G93FPT

TEXTBOOK EVALUATION

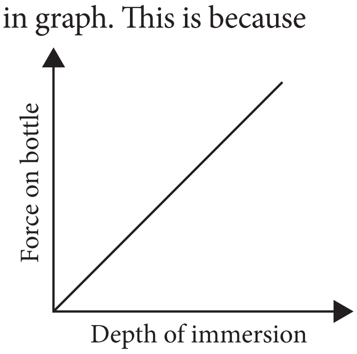
I. Choose the correct answer.

1. The size of an air bubble rising up in water
   (a) decreases
   (b) increases
   (c) remains same
   (d) may increase or decrease

2. Clouds float in atmosphere because of their low
   (a) density (b) pressure
   (c) velocity (d) mass

3. In a pressure cooker, the food is cooked faster because
   (a) increased pressure lowers the boiling point
   (b) increased pressure raises the boiling point
   (c) decreased pressure raises the boiling point
   (d) increased pressure lowers the melting point

4. An empty plastic bottle closed with an airtight stopper is pushed down into a bucket filled with water. As the bottle is pushed down, there is an increasing force on the bottom as shown in graph. This is because



   (a) more volume of liquid is dispaced
   (b) more weight of liquid is displaced
   (c) pressure increases with depth
   (d) all the above

II. Fill in the blanks.

1. In a fluid, buoyant force exists because pressure at the __________ of an object is greater than the pressure at the top.
2. The weight of the body immersed in a liquid appears to be ________ than its actual weight.
3. The instrument used to measure atmospheric pressure is __________.
4. The magnitude of buoyant force acting on an object immersed in a liquid depends on __________ of the liquid.
5. A drinking straw works on the existence of __________.

III. True or False.

1. The weight of fluid displaced determines the buoyant force on an object.
2. The shape of an object helps to determine whether the object will float.
3. The foundations of high-rise buildings are kept wide so that they may exert more pressure on the ground.
4. Archimedes' principle can also be applied to gases.
5. Hydraulic press is used in the extraction of oil from oil seeds.

IV. Match the following.

Density	-	$h\rho g$
1 gwt	-	Milk
Pascal's law	-	$\frac{\text{Mass}}{\text{Volume}}$
Pressure exerted by a fluid	-	Pressure
Lactometer	-	980 dyne

V. Answer in brief.

1. On what factors the pressure exerted by the liquid depends on?
2. Why does a helium balloon float in air?

3. Why it is easy to swim in river water than in sea water?
4. What is meant by atmospheric pressure?
5. State Pascal's law.

VI. Answer in detail.

1. With an appropriate illustration prove that the force acting on a smaller area exerts a greater pressure.
2. Describe the construction and working of mercury barometer.
3. How does an object's density determine whether the object will sink or float in water?
4. Explain the construction and working of a hydrometer with diagram.
5. State the laws of flotation.

VII. Assertion and Reason.

Directions: In each of the following questions, a statement of Assertion (A) is given followed by a corresponding statement of Reason (R) just below it. Of the statements, mark the correct answer as

(a) If both assertion and reason are true and reason is the correct explanation of assertion.

(b) If both assertion and reason are true but reason is not the correct explanation of assertion.

(c) If assertion is true but reason is false.

(d) If assertion is false but reason is true.

1. **Assertion:** To float, body must displace liquid whose weight is equal to the actual weight.

   Reason: The body will experience no net downward force in that case.

2. **Assertion:** Pascal's law is the working principle of a hydraulic lift.

   Reason: Pressure is thrust per unit area.

3. **Assertion:** The force acting on the surface of a liquid at rest, under gravity, in a container is always horizontal.

   Reason: The forces acting on a fluid at rest have to be normal to the surface.

4. **Assertion:** A sleeping mattress is so designed that when you lie on it, a large area of your body comes in its contact.

   Reason: This reduces the pressure on the body and sleeping becomes comfortable.

