in m^3.
3. 1 m^3 = 100 litre.
4. 1 km^2 = 10000 m^2.
5. kilometre is the unit of length.
6. The amount of space occupied by a body is called its area.
7. Volume of a cuboid can be determined by measuring its length, breadth and height.

G. CHOOSE THE ODD ONE OUT GIVING REASON

1. dm^3, cm^3, mm^3, m^2
2. are, hectare, km^2, m^2, cm^3
3. g cm^{-3}, kg m^{-3}, g m^{-3}, cm^{-3}

H. MATCH THE FOLLOWING

Column A	Column B
1. Area	(a) g cm^{-3}
2. Volume	(b) m^2
3. Density	(c) m s^{-1}
4. Speed	(d) cm^{-3}

I. GIVE ONE WORD FOR THE FOLLOWING

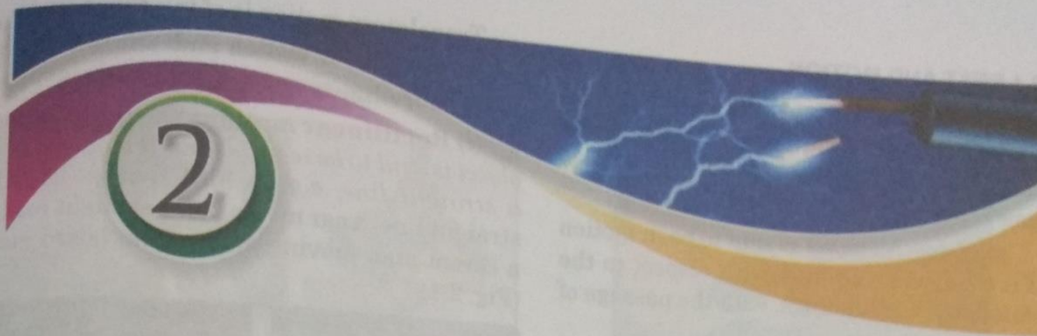
1. Space available in a container.
2. Mass per unit volume.
3. Distance per unit time.

J. NUMERICAL PROBLEMS

1. Calculate the mass of a liquid with a density of 3.2 g mL^{-1} and a volume of 25 mL. (**Ans.** 80 g)
2. An irregular object with a mass of 18 kg displaces 2.5 L of water when placed in a large overflow container. Calculate the density of the object. (**Ans.** 7.2 kg L^{-1} or 7.2 g mL^{-1} or 7.2 g cm^{-3})
3. The density of silver (Ag) is 10.5 g cm^{-3}. Find the mass of Ag that occupies 965 cm^3 of space. (**Ans.** 1.01×10^4 g)
4. A 2.75 kg sample of a substance occupies a volume of 250.0 cm^3. Find its density in g cm^{-3}. (**Ans.** 11 g cm^{-3})
5. Under certain conditions, oxygen gas (O_2) has a density of 0.00134 g mL^{-1}. Find the volume occupied by 250.0 g of O_2 under the same conditions. (**Ans.** 1.87×10^5 mL)
6. Find the volume that 35.2 g of carbontetrachloride (CCl_4) will occupy if it has a density of 1.60 g mL^{-1}. (**Ans.** 22.0 mL)
7. The density of ethanol is 0.789 g mL^{-1}. Find the mass of a sample of ethanol that has a volume of 150.0 mL. (**Ans.** 118.35 g ethanol)
8. An airplane flies with a constant speed of 720 kmph. How long will it take to travel a distance of 360 kilometres? (**Ans.** 0.5 hours)
9. An airplane flies with a constant speed of 880 kmph. How far can it travel in 2 hours? (**Ans.** 1760 km)
10. A van moves with a constant speed of 70 mph. How long will it take to travel a distance of 245 miles? (**Ans.** 3.5 hours)
11. Grace rides her bike with a constant speed of 14 mph. How long will she take to travel a distance of 56 miles? (**Ans.** 4 hours)
12. An airplane flies with a constant speed of 760 kmph. How long will it take to travel a distance of 3040 kilometers? (**Ans.** 4 hours)

Project / Activity

1. Using a graph paper estimate the area of a "peepal tree leaf".
2. Find the density of some bodies in your possession.



Motion

Objectives

- Motion as a change in position of an object with respect to time
- Types of motion: Translatory, circulatory, oscillatory, repetitive (Periodic and non-periodic), Random.
- Uniform and non-uniform motion, concept of distance and speed and average speed.
- Weight: concept, difference between mass and weight

A running cheetah indicates motion.

Introduction

We live in a world that is constantly changing and moving. The movements of animals, of the vehicles, the rivers are easily observed. Less obvious, but just as important, are the motion of plants as they grow and respond to light and other stimuli and the motion of atoms, the building blocks of matter.

Movement is a central part of the Universe in which we live. To understand motion is to understand one of the most fundamental aspects of ourselves and our world. It is a common observation that all living objects, whether plants or animals can move in some way or the other. The motion in animals is more apparent than the motion in plants. A dog running to catch a ball thrown in the air, a horse pulling a cart on the road, a pair of oxen pulling the plough in the fields are all examples of motion in animals. Animals also have the ability to move a part or whole of their bodies. We ourselves have the ability to move run and jump.

Living beings move by themselves by using the energy from within. But the same cannot be said about non-living objects. Non-living objects require energy from some outside source to set them into motion. *e.g.*, you need to apply a force in pulling or pushing your desk.

2.1 REST AND MOTION

Rest : An object is said to be at rest, if it does not change its position with respect to the stationary surroundings, with the passage of time.

Motion : An object is said to be in motion if it changes its position with respect to the stationary surroundings, with the passage of time.

Rest and motion are relative terms. There is nothing like absolute rest. This means that an object can be at rest and also in motion at the same time. *e.g.*, all objects, which are stationary on earth, are said to be at rest with respect to each other, but with respect to the sun are making revolutions at 30 kilometre per hour. In order to study motion, therefore, we have to choose a fixed position or point with respect to which the motion has to be studied. Such a point or fixed position is called a reference point or the origin. In order to describe the motion of an object we need to keep in mind three things :

(*i*) *The distance of the body from a reference point. This reference point is called the origin of the motion of the body.*

(*ii*) *The direction of motion of the body.*

(*iii*) *The time of motion.*

2.2 TYPES OF MOTION

Motion is classified as being of four types:

(*i*) Translatory motion (Rectilinear and Curvilinear)

(*ii*) Rotatory

(*iii*) Oscillatory and

(*iv*) Vibratory

2.2.1 Translatory Motion

A translatory motion is a motion in which all the parts of a body move through the same distance in the same interval of time.

Translatory motion is of two types :

(*i*) Rectilinear motion and

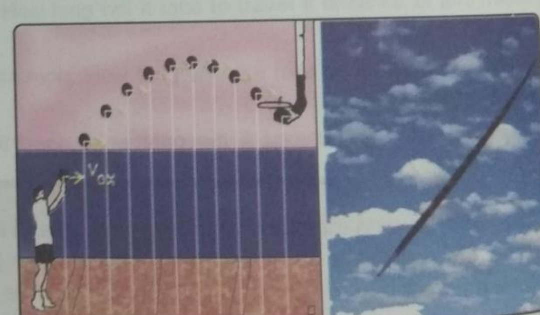
(*ii*) Curvilinear motion.

(*i*) Rectilinear motion: *The motion of an object is said to be rectilinear if it moves along a straight line. e.g.*, a bird flying along a straight line, a car moving on a straight road, a carom men moving on a carom board etc. (Fig. 2.1)

(*a*) (*b*)

Fig. 2.1 Two examples of rectilinear motion : (a) Flight of a bird and (b) Motion of carom men.

(*ii*) Curvilinear motion: *The motion of an object is said to be curvilinear if it moves along a curved path. e.g.*, a stone thrown into the air and at an angle with the ground, a javelin or shot put thrown by an athlete, a basket ball thrown into the basket etc. (Fig. 2.2)



(*a*) (*b*)

Fig. 2.2 Two examples of curvilinear motion : (a) Flight of a basketball and (b) Javelin thrown in the air.

2.2.2 Rotatory Motion

A motion is said to be rotatory if an object moves in a circular path around a fixed axis without changing its position. e.g., Motion of a potter's wheel, motion of an electric fan, motion of a spinning top etc. (Fig. 2.3). Rotatory motion is different from curvilinear motion in the sense that the body moves about a fixed axis without changing its position with time.

(a) (b)

Fig. 2.3 Two examples of rotatory motion : (a) Potter's wheel and (b) Spinning top.

2.2.3 Oscillatory Motion

An oscillatory motion is the back and forth motion which takes place about a mean position. In this motion, the entire body moves to and fro about the mean position. *e.g.*, motion of a simple pendulum, the motion of a swing, the motion of the piston of an engine etc. (Fig. 2.4)

(a) (b)

Fig. 2.4 Two examples of oscillatory motion : (a) Swing and (b) Simple pendulum.

2.2.4 Vibratory Motion

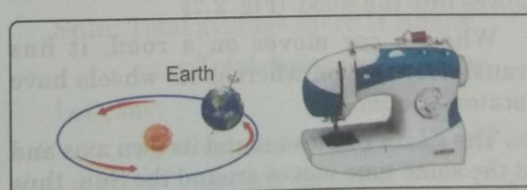
Vibratory motion is a motion in which a part of a body undergoes oscillatory motion and the remaining body stays at rest. When we pluck the strings of a stringed instrument (guitar, sitar etc.) only the string vibrates whereas the instrument remains stationary. *e.g.*, motion of the strings of a guitar. (Fig. 2.5). In fact all musical instruments like tabla, drum, violin show vibratory motion.

Fig. 2.5 The strings of a guitar undergo vibratory motion.

2.2.5 Periodic Motion

A motion is said to be periodic if it repeats itself after a fixed interval of time. For example, motion of the moon around the earth in 37.3 days, beating of our heart, motion of Halley's comet in 76 years and the motion of the Earth around the Sun in one year. The motion of the needle of a sewing machine and the oscillations of a pendulum are also periodic. (Fig. 2.6)

A periodic motion need not be oscillatory, but an oscillatory motion is always periodic.



(a) (b)

Fig. 2.6 Two examples of periodic motion : (a) Revolution of Earth around the Sun and (b) Motion of the needle of a sewing machine.

2.2.6 Simple Pendulum

An ideal simple pendulum is a heavy point mass suspended by a weightless, inextensible and a perfectly flexible string from a rigid support.

In practice, these requirements cannot be fulfilled, as such a practical pendulum consists of a small heavy brass sphere called bob, suspended by a long fine thread from a rigid support. When the bob is displaced from its mean position, then it begins to oscillate in a vertical plane under gravity to and fro about the mean position. The motion is regular and repeating, an example of periodic motion.

2.2.7 Non-Periodic Motion

A motion is said to be non-periodic when it repeats itself at non-regular intervals of time. The motion of a car driving several blocks on a busy downtown street. The motion of your dog on a walk around the block. The motion of fingers as they type on a keyboard. The motion of fingers as they play a song on a keyboard and many more.

2.2.8 Combination of Motions

There are a number of motions taking place in daily life which cannot be classified as purely translatory, rotatory and oscillatory. These motions are a combination of any two of the above mentioned motions. For example, When a ball rolls on the ground, it has rotatory as well as rectilinear motion.

An electric drill has both translatory and rotatory motion. As the drill rotates, its bit moves into the wood. (Fig. 2.7)

When a car moves on a road, it has translatory motion whereas its wheels have rotatory motion.

The Earth rotates around its own axis and at the same time moves around the Sun, thus it too has both rotatory and translatory motion.

Fig. 2.7 *An electric drill. The bit of the drill rotates as well as moves forward into the wood.*

2.2.9 Random Motion

Random motion, also known as Brownian motion, is the chaotic, haphazard movement of atoms and molecules. Random motion is a quality of liquid and especially gas molecules as described by the kinetic theory. The botanist Robert Brown first noticed this phenomenon in 1827 and Albert Einstein later continued Brown's study of the movement of water and pollen molecules. His theory helped to definitively prove the existence of atoms.

2.3 UNIFORM AND NON-UNIFORM MOTION

Uniform motion is the kind of motion in which a body covers equal distances in equal intervals of time. It does not matter how small the time intervals are, as long as the distances covered are equal.

If a body is involved in rectilinear motion and the motion is uniform, then the speed of the body is constant.

Some examples :

- The hour hand of a clock- It moves with uniform speed, completing movement of a specific distance in an hour.
- A car going along a straight level road at steady speed.
- An aircraft cruising at a level height and a steady speed.
- A ship steaming on a straight course at steady speed.
- A train going along the tracks at steady speed.
- A cooling fan running at a fixed speed.
- Earth moving round the sun is a uniform motion.
- Movement of fan.
- A pendulum having equal amplitudes on both sides.
- A vibrating spring in a sewing machine.

Non-Uniform motion on the other hand is the kind of motion in which a body covers unequal distances in equal intervals of time, no matter how small the time intervals are.

Example: If a car covers 10 metre in first two second, and 15 metre in next two second, the motion is non-uniform.

If a body is involved in rectilinear motion, and if the motion is non-uniform, then the speed of the body is not constant.

Some examples:

- A horse running in a race.
- A bus on its way through the market.
- A bouncing ball.
- Movement of an asteroid.
- Aircraft moving through the clouds and then landing.
- Dragging a box from a path.
- A man running a 100 m race.
- A car coming to a halt.
- A train coming to its terminating stop.
- A car colliding with another car.

Most of the motions taking place around us are non-uniform motions.

Distance : Distance is defined as the actual path followed by a body between the points between which it moves.

Suppose a body travels from point A to point B, then the actual path travelled by the body (as shown by the dotted line in figure 2.8) is its distance travelled. Distance is a scalar quantity, the direction of motion is not important in this case. Distance travelled by a body never decreases with time.

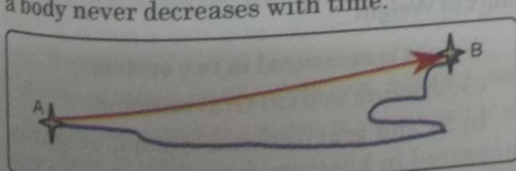


Fig. 2.8 *Displacement and distance. The red arrow shows displacement and the blue line shows distance.*

Speed : Speed is defined as the ratio of the distance travelled by a body to the time taken to do so. It is also defined as the distance travelled in unit time. Mathematically, it is given by the expression

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} \text{ or } S = \frac{D}{T}$$

It is measured in SI in m s^{-1}. Speed is also measured in kilometre per hour (km h^{-1}). The two units are related as:

$1 \text{ km h}^{-1} = 5/18 \text{ m s}^{-1}$

Average Speed : Average speed is the ratio of the total distance travelled to the total time taken to cover that distance. To find average speed, we divide the total amount of distance travelled by the total elapsed time.

Hence,

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}}$$

Let's derive the general formula first and see how it applies it to a couple of examples.

Say, a car travels at a speed S_1 kmph on a trip and at speed S_2 kmph on return trip. What is its average speed for the entire trip?

Soln: Total average speed is simply

= Total distance/Total time

Let's say,

D = distance travelled by the car in each direction

t_1 = time spent on onward trip

t_2 = time spent on return trip

Thus, the total distance travelled by the car

$S = D + D = 2D$

And, by the formula, Speed = Distance/Time

$S_1 = D/t_1$

$\Rightarrow \quad t_1 = D/S_1$

$S_2 = D/t_2$

$\Rightarrow \quad t_2 = D/S_2$

Total average speed = Total distance/Total time

$= 2D/(t_1 + t_2)$

$= 2D/(D/S_1 + D/S_2)$

$= 2S_1S_2/(S_1 + S_2)$

Remember this general formula for a total average speed problems:

$$\text{Average speed} = \frac{2S_1S_2}{(S_1 + S_2)}$$

SAMPLE PROBLEMS

E1. ***A car travels at 60 kmph on a trip and at 100 kmph on return trip. What was its average speed for the entire trip?***

Soln. Given, $S_1 = 60$ kmph, $S_2 = 100$ kmph, $S_{Av} = ?$

$$\text{Average speed} = \frac{2S_1S_2}{(S_1+S_2)}$$

$$= \frac{2 \times 60 \times 100}{100+60}$$

$$= \frac{12000}{160}$$

$= 75$ kmph

E2. ***John drove for 3 hours at a rate of 50 km per hour and for 2 hours at 60 km per hour. What was his average speed for the whole journey?***

Soln. The formula for distance is

Distance = Speed × Time

Total distance $= 50 \times 3 + 60 \times 2 = 270$ km

Total time $= 3 + 2 = 5$

Using the formula

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}}$$

We have

$$\text{Average speed} = \frac{270}{5}$$

$= 54$ kmph

2.4 WEIGHT

We often use the term 'weight' in everyday life - sometimes we mean mass, rather than weight, while at other times we really do mean weight. ***Weight is the measure of the force of gravity on a body.*** Since the weights of different bodies at the same location are proportional to their masses, weight is often used as a measure of mass or the measure of the heaviness of an object.

In other words, *weight is the force with which a body is attracted towards the Earth or another celestial body. Weight is equal to the product of the object's mass and the acceleration of gravity.*

Therefore,

$$W = mg$$

However, mass and weight are not the same; mass is a measure of the amount of matter present in a body and thus has the same value at different locations, and weight varies depending upon the location of the body in the earth's gravitational field (or the gravitational field of some other astronomical body). A given body will have the same mass on the earth and on the moon, but its weight on the moon will be only about 16% of the weight as measured on the earth. *Since acceleration due to gravity varies from place to place, therefore, weight is not same at all places.*

You experience your own weight as the reaction force of the chair you are sitting on or the ground you are standing on. When this reaction force does not act you feel 'weightless'. Weight is a vector quantity.

Units of Weight

Weight is measured in two systems:

(*i*) Absolute and (*ii*) Gravitational.

In SI and gravitational system, weight is measured in kilogram force (kgf) and in CGS in gram force (gf). One kilogram force is the force with which the earth attracts a mass of 1 kg.

In SI and absolute system, weight is measured in newton (N) and in CGS in dyne (dyn).

Weight is measured with the help of a spring balance or digital balance as shown in figures 2.9 and 2.10.

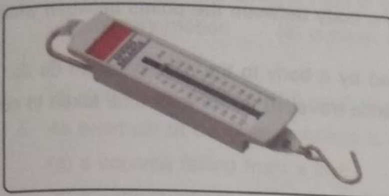


Fig. 2.9 *A spring balance.*

Fig. 2.10 *A digital balance.*

2.5 DIFFERENCE BETWEEN MASS AND WEIGHT

MASS	WEIGHT
It is the amount of matter contained in a body.	It is a force equal to the gravitational pull exerted by a planet.
It is a constant quantity and does not change with respect to position or place.	It is a variable quantity and changes with the change in acceleration due to gravity of a place.
Mass of a body can never be zero.	Weight of a body can be zero during free fall.
It is measured by using a physical balance.	It is measured by using a spring balance.
It is a scalar quantity.	It is a vector quantity.
It is measured in kilogram.	It is measured in newton.

Let's See it Again

1. An object is said to be at rest, if it does not change its position with respect to the stationary surroundings with the passage of time.
2. An object is said to be in motion, if it changes its position with respect to the stationary surroundings with the passage of time.
3. Rest and motion are relative terms. There is nothing like absolute rest.
4. A translatory motion is a motion in which all the parts of a body move through the same distance in the same interval of time.
5. Rectilinear Motion: The motion of an object is said to be rectilinear, if it moves along a straight line.
6. Curvilinear Motion: The motion of an object is said to be curvilinear, if it moves along a curved path.
7. A motion is said to be rotatory if an object moves in a circular path around a fixed axis without changing its position.
8. An oscillatory motion is the back and forth motion which takes place about a mean position.
9. Vibratory motion is a motion in which a part of a body undergoes oscillatory motion and the remaining body stays at rest.
10. A motion is said to be periodic if it repeats itself after a fixed interval of time.

11. An ideal simple pendulum is a heavy point mass suspended by a weightless, inextensible and a perfectly flexible string from a rigid support.
12. Uniform motion is the kind of motion in which a body covers equal distances in equal intervals of time.
13. A motion is said to be non-periodic when it repeats itself at non-regular intervals of time.
14. Non-uniform motion on the other hand is the kind of motion in which a body covers unequal distances in equal intervals of time, no matter how small the time intervals are.
15. Distance: Distance is defined as the actual path followed by a body between the points between which it moves.
16. Speed: Speed is defined as the ratio of the distance travelled by a body to the time taken to do so.
17. Average speed : Average speed is the ratio of the total distance travelled to the total time taken to cover that distance.
18. Weight is the measure of the force of gravity on a body.

Exercises

A. SHORT ANSWER TYPE QUESTIONS

1. A body moves in a straight line, what type of motion does it possess?
2. Displacement can be zero but distance cannot. Why ?
3. An object moving with constant speed may have a variable velocity. Explain.
4. A drilling machine shows a combination of motions. Why ?
5. An object moves to and fro about a mean position, what type of motion does it possess?
6. An oscillatory motion is always periodic, but a periodic motion is not always oscillatory. Explain with an example.
7. What is uniform motion?

B. LONG ANSWER TYPE QUESTIONS

1. Why rest and motion are called relative terms?
2. What factors have to be kept in mind while describing motion?
3. What is the difference between oscillatory and vibratory motion?
4. Identify the types of motion in the following : (*i*) A car moving on a straight road. (*ii*) A basket ball thrown towards a basket. (*iii*) Motion of a potter's wheel. (*iv*) Motion of the string of a guitar. (*v*) Motion of a simple pendulum. (*vi*) Spinning top. (*vii*) Swing.
5. Explain the following terms connected with a simple pendulum: (*i*) Length of a pendulum. (*ii*) One oscillation. (*iii*) Mean position.
6. Discuss how you will measure the time period of a simple pendulum.
7. Define the term motion. How many different types of motion are there? Give an example of each.
8. What is a pendulum?
9. Distinguish between mass and weight.

C. PICK THE CORRECT ONE

1. Motion is of :
   (*a*) three types (*b*) four types (*c*) two types (*d*) one type
2. Translatory motion is of :
   (*a*) three types (*b*) four types (*c*) two types (*d*) one type
3. A car moving on a straight road is an example of :
   (*a*) rotatory motion (*b*) periodic motion (*c*) oscillatory motion (*d*) rectilinear motion
4. A pendulum has :
   (*a*) curvilinear motion (*b*) oscillatory motion (*c*) rotatory motion (*d*) rectilinear motion
5. An example of curvilinear motion is :
   (*a*) a coconut falling from a tree (*b*) the motion of a pendulum
   (*c*) a potter's wheel (*d*) throwing of a javelin
6. A potter's wheel is an example of :
   (*a*) rotatory motion (*b*) periodic motion (*c*) oscillatory motion (*d*) rectilinear motion
7. Distance is a :
   (*a*) scalar quantity (*b*) normal quantity (*c*) vector quantity (*d*) none of these
8. The quantity which tells the distance of a body travels in a certain time is called :
   (*a*) acceleration (*b*) velocity (*c*) displacement (*d*) none of these

D. FILL IN THE BLANKS

1. A bench in a park is in a state of ....
2. A running cheetah is in a state of ....
3. A spinning top has .... motion.
4. Motion of the earth around the sun is ....
5. A potter's wheel has .... motion.
6. Motion of an electric drill is a combination of .... motions.
7. The string's of a guitar has .... motion.
8. The .... travelled by a moving body is the actual length of the path covered by it.
9. When a body completes one revolution, the displacement of the body is ....
10. The rate of change of motion in a specified direction is called ....

E. DEFINE THE FOLLOWING TERMS

1. Rest
2. Motion
3. Speed
4. Velocity
5. Uniform motion
6. Non-uniform motion
7. Mass
8. Weight

F. MARK THE STATEMENT AS TRUE OR FALSE

1. A ball thrown by a boy from a roof-top has oscillatory motion.
2. A motion which repeats itself after a fixed interval of time is called periodic motion.
3. Displacement is a scalar quantity.
4. Velocity is the distance travelled by a moving body per unit time.
5. The motion described by the needle of a sewing machine is a vibratory motion.
6. The motion of a bus going around a traffic round about is a rotatory motion.
7. A runner, running along a circular track at a constant speed has a uniform velocity.