5. **Assertion:** Wide wooden sleepers are kept below railway lines to reduce pressure on the railway tracks and prevent them from sinking in the ground.

   Reason: Pressure is directly proportional to the area in which it is acting.

VIII. Comprehension type.

1. While passing nearby a pond, some students saw a drowning man screaming for help. They alerted another passerby, who immediately threw an inflated rubber tube in the pond. The man was saved. Respond to the given questions using the information provided above.
   a. Why the passerby did use inflated rubber tube to save the drowning man?
   b. Write the principle involved herein.
   c. Which qualities shown by the students and the passerby do you identify that helped in saving the drowning man.

2. A balloon displaces air and it results in buoyant force. This buoyant force is more than the weight of the balloon and hence the balloon moves up.
   a. As the balloon moves up what happens to the density of it?
   b. Write the condition for floating of balloon.
   c. Buoyant force depends on the density of __________.

3. Two different bodies A and B are completely immersed in water and undergo the same loss in weight.
   a. Will the weight of the body A and body B in air be the same?
   b. If 4 kg of material occupy 20 cm^3 and 9 kg of material be occupy 90 cm^3, which has greater density A or B?
   c. What vertical height of mercury will exert a pressure of 99960 Pa? (Density of mercury = 136000 kg m^{-3}).

IX. Numerical Problems.

1. A block of wood of weight 200 g floats on the surface of water. If the volume of block is 300 cm^3 calculate the upthrust due to water.
2. Density of mercury is 13600 kg m^{-3}. Calculate the relative density.
3. A body of voloume 100 cc is immersed completely in water contained in a jar. The weight of water and the jar before immersion of the body was 700 g. Calculate the weight of water and jar after immersion.
4. The density of water is 1 g cm^{-3}. What is its density in S.I. units?
5. Calculate the apparent weight of wood floating on water if it weighs 100g in air.

X. HOTS

1. How high does the mercury barometer stand on a day when atmospheric pressure is 98.6 kPa?
2. How does a fish manage to rise up and move down in water?
3. If you put one ice cube in a glass of water and another in a glass of alcohol, what would you observe? Explain your observations.
4. You have a bag of cotton and an iron bar, each indicating a mass of 100 kg when measured on a weighing machine. In reality, one is heavier than other. Can you say which one is heavier and why?
5. Why does a boat with a hole in the bottom would eventually sink?