G. CHOOSE THE ODD ONE OUT GIVING REASON

1. Translatory motion, rectilinear motion, curvilinear motion, rotatory motion.
2. Vibratory motion, tabla, drum, violin, javelin thrown in the air.

H. MATCH THE FOLLOWING

Column A	Column B
1. Vibratory	(*a*) javelin thrown in the air
2. Curvilinear	(*b*) spinning top
3. Oscillatory	(*c*) table
4. Rotatory	(*d*) simple pendulum

I. GIVE ONE WORD FOR THE FOLLOWING

1. A state in which a body does not change its position with respect to the surroundings.
2. A state in which a body changes its position with respect to the surroundings.
3. A motion in which all the parts of a body move through the same distance in the same time interval.
4. A motion in which objects move along a straight line.
5. The back and forth motion.
6. A motion which repeats itself after regular intervals of time.
7. A pendulum whose time period is 2 second.

Project / Activity

1. For a set of different objects/toys, identifying the motion they possess.
2. Demonstrating motion of a simple pendulum as periodic.

3 Energy

Objectives

- Energy: Energy as capacity to do work, Units of energy, joule and calorie, Different forms of energy, inter-conversion of energy
- Law of conservation of energy, real world examples

This multi-flash photograph illustrates various forms of mechanical energy which you will study in this chapter. The energy stored in the temporarily bent pole is potential energy.

Introduction

You have learnt that when force acts on a body, it enables the body to move. When an applied force moves a body through a distance, work is said to be done. Work is a form of energy. Any amount of energy spent produces an equivalent amount of work and vice-versa. In fact, any human activity in everyday life is doing work. The term 'work' is used along with energy in our day-to-day life.

When water is lifted to a certain height, the work done on water is stored in the form of potential energy. This potential energy of the falling water is used to produce electrical energy in hydroelectric power stations. It is interesting to note that, "energy can neither be created nor destroyed, but it can be changed from one form to another". This statement was first coined by Robert Mayer and is commonly known as the 'Law of conservation of energy'.

3.1 ENERGY AND WORK

Work refers to an activity involving aforceand movement in the direction of the force. A force of 20 newton pushing an object 5 metre in the direction of the force does 100 joule of work.

Energy is the capacity for doing work. You must have energy to accomplish work - it is like the "currency" for performing work. To do 100 joule of work, you must expend 100 joule of energy.

Energy wasn't understood very well during the lifetime of Isaac Newton. Today, the concept of energy is ingrained in all branches of science. Most of the energy here on Earth originated from the sun and can be transformed into many different types of energy. And, in order for *work to be done, there needs to be a source of energy.*

Work is defined as the product of force and the distance moved by a body under this force.

Mathematically, $W = F \times S$

For instance, work is done on books when a person carries them up stairs. If there are more books (more force required), then more work is done. If there are more stairs to climb (more distance travelled), then more work is done. Work is directly proportional to both force and distance – as one increases, so does the other. *In order to say that work is done on the books, the force applied and the distance travelled have to be in the same direction* (holding books **up** and moving them **up**). If the books were simply carried across the room, the work is not done on the stack of books. Work is done, just not on the stack of books!

Work is measured in units of *joule (J),* after James Joule. 1 joule is defined as the amount of work done when 1 newton of force is applied over the distance of 1 metre.

Work is done only if a body possesses energy, therefore, energy is defined as the capacity of a body to do work. Without energy no work can be done.

Work and energy are related by the following relation

Work = Change in energy

Units of Energy

Energy is measured in different units. Two such units are joule (J) and calorie (cal).

The calorie (cal) is defined as the amount of heat required to raise the temperature of one gram of water from 14.5°C to 15.5°C.

In SI, the unit of heat is joule (J). One joule is the amount of energy required to do one joule of work. Work done is said to be one joule if a force of one newton displaces a body through a distance of one metre in its own direction.

The unit calorie is related to joule as

$$1 \text{ cal} = 4.186 \text{ J} \approx 4.2 \text{ J}$$

3.2 DIFFERENT FORMS OF ENERGY

The most striking fact about energy is its diversity. Like a clever actor energy assumes many disguises. Energy appears in many forms such as: Mechanical, Electrical, Solar, Nuclear, Chemical, Electromagnetic etc. Because of this richness of form, energy appears in nearly every part of the description of nature either microscopic or macroscopic.

Mechanical Energy : It is moving energy. It is the form that we most see around us. All moving objects produce mechanical energy. The movements within machines is also mechanical energy.

Examples: People, a rolling bicycle, moving gears and running cars.

It is of two types : Kinetic and Potential.

1. Kinetic Energy : It is defined as the energy possessed by a body by virtue of its motion. *e.g.*, Any moving body possesses KE.

2. Potential Energy : It is the energy possessed by a body by virtue of its position or configuration. *e.g.*, A body at a certain height from earth possesses PE.

Sound Energy : It is produced when an object is made to vibrate. Sound energy travels out as waves in all directions. Sound needs a medium to travel through, such as air, water wood and even metal.

Examples: Voices, whistles, horns and musical instruments.

Chemical Energy : It is really a form of potential energy and is the energy stored in food, gasoline or chemical combinations.

Examples: Striking a match, combining vinegar and baking soda to form CO_2 gas, breaking light sticks releases chemical energy.

Electromagnetic Energy : It is a combination of heat and light energy. Light energy, like sound energy, travels out in all directions in waves.

Examples: A light bulb, the glowing coils on a toaster, the sun and even headlights on cars.

Electrical Energy : Energy produced by electrons moving through a substance is known as electrical energy. We mostly see electric energy in batteries and from the outlets in our homes. Electrical energy lights our homes, runs motors and makes our TVs and radios work.

Examples: CD players, TVs and Video games.

Nuclear Energy : It is produced when you split atoms. A tremendous amount of energy is released when this happens.

Examples: Atomic bombs, nuclear power plants, nuclear submarines, and the sun.

Solar Energy : It is the energy radiated by the Sun. It has been used for thousands of years in many different ways by people all over the world. As well as its traditional human uses in heating, cooking and drying, it is used today to make electricity where other power supplies are absent, such as in remote places and in space. It is becoming cheaper to make electricity from solar energy and in many situations it is now competitive with energy from coal or oil. A solar cooker can be used for cooking food.

3.3 INTER-CONVERSION OF ENERGY

In most basic terms, this is the changing of energy from one state to another. For instance, energy may change from motion energy to kinetic energy and from kinetic energy to potential energy. This is difficult to understand in most cases, which is why it's important to remember that energy simply can change forms.

One easy way to prove this is by rubbing your hands together. The movement of your hands creates friction. The friction force, however, also creates heat. This is the inter-conversion of energy.

Some inter-conversion of energies are listed below:

Inter-conversion of potential energy and kinetic energy :

We have already seen that one form of energy can change into another. We have seen, for example, that when a bowling ball is dropped its potential energy changes into kinetic energy. The slamming of a screen door is analogous: the potential energy of the open door with the stretched spring turns into the kinetic energy of the moving door as the door slams.

The swinging of a pendulum also exemplifies the inter-conversion of potential energy and kinetic energy. At the extremes of its arc the pendulum is at rest and its energy is entirely potential. At the lowest point of its arc the energy of the pendulum is entirely kinetic.

Inter-conversion of mechanical energy and electrical energy :

Mechanical energy can be converted to electrical energy by generators and that the reverse, the conversion of electrical energy to mechanical energy, can be accomplished by motors.

Inter-conversion of chemical energy and electrical energy :

We are also familiar with the effect of a battery, a device that converts chemical energy to electrical energy. For some batteries this is a process than cannot be reversed, but for others it can. Batteries for which the process can be reversed are called rechargeable batteries.

Fuel cells are similar to batteries in that they convert chemical energy to electrical energy. Fuel cells differ from batteries, however, in that the chemicals that are consumed by the fuel cell can be continually replaced while the device is in operation.

Inter-conversion of light energy and chemical energy :

Most of us are familiar with devices that convert chemical energy to light energy and that can convert light energy to chemical energy. The firefly and other luminescent organisms, converts some chemical energy to light, so called "cold" light, and every living plant converts light energy, sunlight, to sources of chemical energy, typically sugars and starches. The mechanism is the same for all plants, and it involves the green pigment chlorophyll. It is the chemical energy thus produced that provides us humans with the energy we need to stay alive. Yes; our diet consists exclusively of chemicals.

Inter-conversion of electrical energy and light energy :

We all know about electric lights. One type of electric light is the incandescent light bulb. In this device the light is produced indirectly. The electricity heats a wire, the filament, to incandescence, a temperature at which the filament glows "white" hot. An electric toaster or toaster-oven operates in the same way, but at a lower temperature, only "red" hot. Incandescent lights produce far more heat than light and for that reason are said to be inefficient since the main purpose is to produce light.

Light energy can also be converted to electrical energy. In a "solar cell", light energy is converted into electrical energy

Other inter-conversions of forms of energy :

Almost any form of energy can be converted into another form of energy. Electrical energy and thermal energy can be inter-converted by thermocouples, and mechanical energy and electrical energy can be inter-converted by piezoelectric crystals.

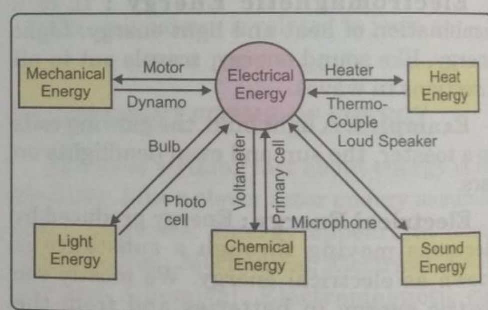


Fig. 3.1 *Some energy inter-conversions.*

3.4 LAW OF CONSERVATION OF ENERGY

In a closed system, the amount of energy is fixed. You can't create any more energy inside the system or destroy any of the energy that's already in there. But you can convert the energy you have from one form to another (and sometimes back again).

Thus, energy can neither be created nor destroyed but can only change its form.

The conservation of energy (and the idea of a "closed system") sounds a bit abstract, but it becomes an awful lot clearer when we consider some real-life examples.

Driving a car

Fill a car up with fuel and you have a closed system. All the energy you have at your disposal is locked inside the fuel in your tank in chemical form. When the fuel flows into your engine, it burns with oxygen in the air. *The chemical energy in the fuel is converted first into heat energy: the burning fuel makes hot expanding gas, which pushes the pistons in the engine cylinders. In this way, the heat is converted into mechanical energy.* The pistons turn the crankshaft, gears and driveshaft and-eventually-the car's wheels. As the wheels turn, they speed the vehicle along the road, giving it kinetic energy (energy of movement).

Boiling a kettle

Boil water with an electric kettle and you're seeing the conservation of energy at work again. Electrical energy drawn from the power outlet on your wall flows into the heating element in the base of your kettle. As the current flows through the element, the element rapidly heats up, so the electrical energy is converted into heat energy that gets passed to the cold water surrounding it. After a couple of minutes, the water boils and (if the power stays on) starts to turn to steam.

Pushing a car uphill

In the everyday world, "work" is something you do to earn money; in physics, work has a different meaning. When you do a useful job with a force (a push or a pull), such as moving a car uphill, we say you're doing work and that takes energy. If you push a car uphill, it has more potential energy at the top of the hill than it had at the bottom. Have you violated the conservation of energy by creating potential energy out of thin air?

No! To push the car, you have to do work against the force of gravity. Your body has to use energy to do work. Most of the energy your body uses is gained by the car as you push it uphill. The energy your body loses is pretty much equal to the work it does against gravity. And the energy the car gains is the same as the work done. So no energy is created or destroyed here: *you're simply converting energy stored as fuel inside your body into potential energy stored by the car (because of its height).*

Roller Coaster

A roller coaster ride is a thrilling experience which involves a wealth of physics. Part of the physics of a roller coaster is the physics of work and energy. The ride often begins as a chain and motor (or other mechanical device) exerts a force on the train of cars to lift the train to the top of a very tall hill. Once the cars are lifted to the top of the hill, gravity takes over and the remainder of the ride is an experience in energy transformation.