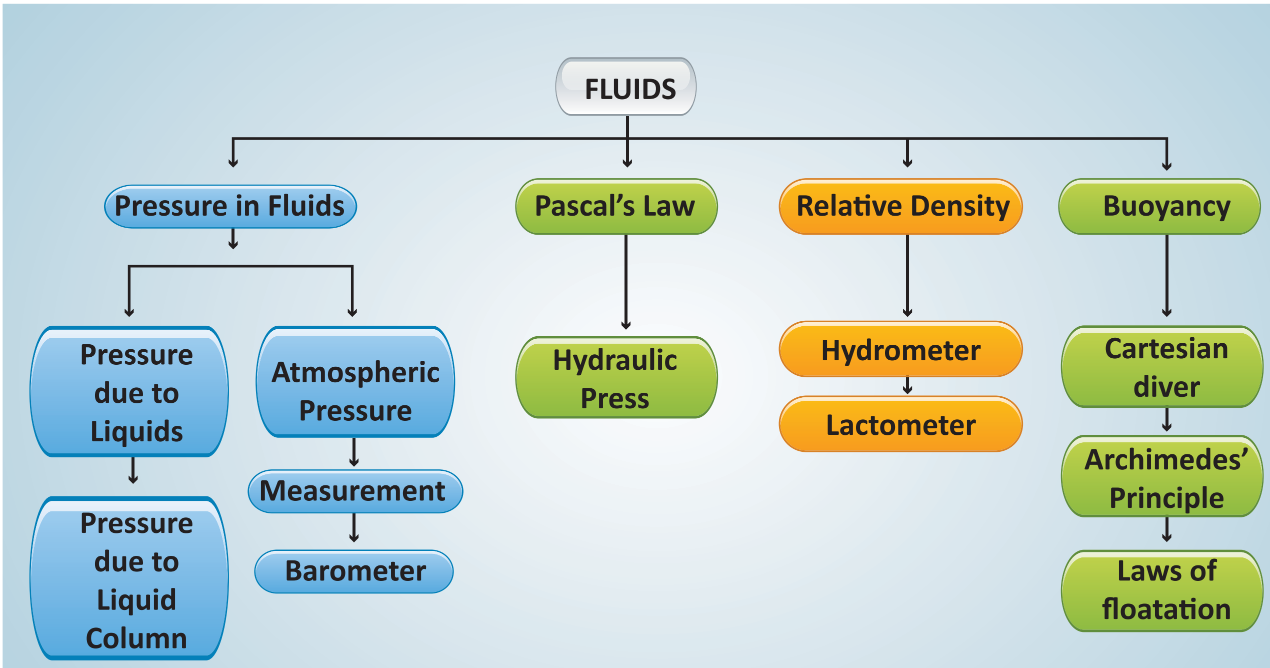
REFERENCE BOOKS

1. Fundamentals of Physics - By David Halliday and Robert Resnick.
2. I.C.S.E Concise Physics - By Selina publisher.
3. Physics - By Tower, Smith Tuston & Cope.

INTERNET RESOURCES

https://www.sciencelearn.org.nz/resources/390-rockets-and-thrust
https://www.teachengineering.org/lessons/view/cub_airplanes_lesson04
http://www.cyberphysics.co.uk/topics/earth/atmosphr/atmospheric_pressure.htm
http://discovermagazine.com/2003/mar/featscienceof
http://northwestfloatcenter.com/how-flotation-can-help-your-heart/

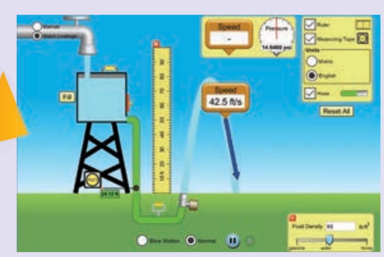
Concept Map



ICT CORNER

Fluid

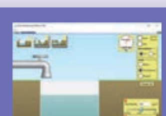
Experiment with Fluid Pressure and Flow using virtual simulator.

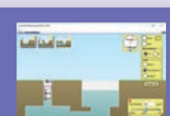


Steps

- Type the given URL to reach "pHET Simulation" page and download the "java" file of "Fluid Pressure and Flow".
- Open the "java" file. Open the water tap and observe the "Pressure" fluctuations by increasing "Fluid density" and "Gravity".
- Select the third picture and drop down a weight scales to transform weight into pressure.
- Switch to "Flow" tab from the top to simulate fluid motion under a given shape and pressure. Click the "red" button to drop dots into the fluid and alter the pipe shape by dragging the yellow holders.


Step1


Step2


Step3


Step4

Fluid Pressure and Flow Simulator

URL: https://phet.colorado.edu/en/simulation/fluid-pressure-and-flow or Scan the QR Code.

*Pictures are indicative only

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UNIT 2

Sound

G9CBRG

Learning Objectives

After completing this lesson, students will be able to

- understand that sound is produced due to vibration of objects.
- know that sound requires a medium to travel.
- understand that sound waves are longitudinal in nature.
- explain the characteristics of sound.
- understand the parameters on which speed of sound depends.
- explain ultrasonic sound and understand the applications of ultrasonic sound.

Introduction

Sound is a form of energy which produces sensation of hearing in our ears. Some sounds are pleasant to hear and some others are not. But, all sounds are produced by vibrations of substances. These vibrations travel as disturbances in a medium and reach our ears as sound. Human ear can hear only a particular range of frequency of sound that too with a certain range of energy. We are not able to hear sound clearly if it is below certain intensity. The quality of sound also differs from one another. What are the reasons for all these? It is because sound has several qualities. In this unit we are going to learn about production and propagation of sound along with its various other characteristics. We will also study about ultrasonic waves and their applications in our daily life.