At the top of the hill, the cars possess a large quantity of potential energy. As the cars descend the first drop they lose potential energy and gain kinetic energy. As the ride continues, the train of cars are continuously losing and gaining height. Each gain in height corresponds to the loss of speed as kinetic energy (due to speed) is transformed into potential energy (due to height). Each loss in height corresponds to a gain of speed as potential energy (due to height) is transformed into kinetic energy (due to speed). Thus, there is a continuous transformation of kinetic energy into potential energy and vice-versa, the overall energy remaining conserved.

Fig. 3.2 *Conservation of energy in Roller coaster.*

Production of hydroelectricity

Hydroelectricity is produced by storing water in dams. The energy stored in water in the dams is in the form of potential energy. This water is made to run through pipes to run turbines which are placed at a lower level. The potential energy of water gets converted into its kinetic energy at the bottom of the dam. The kinetic energy of running water gets converted into the mechanical energy of the turbines. The turbines run the generator which produce electrical energy. Thus, in the production of hydroelectricity potential energy is converted into kinetic and then to electrical energy. The overall energy remaining conserved.

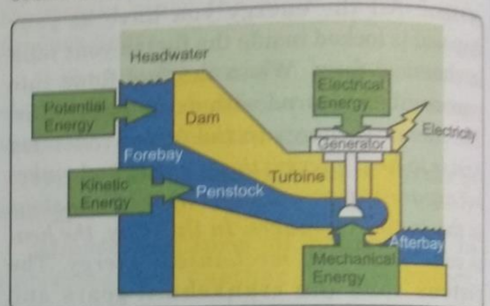


Fig. 3.3 *Conservation of energy in the production of hydroelectricity.*

Let's See it Again

1. Work refers to an activity involving a force and movement in the direction of the force.
2. Energy is the capacity for doing work in order for work to be done, there needs to be a source of energy.
3. Work is defined as applying a force over a certain distance.
4. Work = Change in energy.
5. Work done is said to be one joule if a force of one newton displaces a body through a distance of one metre in its own direction.
6. Energy appears in many forms such as : Mechanical, Electrical, Solar, Nuclear, Chemical, Electromagnetic etc.
7. Law of conservation of energy states that energy can neither be created nor destroyed but can only change its form.

Exercises

A. SHORT ANSWER TYPE QUESTIONS

1. Give an example in which a body possesses both kinetic energy and potential energy.
2. Energy is interconvertible. Give example.
3. In a solar cell, light energy is converted to what ?
4. State the law of conservation of energy.
5. List the different forms of energy.

B. LONG ANSWER TYPE QUESTIONS

1. Distinguish between kinetic energy and potential energy. Give one example of each.
2. What do you understand by the law of conservation of energy ? Discuss how it works in case of a simple pendulum.
3. What is mechanical energy ? What are its different forms ?
4. Explain the different forms of energy by giving one example each.
5. Write a short note on production of hydroelectricity.

C. PICK THE CORRECT ONE

1. Water stored in a dam possesses :
   (*a*) no energy (*b*) electrical energy (*c*) kinetic energy (*d*) potential energy
2. Which one of the following is not the unit of energy ?
   (*a*) joule (*b*) newton metre (*c*) kilowatt (*d*) kilowatt hour
3. The SI unit of work is :
   (*a*) joule (*b*) erg (*c*) dyne (*d*) watt
4. One joule work is said to be done when :
   (*a*) a force of 1 N displaces a body by 1 cm
   (*b*) a force of 1 N displaces a body by 1 m
   (*c*) a force of 1 dyne displaces a body by 1 cm
   (*d*) a force of 1 dyne displaces a body by 1 m

D. FILL IN THE BLANKS

1. The capacity of a body to do work is called its ....
2. Joule is another name of SI unit of ....
3. Energy can neither be created nor destroyed but can be changed from one form to another was first coined by ....
4. .... is a combination of heat and light energy.
5. In a .... light energy is converted into electrical energy.

E. DEFINE THE FOLLOWING TERMS

1. Energy
2. Work
3. Joule (J)
4. Calorie (cal)
5. Law of conservation of energy

F. MARK THE STATEMENT AS TRUE OR FALSE

1. When energy changes from one form to another, the energy that disappears from one form, reappears in exactly equivalent amount in other form.
2. When an arrow is released from a bow, potential energy changes into kinetic energy.
3. The unit of work is watt.
4. Work done by a force depends upon how fast work is done.
5. The kinetic energy of a body is by virtue of its position.

G. CHOOSE THE ODD ONE OUT GIVING REASON

1. Potential energy, kinetic energy, momentum, electromagnetic energy.
2. Motor, lamp, generator, work.
3. Kinetic energy, a rolling bicycle, a running car, a light bulb.
4. Atomic bombs, swinging of a pendulum, nuclear power plant, nuclear submarines.
5. Batteries, players, musical instrument, video games.

H. MATCH THE FOLLOWING

Column A	Column B
1. Motor	(a) light into electrical energy
2. Voltmeter	(b) electrical into mechanical energy
3. Loudspeaker	(c) electrical into chemical energy
4. Photo cell	(d) electrical into sound energy

I. GIVE ONE WORD FOR THE FOLLOWING

1. The energy possessed by a body by virtue of its position.
2. The capacity to do work.
3. The product of magnitude of force and the distance moved by the object in the direction of force.
4. The amount of work done on an object when a force of 1 N moves it over a distance of 1 m.
5. The amount of heat required to raise the temperature of one gram of water from 14.5°C to 15.5°C.

Project / Activity

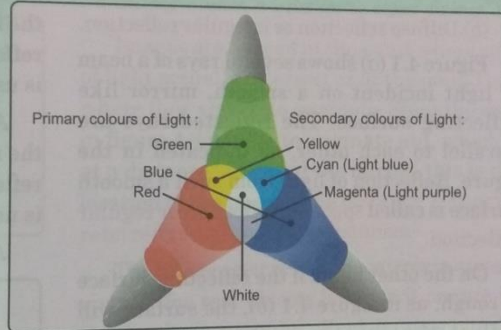
1. • Take a rubber band.
   • Hold it at one end and pull from the other. The band stretches.
   • Release the band at one of the ends.
   • What happens ?
   • The band will tend to regain its original length. Obviously the band had acquired energy in its stretched position.
   • How did it acquire energy when stretched ?
2. • Take a toy car. Wind it using its key.
   • Place the car on the ground.
   • Did it move ?
   • From where did it acquire energy ?
   • Does the energy acquired depend on the number of windings.
   • How can you test this ?
3. Study the interconversion of energy in a simple pendulum.

4

Light Energy

Objectives

- Reflection: Definition and examples, terms reflection normal, plane, point of incidence, angle of incidence, angle of reflection
- Laws of reflection
- Plane Mirror: Uses, Ray diagram (No mention of virtual image), characteristics of image formed (Lateral inversion, same size, distance is preserved)
- Speed of light (3×10^8 m s^{-1})
- Primary colours (RGB)
- Formation of secondary colours by colour addition
- Appearance of colour of an object (Based on reflection and absorption)
- Colour subtraction



Mixing of primary colours.

Introduction

Light is a form of energy which excites in us the sensation of sight. We see an object because of the light it reflects. A great deal of evidence suggests that light travels in straight lines under a wide variety of circumstances. For example, a point source of light like the sun casts distinct shadows; the beam of a torch appears to be in a straight line. In fact, we infer the position of objects in our environment by assuming that light moves from object to our eyes in straight line paths. One might have noticed, light rays from the sun entering a dust filled room from a small opening. What do you see? You find that the light rays form parallel lines. Light coming out of small openings in between the trees seem to travel along straight lines.

Light travels at 299,792,458 m s^{-1}, *i.e.*, about 300,000,000 m s^{-1} or 3×10^8 m s^{-1}. It takes 8 minutes for a light wave (or a photon) to travel from the sun to the earth. We see the moon because it reflects the sun's light. It takes 1 second for light reflected off the moon to reach the earth.

4.1 REFLECTION OF LIGHT

When a light ray travelling in a medium encounters a boundary leading into a second medium, part of the incident ray is thrown back into the original medium. This is termed as reflection of light.

In other words, the bouncing back of light when it strikes a smooth or polished surface is called reflection of light. While studying the reflection of light we consider light to be a ray. A ray of light represents the direction of the propagation of light, *i.e.*, light travels in the direction of the ray of light.

Reflection is of two types :

(*a*) Specular reflection or regular reflection and

(*b*) Diffuse reflection or irregular reflection.

Figure 4.1 (*a*) shows several rays of a beam of light incident on a smooth, mirror like reflecting surface. The reflected rays are parallel to each other, as indicated in the figure. Reflection of light from such a smooth surface is called specular reflection or regular reflection.

On the other hand, if the reflecting surface is rough, as in figure 4.1 (*b*), the surface will reflect the rays in various directions. Reflection from any rough surface is known as diffuse reflection or irregular reflection. A surface will behave as a smooth surface as long as the surface variations are small as compared with the wavelength of the incident light.

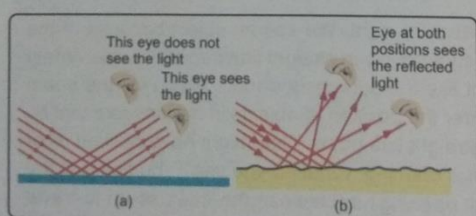


Fig. 4.1 *Schematic representation of (a) Diffuse reflection, where the reflected rays travel in random directions and (b) Specular reflection, where the reflected rays are all parallel to each other.*

4.2 TERMS CONNECTED WITH REFLECTION OF LIGHT

Incident ray: It is a light ray which strikes the reflecting surface.

Reflected ray: It is a light ray which bounces back into the same medium after reflection from the reflecting surface.

Point of incidence: It is a point on the reflecting surface where the incident ray strikes.

Normal: It is a perpendicular drawn at the point of incidence on the reflecting surface.

Angle of incidence: It is the angle which the incident ray makes with the normal to the reflecting surface at the point of incidence. It is usually represented by the letter *i*.

Angle of reflection: It is the angle which the reflected ray makes with the normal to the reflecting surface at the point of incidence. It is usually represented by the letter *r*.

All these are shown in figure 4.2.

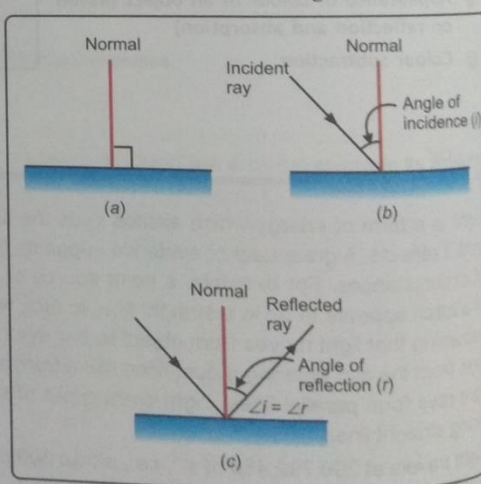


Fig. 4.2 *Normal, angle of incidence and angle of reflection*

4.3 LAWS OF REFLECTION

The reflecting surfaces obey the following two laws called the laws of reflection :

(i) The angle of incidence (i) is equal to the angle of reflection (r).

(ii) The incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane.

Consider a light ray travelling in air and incident at an angle on a flat, smooth surface as shown in the figure 4.3. The incident ray (AO) and the reflected ray (BO) make angles i and r respectively, with a line ON drawn perpendicular to the surface at the point of incidence O. Then experiments show that

$$\angle i = \angle r$$

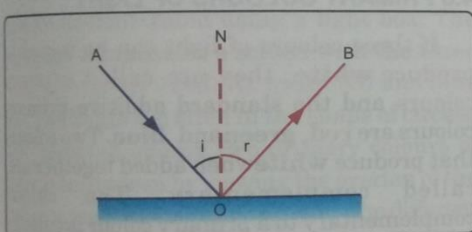


Fig. 4.3 Reflection at a plane surface.

4.4 A PLANE MIRROR

A plane mirror is a plane reflecting surface. Image formed by a plane mirror can be studied under two different headings.

(i) When object is a point object and

(ii) When object is an extended object.

4.4.1 When the object is a point object

Consider a point source of light placed at point O as shown in the figure 4.4 distance 'u' in front of a plane mirror. The distance 'u' is often referred to as the object distance. Light rays leave the source and are reflected from the mirror obeying the laws of reflection. After reflection, the rays diverge (spread out). These diverging rays appear to the viewer to come from a point I located behind the mirror. Point I is called the image of the object O.

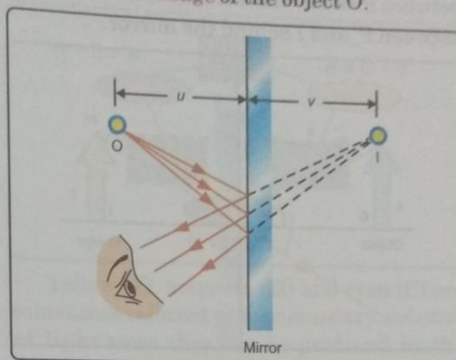


Fig. 4.4 An image formed by reflection from a plane mirror. The image point I is located behind the mirror at a distance v, which is equal to the object distance u.

Images are formed at the point where rays of light actually intersect or at the point from where they appear to originate. Since the rays in figure 4.4 appear to originate at I, which is at a distance 'v' behind the mirror, this is the location of the image. The distance 'v' is often referred to as the image distance.

The image seen in a plane mirror is always virtual; for real objects because it cannot be obtained on a screen. Real images can be displayed on a screen, but virtual images cannot be displayed on a screen.

4.4.2 When the object is an extended object

Consider an extended object PS as shown in figure 4.5. One of those rays starts at P, follows a horizontal path to the mirror, and reflects back on it as shown in figure 4.5. The second ray follows the oblique path PR and reflects as shown. An observer to the left of the mirror would trace the two reflected rays back to the point from which they appear to have originated, that is, point P'. Similarly, any ray that will originate from O will seem to come from I after reflection from the mirror. All rays between P and O will seem to come from points between P′ and I behind the mirror.

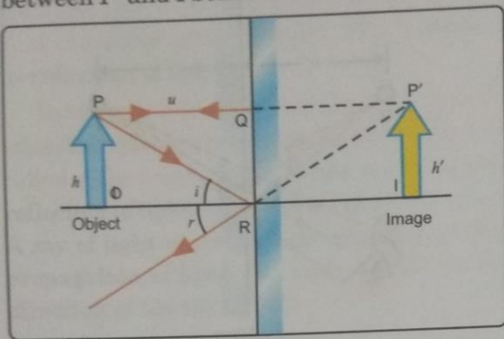


Fig. 4.5 Geometric construction used to locate the image of an object placed in front of a plane mirror.

A continuation of this process for points on the object either than P would result in a virtual image to the right of the mirror.

Hence, it can be conclude that the images formed by an object in front of a plane mirror is as far behind the mirror as the object is in front of the mirror. It can also be shown, with the help of geometry, that the object height h is equal to the image height h′.

If standing in front of a plane mirror you close your left eye, your image in the plane mirror seems to be closing its right eye. If there is a mark on your right cheek, the mirror shows it on your left cheek. In a plane mirror, the left and right sides are interchanged. It appears that the image has been reversed sideways, *i.e.*, left becomes right and right becomes left. This is called lateral inversion. Thus, the image formed by a plane mirror suffers from lateral inversion.

4.5 SPEED OF LIGHT

Light travels at a constant, finite speed of 299,792,458 m s^{-1} about 3×10^8 m s^{-1}. A traveller, moving at the speed of light, would circumnavigate the equator approximately 7.5 times in one second. By comparison, a traveller in a jet aircraft, moving at a ground speed of 800 kmh^{-1}, would take over 50 hours to circle the planet just once.

To put that into an astronomical perspective, the average distance from the Earth to the Moon is 384,398.25 km. So light crosses that distance in about a second. Meanwhile, the average distance from the Sun to the Earth is ~149,597,886 km, which means that light takes only about 8 minutes to make that journey.

Thespeed of lightis constant, or so textbooks say. But some scientists are exploring the possibility that this cosmicspeedlimit changes, a consequence of the nature of the vacuum of space.

4.6 PRIMARY COLOURS OF LIGHT

If three colours of light can be mixed to produce **white**, they are called primary colours and the standard additive primary colours are **red**, **green**and **blue**. Two colours that produce **white**when added together are called complementary. The colour complementary to a primary colour is called a secondary colour.

We should be aware that *white is not a colour at all*, but rather the presence of all the frequencies of visible light. When we speak of white light, we are referring to VIBGYOR - the presence of the entire spectrum of visible light. But combining the range of frequencies in the visible light spectrum is not the only means of producing white light. White light can also be produced by combining only three distinct frequencies of light, provided that they are widely separated on the visible light spectrum. Any three colours (or frequencies) of light that produce white light when combined with the correct intensity are called primary colours of light. There are a variety of sets of primary colours. The most common set of primary colours is red (R), green (G) and blue (B). When red, green and blue light are mixed or added together with the proper intensity, white (W) light is obtained. This is often represented by the equation below:

$$R + G + B = W$$

In fact, the mixing together (or addition) of two or three of these three primary colours of light with varying degrees of intensity can produce a wide range of other colours. For example, red light and green light added together are seen as yellow light. This additive colour system is used by light sources, such as televisions and computer monitors, to create a wide range of colours. When different proportions of red, green and blue light enter your eye, your brain is able to interpret the different combinations as different colours.

The addition of the primary colours of light can be demonstrated using a light box. The light box illuminates a screen with the three primary colours - red (R), green (G) and blue (B). The lights are often in the shape of circles. The result of adding two primary colours of light is easily seen by viewing the overlap of the two or more circles of primary light. The different combinations of colours produced by red, green and blue are shown in the graphic below :

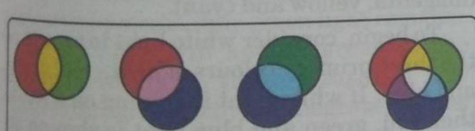
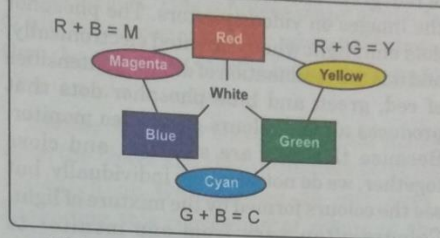


Fig. 4.6 *Combining primary colours of light to produce different colours.*

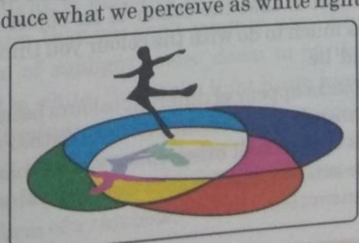
4.7 COLOUR ADDITION

These demonstrations with the colour box illustrate that red light and green light add together to produce yellow (Y) light. Red light and blue light add together to produce magenta (M) light. Green light and blue light add together to produce cyan (C) light. And finally, red light and green light and blue light add together to produce white light. This is sometimes demonstrated by the following colour equations and graphic:



Yellow (Y), magenta (M) and cyan (C) are sometimes referred to as **secondary colours of light** since they can be produced by the addition of equal intensities of two primary colours of light. The addition of these three primary colours of light with varying degrees of intensity will result in countless other colours that we are familiar (or unfamiliar) with.

Television and computer monitors create colour using the primary colours of light. Each pixel on a monitor screen starts out as black. When the red, green and blue phosphors of a pixel are illuminated simultaneously, that pixel becomes white. *This phenomenon is called additive colour.* To illustrate additive colour, imagine three spotlights, one red, one green and one blue focussed from the back of an ice arena on skaters in an ice show. Where the blue and green spotlights overlap, the colour cyan is produced; where the blue and red spotlights overlap, the colour magenta is produced; where the red and green spotlights overlap the colour yellow is produced. When added together, red, green and blue lights produce what we perceive as white light.



As mentioned before, television screens and computer monitors are examples of systems that use additive colour. Thousands of red, green and blue phosphor dots make-up the images on video monitors. The phosphor dots emit light when activated electronically, and it is the combination of different intensities of red, green and blue phosphor dots that produces all the colours on a video monitor. Because the dots are so small and close together, we do not see them individually, but see the colours formed by the mixture of light. Colours often vary from one monitor to another. This is not new information to anyone who has visited an electronics store with various brands of televisions on display. Also, colours on monitors change over time. Currently, there are no colour standards for the phosphors used in manufacturing monitors for the graphics arts industry.

4.8 APPEARANCE OF COLOUR OF AN OBJECT

The 'colour' of an object is the wavelengths of light that it reflects. This is determined by the arrangement of electrons in the atoms of that substance that will absorb and re-emit photons of particular energies according to complicated quantum laws. So tomatoes are red because the pigment atoms in the skin absorb photons of all energies except those that correspond to red wavelengths of light, which they reflect back to your eye. But the colour that you perceive is about much more than the wavelengths of light. The visual cortex of your brain has evolved to perform lots of context-dependent corrections to correct for the colour and intensity of the ambient light. The effect is that the colour of an object has just as much to do with the colour you think it 'should' be.

Objects appear of different colours because they absorb some colours (wavelengths) and reflect or transmit other colours. The colours we see are the wavelengths that are reflected or transmitted.

For example, a red shirt looks red because the dye molecules in the fabric have absorbed the wavelengths of light from the violet/blue end of the spectrum. Red light is the only light that is reflected from the shirt. If only blue light is shone onto a red shirt, the shirt would appear black, because the blue would be absorbed and there would be no red light to be reflected. White objects appear white because they reflect all colours. Black objects absorb all colours so no light is reflected.

4.9 COLOUR SUBTRACTION

We have already learnedthat materials contain atoms that are capable of selectively absorbing one or more frequencies of light. Consider a shirt made of a material that is capable of absorbing blue light. Such a material will absorb blue light (if blue light shines upon it) and reflect the other frequencies of the visible spectrum. What appearance will such a shirt have if illuminated with white light and how can we account for its appearance? To answer this question (and any other similar question), we will rely on our understanding of the three primary colours of light (red, green and blue) and the three secondary colours of light (magenta, yellow and cyan).

To begin, consider white light to consist of the three primary colours of light - red, green and blue. If white light is shining on a shirt, then red, green and blue light is shining on the shirt. If the shirt absorbs blue light, then only red and green light will be reflected from the shirt. So while red, green and blue light shine upon the shirt, only red and green light will reflect from it. Red and green light striking your eye always gives the appearance of yellow; for this reason, the shirt will appear yellow. This discussion illustrates **the process of colour subtraction**. In this process, the ultimate colour appearance of an object is determined by beginning with a single colour or mixture of colours and identifying which colour or colours of light are subtracted from the original set. The process is depicted visually by figure 4.7.

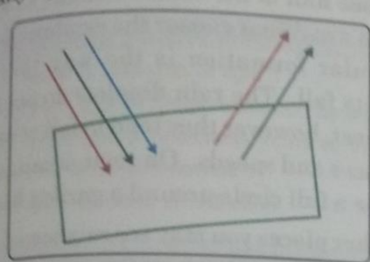


Fig. 4.7 Colour subtraction: Absorbs blue appears yellow.