2.1 Production of sound

In your daily life you hear different sounds from different sources. But have you ever thought how sound is produced? To understand the production of sound, let us do some activities.

Activity 1

Take a tuning fork and strike its prongs on a rubber pad. Bring it near your ear. Do you hear any sound? Now touch the tuning fork with your finger. What do you feel? Do you feel vibrations?

When you strike the tuning fork on the rubber pad, it starts vibrating. That's what you feel with your fingers. These vibrations cause the nearby molecules to vibrate.

Activity 2

Take a steel tumbler and fill it with water. Take a spoon and gently tap the tumbler. What do you observe? Can you hear some sound? Do you see any vibration on the surface of the water?

From the above activities we see that vibrations are produced when some mechanical work is done. Vibration is nothing but to and fro movement of a particle. Thus, mechanical energy vibrates an object and when these vibrations reach our ear we hear the sound. At the end of this chapter, we will study how our ear senses sound.

2.2 Propagation of sound waves

2.2.1 Sound needs a medium for Propagation

In the activities given above we saw that sound needs a material medium like air, water, steel etc., for its propagation. It cannot travel through vacuum. This can be demonstrated by the Bell – Jar experiment.

An electric bell and an airtight glass jar are taken. The electric bell is suspended inside the airtight jar. The jar is connected to a vacuum pump, as shown in Figure 2.1. If the bell is made to ring, we will be able to hear the sound of the bell. Now when the jar is evacuated with the vacuum pump, the air in the jar is pumped out gradually and the sound becomes feebler and feebler. We will not hear any sound, if the air is fully removed (if the jar has vacuum).

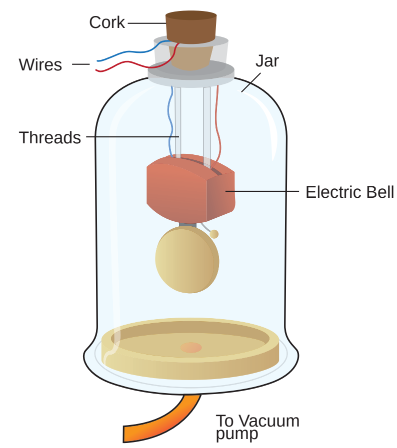

Figure 2.1 Bell-Jar experiment

2.2.2 Sound is a wave

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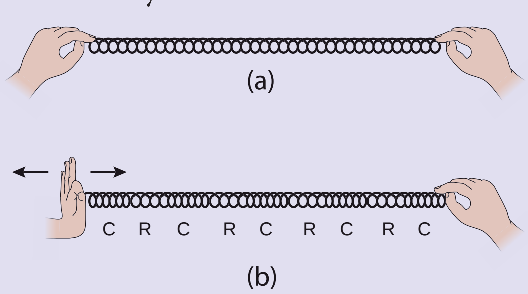
Sound moves from the point of generation to the ear of the listener through a medium. When an object vibrates, it sets the particles of the medium around to vibrate. But, the vibrating particles do not travel all the way from the vibrating object to the ear. A particle of the medium in contact with the vibrating object is displaced from its equilibrium position. It then exerts a force on an adjacent particle. As a result of which the adjacent particle gets displaced from its position of rest. After displacing the adjacent particle the first particle comes back to its original position. This process continues in the medium till the sound reaches our ears. It is to be noted that only the disturbance created by a source of sound travels through the medium and not the particles of the medium. All the particles of the medium restrict themselves with only a small to and fro motion called vibration which enables the disturbance to be carried forward. This disturbance which is carried forward in a medium is called wave.

2.2.3 Longitudinal nature of sound waves

Activity 3

Take a coil or spring and move it forward and backward. What do you observe? You can observe that in some parts of the coil the turns will be closer and in some other parts the turns will be far apart. Sound also travels in a medium in the same manner. We will study about this now.