Furthermore, the process is depicted in terms of an equation as

$$W - B = (R + G + B) - B = R + G = Y$$

Now, suppose that cyan light is shining on the same shirt - a shirt made of a material that is capable of absorbing blue light. What appearance will such a shirt have if illuminated with cyan light and how can we account for its appearance? To answer this question, the process of colour subtraction will be applied once more. In this situation, we begin with only blue and green primary colours of light (recall that cyan light consists of blue and green light). From this mixture, we must subtract blue light. After the subtractive process, only green light remains. Thus, the shirt will appear green in the presence of cyan light. Observe the representation of this by the diagram and the equation below :

$$C - B = (G + B) - B = G$$

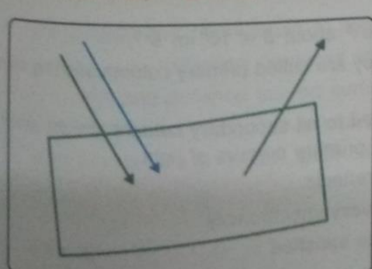
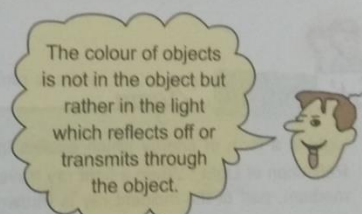


Fig. 4.8 Absorbs blue appears green.

From these two examples, we can conclude that a shirt that looks yellow when white light shines upon it will look green when cyan light shines upon it. This confuses many students of physics, especially those who still believe that the colour of a shirt is in the shirt itself. This is a misconception.

Rather, the colour is in the light that shines upon the object and that ultimately becomes reflected or transmitted to our eyes. Extending this conception of colour to the above two scenarios, we would reason that the shirt appears yellow if there is some red and green light shining upon it. Yellow light is a combination of red and green light. A shirt appears yellow if it reflects red and green light to our eyes. In order to reflect red and green light, these two primary colours of light must be present in the incident light.



4.10 FORMATION OF A RAINBOW

Rainbows are formed when sunlight and rain combine in a very specific way. The beams of sunlight separate into the colours we see in the rainbow as they enter a raindrop. Sunlight is actually made-up of different colours that we don't usually see. When a beam of sunlight comes down to earth, the light is white. But, if the light beam happens to hit raindrops on the way down at a certain angle, the different colours that make-up the beam separate so that we can see them – in the form of a rainbow.

The angle for each colour of a rainbow is different, because the colours slow down at different speeds when they enter the raindrop. The light exits the raindrop in one colour, depending on the angle it came in, so we see only one colour coming from each raindrop. Light at different angles coming through many raindrops form the rainbow that we see, in stripes of red, orange, yellow, green, blue, indigo and violet.

Rainbows form a complete circle, however only half is visible. The horizon only allows us to see half of the rainbow circle, so we see just an arc. What causes the rainbow to have a circular formation is the way that rain droplets fall. The rain droplets do not fall is flat sheet, however they tend to fall at various distances and speeds. On some occasions you can see a full circle around a garden hose.

Other places you may see rainbows formed are fountains, in the ocean as the waves crash against the rock which create a mist in the air, waterfalls, sprinklers and mist from a garden hose.

For a rainbow to be formed the following conditions must be satisfied :

(*i*) There should be moisture in the air.

(*ii*) The sun should be behind you.

Let's See it Again

1. Light is a form of energy which excites in us the sensation of sight.
2. Reflection of Light : When a light ray travelling in a medium encounters a boundary leading into a second medium, part of the incident ray is thrown back into the original medium.
3. Laws of Reflection : The reflecting surfaces obey the following two laws called the laws of the reflection. The angle of incidence (i) is equal to the angle of reflection (r).
4. The incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane.
5. The image formed by an object in front of a plane mirror is as far behind the mirror as the object is in front of the mirror. It can also be shown, with the help of geometry, that the object height h is equal to the image height h'.
6. A plane mirror shows lateral inversion.
7. Light travels at a constant, finite speed of 299,792,458 m s^{-1} about 3×10^8 m s^{-1}.
8. If the three colours of light can be mixed to produce white, they are called primary colours and the standard additive primary colours are red, green and blue.
9. Yellow (Y), magenta (M) and cyan (C) are sometimes referred to as secondary colours of light since they can be produced by the addition of equal intensities of two primary colours of light.
10. The 'colour' of an object is the wavelengths of light that it reflects.
11. Rainbows are formed when sunlight and rain combine in a very specific way.
12. For a rainbow to be formed the following conditions must be satisfied :
    (*i*) There should be moisture in the air.
    (*ii*) The sun should be behind you.

Exercises

A. SHORT ANSWER TYPE QUESTIONS

1. What is reflection of light ?
2. What type of image is formed by a plane mirror ?
3. What type of reflections forms an image ?
4. How is rainbow formed ?
5. State the laws of reflection.

B. LONG ANSWER TYPE QUESTIONS

1. State the laws of reflection. Draw a diagram to show incident and reflected rays.
2. List some characteristics of plane mirror.
3. Distinguish between regular and diffused reflection. Does diffused reflection mean the failure of the laws of reflection ?
4. What are primary colours of light ? Explain.
5. Write a short note on :
   (*a*) colour addition
   (*b*) colour subtraction

C. PICK THE CORRECT ONE

1. What is reflection of light ?
   (*a*) bouncing back of light from a polished surface
   (*b*) bending of light when it moves from one medium into another
   (*c*) splitting of light into seven colours
   (*d*) all of these
2. Reflection is of how many types ?
   (*a*) one (*b*) two (*c*) three (*d*) four
3. Diffused reflection takes place when light is reflected from a/an :
   (*a*) highly polished surface (*b*) irregular surface (*c*) plane mirror (*d*) convex mirror
4. A plane mirror produces :
   (*a*) virtual and erect image (*b*) virtual and inverted image
   (*c*) a real and erect image (*d*) a real and inverted image

D. FILL IN THE BLANKS

1. The straight line propagation of light is called ....
2. .... reflection produces image.
3. A smooth and polished curved surface which reflects light is known as ....
4. The angle of .... is equal to the angle of ....
5. Light travels at a constant, finite speed of ....

E. DEFINE THE FOLLOWING TERMS

1. Reflection
2. Plane mirror
3. Light
4. Laws of reflection
5. Lateral inversion
6. Colour addition

F. MARK THE STATEMENT AS TRUE OR FALSE

1. Transparent materials do not allow light to pass through them.
2. A plane mirror forms a virtual image.
3. Any highly polished surface can act as mirror.
4. Light propagates along a straight line.
5. The angle of incidence is the angle between the normal and the reflected ray.

G. CHOOSE THE ODD ONE OUT GIVING REASON

1. Glass, water, wood.
2. Dentist mirror, microscope, floodlights.
3. Diffused reflection, regular reflection, formation of image.
4. Kaleidoscope, periscope, mirror.
5. Convex lens, concave lens, plane mirror.

H. MATCH THE FOLLOWING

Column A	Column B
1. Glass	(*a*) irregular surface
2. Lateral inversion	(*b*) VIBGYOR
3. Diffused reflection	(*c*) transparent
4. Reflection	(*d*) always erect image
5. White light	(*e*) regular

I. GIVE ONE WORD FOR THE FOLLOWING

1. A highly polished reflecting surface that can return the rays of light into the same medium.
2. Spectrum of seven colours.
3. A light ray which strikes the reflecting surface.
4. Reflection from any rough surface.
5. A flat mirror.

Project / Activity

1. To prove that shining surface reflects light.

   Things needed : A plane mirror, a plate of stainless steel, a notebook and sunlight.

   Take the plane mirror and let sunlight fall on it. You will see sunlight being reflected by the mirror on a wall. As you change the angle of the mirror, the position of light on the wall also changes.

   The proves that a mirror can reflect light.

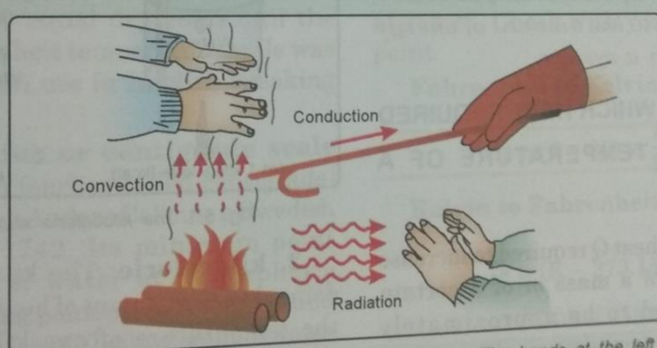
   Now, take the stainless steel plate and repeat the activity.

   In this case too, you will observe the light is reflected with lesser intensity.
2. Take a cardboard and cut it round and make it look like a CD. Mark seven equal cones and paint them with the colours of rainbow. Insert a pen in it making it look like a top and spin in. You will see only white colour.

5 Heat

Objectives

- Heat as a form of energy and its unit, joule (J) and calorie
- Different units of temperature (°C, °F, K)
- Effects of heat: Change in temperature, change in size (expansion and contraction), change in state, Good conductors and Bad conductors of heat and their examples, choice of conductors and insulators in day-to-day life (Pan handles, metal cooking utensils etc.)
- Methods of heat transfer: Conduction, convection and radiation.
- Thermos flask (Application of heat transfer): Construction, working



Heating by conduction, convection and radiation. The hands at the left are warmed by the convection of rising hot air (and some radiation). The gloved hand at upper right is warmed by conduction. The hands at lower right are warmed by radiation.

Introduction

Heat is a form of energy in transit, which excites in us the sensation of warmth. It is the difference in temperature of two bodies, which causes heat to flow between them. The concept of temperature is rooted in qualitative ideas of "hot" and "cold" based on our sense of touch. A body that feels hot usually has a higher temperature than the same body when it feels cold. That's pretty vague, and the senses can be deceived. Heat is energy in transit. When energy flows between two bodies because of their temperature difference, we term this energy as heat.

5.1. FLOW OF HEAT

Heat is a form of energy which flows from a body at a higher temperature to a body at a lower temperature. Have you ever watched an ice cube melt on a hot sidewalk? Heat is being transferred from the sidewalk into the ice cube, which causes the molecules inside the ice crystals to break apart and turn into liquid water.

When you touch an ice cube you feel cold. This is due to the fact that heat from your hand, which is at a higher temperature, flows into the ice cube, which is at a lower temperature. When you put your hand into warm water you feel warm. Now, the heat flows from the warm water into your hand, because the water is at a higher temperature than your hand.

In Physics the term "heat" refers to energy in transit from one body to the other because of the temperature difference, never to the amount of energy contained within a system.

5.2 FACTORS ON WHICH HEAT REQUIRED TO RAISE THE TEMPERATURE OF A BODY DEPENDS

The quantity of heat Q required to increase the temperature of a mass m of a certain material is found to be approximately proportional to the temperature change. It is also proportional to the mass m of material. When you're heating water to make tea, you need twice as much heat for two cups as for one if the temperature change is the same. The quantity of heat needed also depends on the nature of the material; raising the temperature of 1 kilogram of water by 1 °C requires 4190 J of heat, but only 910 J is needed to raise the temperature of 1 kilogram of aluminium by 1 °C.

Thus, the factors on which heat required to raise the temperature of a body depends upon:

(*i*) Mass of the body,

(*ii*) The rise in temperature and

(*iii*) The nature of the substance of which the body is made.

5.3 UNITS OF MEASUREMENT OF HEAT ENERGY

We can define a unit of quantity of heat based on the temperature changes of some specific material most of the times water. The practical unit of heat is calorie (cal).

1. Calorie: The calorie (cal) is defined as the amount of heat required to raise the temperature of one gram of water through 1 °C (from 14.5 °C to 15.5 °C). (Fig. 5.1)

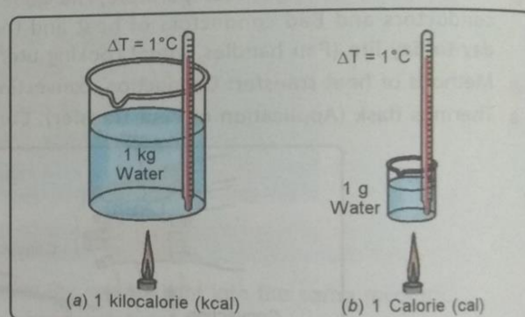


Fig. 5.1 *The kilocalorie and the calorie.*

2. kilocalorie: The kilocalorie (kcal) is defined as the amount of heat required to raise the temperature of one kilogram of water through 1 °C (from 14.5 °C to 15.5 °C). (Fig. 5.1)

The kilocalorie (kcal) is equal to 1000 cal. *i.e.*

1 kilocalorie = 1000 calorie

3. Joule (J) : In SI, the unit of heat is joule. It was not until the time of James Joule, that the relationship between energy in the form of work (in units of joule) and energy in the form of heat (in units of calorie) was firmly established. Joule's experiments revealed that the performance of mechanical work can make the temperature of a substance rise, just as the absorption of heat can. His experiments and those of later workers have shown that

1 calorie = 4.186 joule

Because of its historical significance, this conversion factor is known as the mechanical equivalent of heat.

5.4 THERMOMETRIC SCALES

There are three temperature scales in use today :

1. Fahrenheit,
2. Celsius and
3. Kelvin.

1. The Fahrenheit scale (°F): Itis the classic English system of measuring temperatures. Water freezes at 32°F and boils at 212°F at atmospheric pressure. The scale was created by Gabriel Daniel Fahrenheit, a German, in 1724 and divides the difference between the boiling point and freezing point of water into 180 equal degrees. Until the 1970s, the Fahrenheit temperature scale was in general common use in English-speaking countries.

2. The Celsius or centigrade scale (°C): The Celsius (earlier called centigrade) was put forward by Anders Celsius, a Swedish astronomer, in 1742. Its minimum point (freezing point of water at atmospheric pressure or melting point of ice) is at 0°C and its upper end is at 100°C (boiling point of water at atmospheric pressure). It is divided into 100 divisions. Each division is called one degree Celsius. More sensitive thermometers may be divided into 200 divisions. These thermometers are called half degree Celsius thermometers.

3. The Kelvin scale (K): It is an important scale used in most of science. The big difference is that it is based on a single point (**absolute zero**) which is given a value of 0 kelvin (0 K). From these, the scale increases by degrees that are the same size as Celsius degree. It is a scale that is based on energy content, rather than on arbitrary temperature values like the other two scale (based on water). Water freezes at 273.15 K and boils at 373.15 K. The word "Kelvin" comes from Lord Kelvin, who did a lot of work with temperatures.

The conversion formula between these three scales is :

Celsius (C) to Fahrenheit (F)

$$F = \frac{9}{5}C + 32$$

Fahrenheit (F) to Celsius (C)

$$C = \frac{5}{9}(F - 32)$$

Celsius (C) to Kelvin (K)

$$K = C + 273.15$$

Kelvin (K) to Celsius (C)

$$C = K - 273.15$$

Often, the value of 273 is used instead of 273.15. Check with your teacher on this point.

Fahrenheit to Kelvin

$$K = (F - 32) \times \frac{5}{9} + 273.15$$

Kelvin to Fahrenheit

$$F = (K - 273.15) \times \frac{9}{5} + 32$$

THE CONVERSION TABLE

From	To Fahrenheit (°F)	To Celsius (°C)	To Kelvin (K)
Fahrenheit	F	(F–32) × 5/9	(F–32) × 5/9+273.15
Celsius	(C×9/5) +32	C	C + 273.15
Kelvin	(K–273.15) ×9/5 + 32	K–273.15	K

NOTE : Never, ever, use a degree sign on kelvin. Do not do this: °K. Also, never say 'degree kelvin.' This value 225 K is said "two hundred twenty five kelvin."

The equivalence of the three scales is shown in figure 5.2.

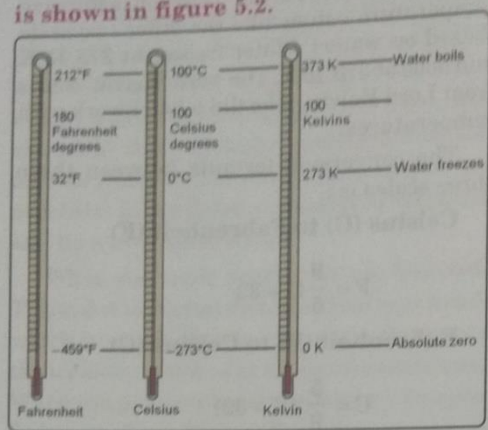


Fig. 5.2 *The three scales of temperature.*

5.5 HEAT AND ITS EFFECTS

When a body is heated it undergoes a number of changes. Some of these changes are listed below :

(*a*) Change in temperature: When a material body (solid, liquid or gas) is supplied with heat energy, its temperature rises. Conversely, if a hot material body gives out heat energy, its temperature falls.

(*b*) Change in dimensions: When a body (solid, liquid or gas) is supplied with heat energy, its dimensions change, *i.e.*, on the absorption of heat energy, the length, the area and the volume of the body increases. Conversely, when a hot material body gives out heat energy, *i.e.*, it cools, its length, area and volume decrease. In other words, material bodies expand on heating and contract on cooling.

(*c*) Change in state: Heat supplied to a body can also cause the change in its state. When a solid is heated, initially its temperature rises. However, at some particular temperature, its temperature stops rising. The heat energy supplied to the solid now changes it into the liquid state. Similarly, when the liquid so formed is further heated its temperature rises, till at some particular temperature, it starts boiling and changes into gaseous state. During this change of state from liquid into gaseous state the temperature remains constant. It is the heat energy which changes the liquid into gaseous state. Conversely, when a gas loses heat energy, it changes into liquid state and then to solid state.

(*d*) Chemical change: Large number of chemical reactions take place, when the reactants are heated. The heat energy breaks the original bonds between the elements; with the result they form new bonds and hence new products. For example, potassium chlorate on heating decomposes to form potassium chloride and oxygen gas.

(*e*) Effects on living beings: All mammals function effectively at some fixed body temperature. The temperature of human body for effective functioning is 98.6°F (37°C). If the temperature of surroundings becomes more than 98.6°F, it becomes hot and body functions slow down. Similarly, in too cold climate the body functions slow down. It is not true only for animals, but all kinds of living beings including plants. The plants wilt in too hot climate and die. Similarly, they die in too cold climate. It is for the same reason that we boil milk as well as water to kill harmful bacteria.

5.6 GOOD AND BAD CONDUCTORS OF HEAT

Although the transfer of heat through a metal can partially be explained by atomic vibrations, the rate of heat conduction also depends upon the properties of the substance being heated. For example, it is possible to hold a piece of asbestos in a flame indefinitely. This implies that very little heat is being conduct through the asbestos.

In general, metals are good conductors of heat and materials like asbestos, cork, paper and fibre glass are bad conductors of heat or insulators. Gases are also poor conductors of heat because of their dilute nature. Metals are good conductors of heat because they contain large number of free electrons that are relatively free to move through the metal and transport energy from one region to the other. Thus, in a good conductor, such as copper, heat conduction takes place via the vibration of atoms via the motion of free electrons.

Good conductors are the substances which readily conduct heat whereas bad conductors are the substances which do not conduct heat.

5.6.1 Examples to Illustrate Good and Bad Conductors

All substances do not have the same ability to conduct. While copper is a good conductor, wood is not.

Experiment 1:

The arrangement shown in figure 5.3 is an illustration showing the difference between good and bad conductors of heat. The arrangement consists of a piece of paper wrapped equally over the joint in the rod consisting of brass and wood. When the rod is passed through the flame, slightly above it we find that the paper over wood gets charred whereas nothing happens to the piece of paper over the brass portion. This is due to the reason that brass being a good conductor conducts the heat away from the paper quickly and prevents it reaching a temperature at which it burns whereas the wood hardly conducts away the heat.

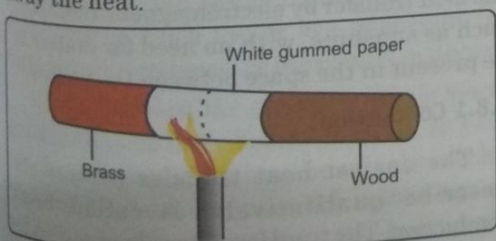


Fig. 5.3 Brass is a good conductor of heat, therefore, the paper over the brass rod does not burn.

Experiment 2: The Ingen Hauz experiment:

The arrangement shown in figure 5.4 was used by Ingen Hauz to demonstrate the conductivity of different metals. The apparatus consists of a vessel with holes drilled in its sides. Rods of different metals are inserted into these holes. The portion of the rods outside the vessel is coated with a uniform layer of wax. When the vessel is filled with boiling water and a steady state has been reached, it is found that the wax has melted upto different lengths on these rods. This indicates that different rods have different conductivity. The thermal conductivity of the different metals can be gauged by the extent to which the wax has melted on the rods. Greater the length to which the wax has melted, greater is the thermal conductivity of the metal.

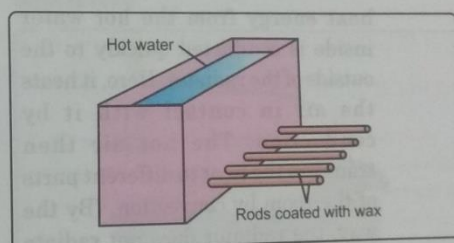


Fig. 5.4 The wax melts at different rates depending upon the nature of the material.

5.7 USES OF GOOD AND BAD CONDUCTORS

Thermal conduction can be put to a number of uses. There are many uses of the good and bad conductors of heat. Some of the uses are discussed below :

(a) Good conductors :

(i) These days cooking vessels have a base made of copper. Since copper is a good conductor of heat, therefore, it allows heat to flow quickly from the flame to the material being cooked. (Fig. 5.5)

Fig. 5.5 *Utensils having copper base. The heat conductivity of copper ensures the rapid and even spread of heat from the burner.*

(ii) Some tea kettles have copper bottom to ensure greater conductivity of heat.

(iii) The hot water radiator (used for heating up rooms in western countries) is made of metal so that heat energy from the hot water inside is conducted quickly to the outside of the radiator. Here, it heats the air in contact with it by conduction. The hot air then transfers the heat to different parts of the room by convection. (By the way, the radiator does not radiate much heat as the temperature difference between the metal radiator surface and the room is rather small).

(iv) The boilers used in industry are made-up of steel to conduct heat quickly from the source of heat to the liquid being boiled.

(b) Bad conductors :

(i) To handle hot vessels in the kitchen, for example, sauce pans, kettles, "tavas" etc., they are fitted with handles made of non-conducting materials.

(ii) Gloves, mittens (gloves with no partitions between the fingers) and pieces of clothes (all insulators) are used to pick up hot vessels with safety.

(iii) Table mats are made of non-conducting materials like cloth, straw, wood, special plastics etc., so that hot plates and dishes do not damage the table surface.

(iv) Dishes made-up of toughened glass (a poor conductor) take much longer to cool than metal dishes. So, they keep the food inside them hot for a long time.

(v) Ovens have double walls and lining of cotton wool or glass wool which are bad conductors to minimize loss of heat to the surroundings.

(vi) Air is a bad conductor and so trapped air in cotton, wool etc., helps us to keep ourselves warm in winters. Use of blankets, quilts etc. are the examples.

5.8 METHODS OF HEAT TRANSFER

The three ways of heat transfer are **CONDUCTION**, **CONVECTION** and **RADIATION**. Conduction occurs within a body or between two bodies in contact. Convection depends on motion of mass from one region of space to another. Radiation is the heat transfer by electromagnetic radiation, such as sunshine, with no need for matter to be present in the space between the bodies.

5.8.1 Conduction

The easiest heat transfer process, to describe qualitatively, is called heat conduction. The transfer of heat from one point to the other, in such a way that there is no actual motion of the particles of the medium is called conduction. In this process, the heat transfer can be viewed on an atomic scale as an exchange of kinetic energy. Particles gain energy by colliding with the most energetic particles. For example, if we insert a copper rod into a flame while holding one end, we find that the temperature of the metal in our hand increases rapidly. The heat reaches our hand through conduction.

5.8.2 Convection

Convection is transfer of heat by mass motion of a fluid from one region of space to another. Familiar examples include hot air and hot water home heating systems, the cooling systems of an automobile engine and the flow of blood in the body.

If a blower or pump circulates the fluid, then the process is called forced convection; if the flow is caused by differences in density due to thermal expansion, such as hot air rising, the process is called natural convection or free convection. One of the real life application is in the explanation of sea and land breeze.

Sea and Land breeze: Natural convection cycles occur in liquids and gases. For example, when cold water is in contact with a hot object, such as the bottom of a pot on a stove, the object transfers heat to the water adjacent to the pot by conduction. But the water carries the heat away with it by natural convection and a cycle is set up in which upper, cold water replaces the rising warm water. Such cycles are important in atmospheric processes, as illustrated in figure.

During the day, the ground heats up more quickly than do large bodies of water, as you may have noticed if you have been to the beach. This occurs both because the water has a greater specific heat than the land and because convection currents disperse the absorbed heat throughout the great volume of water. The air in contact with the warm ground is heated by conduction. That air expands, becoming less dense than the surrounding cooler air. As a result, the warm air rises (air currents) and, to fill the space, other air moves horizontally (winds) creating a sea breeze near a large body of water. Cooler air moves down and a thermal convection cycle is set up, which transfers heat away from the land. At night, the ground loses its heat more quickly than the water and the water surface is warmer than the land. As a result, the cycle is reversed and a land breeze blows.

Sea breeze: The cold air blowing from the sea towards the land during the day is called sea breeze.

Land breeze: The cold air blowing from the land towards the sea during night is called land breeze.

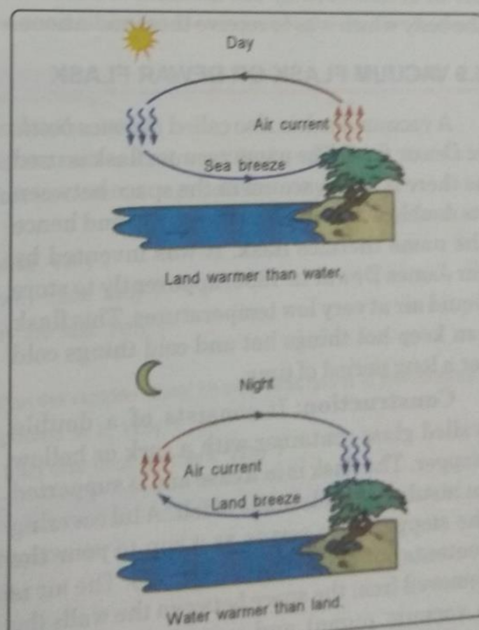


Fig. 5.6 *During the day, natural convection cycles give rise to sea breezes near large bodies of water. At night, the pattern of circulation is reversed and land breezes blow.*

5.8.3 Radiation

Radiation is the process of transmission of heat in which heat travels directly from one place to another without the agency of any intervening medium.

From the above statement, it is sometimes wrongly understood that, a material medium has nothing to do with radiation and that it remains absolutely unaffected during the process of heat transmission.

Though the medium does not play that active a role as it does in the case of conduction and convection, it may absorb heat that is being transmitted through it and thus get heated itself. *Therefore, it should be clearly understood that the medium apart from getting slightly heated, has no concern with the process of transmission of heat.* It is, in fact, a hindrance to the process of transmission as the heat absorbed by the medium is a loss to the body which was to receive these radiations.

5.9 VACUUM FLASK OR DEWAR FLASK

A vacuum flask is also called *thermos bottle* or *Dewar flask*. The name vacuum flask is used as there is near vacuum in the space between its double walls. It keeps things hot and hence the name thermos flask. It was invented by Sir James Dewar in 1890, apparently to store liquid air at very low temperatures. This flask can keep hot things hot and cold things cold for a long period of time.

Construction: It consists of a double walled glass container with a cork or hollow stopper. The flask is in a case and is supported on insulating pads made of felt. A lid covering the stopper, also serves as a cup to pour the contents out of the flask, (Fig. 5.7). The air is removed from the space between the walls (by a vacuum pump) and is sealed. The outer surface of the inner wall and the inner surface of the outer wall are coated with silver to reduce transfer of energy by radiation.

Working: Heat energy cannot be transferred by convection or conduction due to the vacuum between the walls as a medium is necessary for these processes. The silvering of the outer surface of the inner wall makes it a poor radiator of heat while the silvering of the inner surface of the outer wall makes it a good reflector of heat which it receives from outside. The reverse is also true for the heat entering from outside. The stopper prevents heat loss by evaporation from hot liquids or by convection currents set up above the liquid surface.

The transfer of energy is a two way process. It may be from the hot things kept inside to the outside or heat may flow from the hot surroundings outside to the cold things kept inside. By providing near perfect thermal insulation, a vacuum flask is used to keep things warm or cool as desired. The thermal insulation provided by a vacuum flask is not perfect. Some heat may be lost at a very low rate by conduction from the neck of the flask and by radiation from the walls. This means that hot coffee may not remain hot and your favourite cold drink may become hot after a few hours.

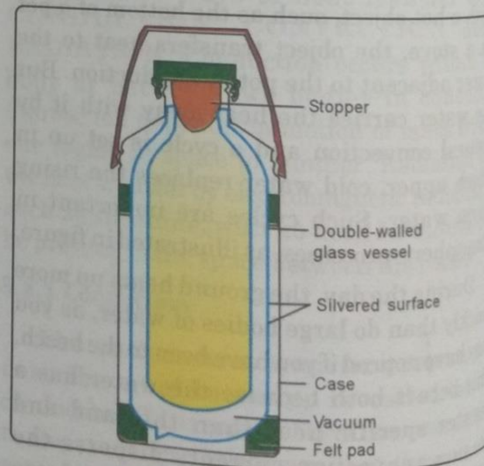


Fig. 5.7 *A vacuum or Dewar flask*

Let's See it Again

1. Heat is a form of energy in transit, which excites in us the sensation of warmth.
2. Heat is a form of energy which flows from a body at a higher temperature to a body at a lower temperature.
3. The calorie (cal) is defined as the amount of heat required to raise the temperature of one gram of water through 1°C (from 14.5°C to 15.5°C).
4. The kilocalorie (kcal) is defined as the amount of heat required to raise the temperature of one kilogram of water through 1°C (from 14.5°C to 15.5°C).
5. There are three temperature scales in use today, Fahrenheit, Celsius and Kelvin.
6. Heat and its effects : Change in temperature, Change in dimensions, Change in state, Chemical change, Effects on living beings.
7. Good conductors are the substances which readily conduct heat whereas bad conductors are the substances which do not conduct heat.
8. The transfer of heat from one point to the other, in such a way that there is no actual motion of the particles of the medium is called conduction.
9. Convection is transfer of heat by mass motion of a fluid from one region of space to another.
10. Radiation is the process of transmission of heat in which heat travels directly from one place to another without the agency of any intervening medium.

Exercises

A. SHORT ANSWER TYPE QUESTIONS

1. Cooking pots are provided with wooden or plastic handles. Why ?
2. We prefer white clothes in summer and dark coloured clothes in winter. Why ?
3. The underside of cooking utensils is blackened but its sides are kept polished. Why ?
4. The radiator of a car is painted black. Why ?
5. The top of a roof made of asbestos is painted white. Why ?
6. Gaps are left in between rails while laying a railway track. Why ?
7. Telephone wires are kept slightly loose when they are laid. Why ?
8. Bridges are mounted on rollers. Why ?
9. The diameter of an iron tyre is kept slightly smaller than the wooden wheel on which this tyre is to be mounted.
10. A thick glass tumbler cracks when hot water is poured in it. Why ?
11. We wear a number of garments in winter rather than one thick garment. Why ?

B. LONG ANSWER TYPE QUESTIONS

1. What are the lower and upper fixed points of a thermometer?
2. Name some effects which can be caused by heat.
3. In how many ways can heat be transferred?
4. Name the three modes of transmission of heat energy.
5. Name four good conductors and four bad conductors of heat.
6. Give three practical uses of good conductors.
7. Draw a neat and labelled diagram of a thermos flask.

C. PICK THE CORRECT ONE

1. Heat gives us a :
   (a) sensation of hotness (b) sensation of coldness
   (c) sensation of hotness and coldness (d) none of these
2. Heat causes :
   (a) change in temperature (b) change in dimensions (c) change in state (d) all of these
3. In a laboratory thermometer, the lower fixed point is :
   (a) 100°C (b) –10°C (c) –100°C (d) 0°C
4. The property of matter to increase in size on heating is called :
   (a) thermal work (b) thermal energy (c) thermal expansion (d) thermal contraction
5. The mode of transfer of heat, when molecules pass on heat energy to neighbouring molecules without their actual motion is called :
   (a) convection (b) radiation (c) conduction (d) none of these
6. The only liquid in which conduction is possible is :
   (a) alcohol (b) mercury (c) water (d) iodine
7. A device in which heat loss due to conduction, convection and radiation is minimised is :
   (a) solar cooker (b) thermos flask (c) thermometer (d) electric heater
8. Shining surfaces are :
   (a) good absorbers of heat (b) good radiators of heat
   (c) poor absorbers and poor radiators of heat (d) good absorbers and good radiators of heat
9. Heat which can also get transferred is :
   (a) thermal heat (b) radiant heat (c) mechanical heat (d) none of these
10. The fastest method of heat transfer from a hot body to :
    (a) conduction (b) convection (c) radiation (d) none of these
11. During daytime air blows :
    (a) from the land to the sea (b) from the sea to the land
    (c) from one sea to another (d) none of these

D. FILL IN THE BLANKS

1. The lower fixed point of a thermometer is ....
2. At its .... point a solid starts changing into its liquid state.
3. The transfer of heat from one point to the other with the actual motion of the particles of the medium is called ....
4. The cold air blowing from the sea to land during the day is called ....
5. Solids .... on heating and .... on cooling.
6. Among matter .... expands the most and .... the least.
7. Liquids and gases are generally .... conductors of heat.
8. During night-time, cool breeze blows from .... to ....
9. .... are good conductors
10. Transfer of heat takes place from a body at .... temperature to a body at .... temperature
11. Black surfaces are better .... of heat than polished surfaces.
12. Bridges are mounted on .... to prevent their collapse.
13. Shining bodies are .... absorbers of radiant heat.
14. Convection cannot take place in ....

E. DEFINE THE FOLLOWING TERMS

1. Heat
2. Calorie
3. Thermometer
4. Celsius scale
5. Good conductors
6. Bad conductors
7. Conduction
8. Convection
9. Radiation
10. Sea and land breezes

F. MARK THE STATEMENT AS TRUE OR FALSE

1. When heat is provided to a solid it causes a change in its length.
2. The upper fixed point of a thermometer is 100°C.
3. The bottom part of cooking utensils is polished.
4. In summer, telephone wires sag.
5. The heat coming from the sun travels by convection.
6. More is the heating, more is the expansion of solids.
7. Thermal expansion only has bad effects.
8. We can hold a glass rod for a longer time than a metal rod when both the rods are heated.
9. Iron is a better conductor of heat than copper.
10. Air conducts heat.
11. Solids expand more than liquids and gases.
12. Expansion of different liquids is different.
13. A thick glass tumbler cracks when hot water is poured into it.
14. Mud houses are hot in summer and cold in winter

G. CHOOSE THE ODD ONE OUT GIVING REASON

1. Calorie, kilocalorie, joule, kelvin.
2. Copper, aluminium, steel, plastic.
3. Conduction, convention, radiation, thermometer.

H. MATCH THE FOLLOWING

Column A	Column B
1. Copper vessel	(*a*) convection
2. Sun's heat reaching the earth	(*b*) conduction
3. Plastic handle	(*c*) radiation
4. Ventilator	(*d*) bad conductor

I. GIVE ONE WORD FOR THE FOLLOWING

1. Instrument for measuring the temperature in science laboratories.
2. Transfer of heat with the actual motion of particle.
3. Transfer of heat without the need of a medium.
4. Transfer of heat without the actual motion of particle.
5. The cold air blowing from the land towards the sea during night is called land breeze.
6. The cold air blowing from the sea towards the land during the day is called sea breeze.

Project / Activity

1. Showing the students the various ways of heat transfer.
2. Making a cooling pack with the help of thermocol.
3. Engaging children in activity to measure temperature in Celsius and Fahrenheit.