In the above activity you noticed that in some parts of the coil, the turns are closer together. These are regions of compressions. In between these regions of compressions we have regions where the coil turns are far apart called rarefactions. As the coil oscillates, the compressions and rarefactions move along the coil. The wave that propagates with compressions and rarefactions are called longitudinal waves. In longitudinal waves the particles of the medium move to and fro along the direction of propagation of the wave.

Sound is also a longitudinal wave. Sound can travel only when there are particles which can be compressed and rarefied. Compressions are the regions where particles are crowded together. Rarefactions are the regions of low pressure where particles are

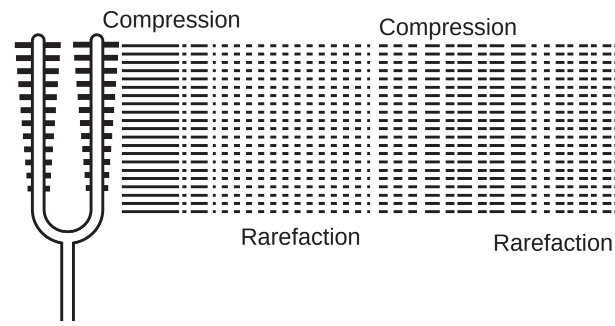


Figure 2.2 Sound is a wave

spread apart. A sound wave is an example of a longitudinal mechanical wave. Figure 2.3 represents the longitudinal nature of sound wave in the medium.

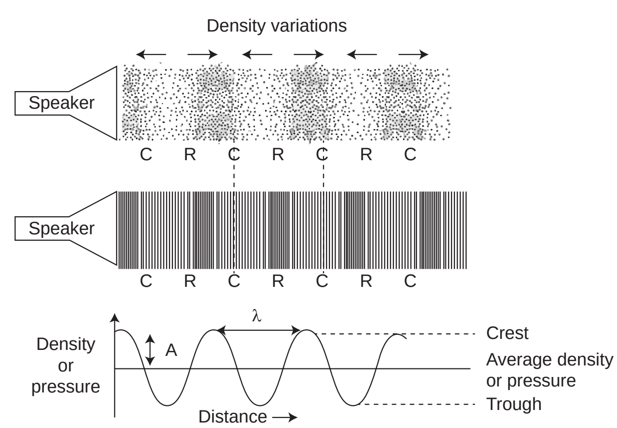


Figure 2.3 Longitudinal nature of sound

2.3 Characteristics of a sound wave

Activity 4

Listen to the audio of any musical instrument like *flute, nathaswaram, tabla, drums, veena* etc., Tabulate the differences between the sounds produced by the various sources.

A sound wave can be described completely by five characteristics namely amplitude, frequency, time period, wavelength and velocity or speed.

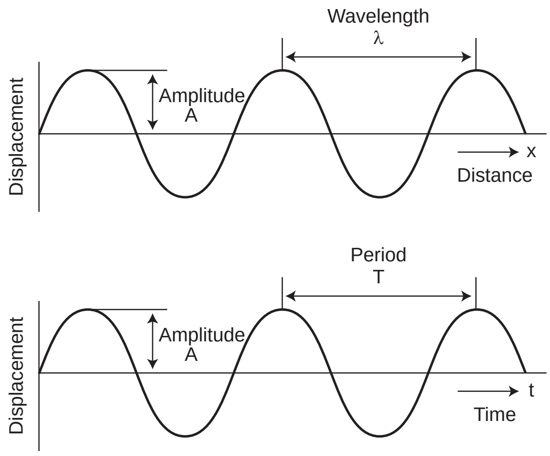


Figure 2.4 Characteristics of sound wave

Amplitude (A)

The maximum displacement of the particles of the medium from their original undisturbed positions, when a wave passes through the medium is called amplitude of the wave. If the vibration of a particle has large amplitude, the sound will be loud and if the vibration has small amplitude, the sound will be soft. Amplitude is denoted as A. Its SI unit is meter (m).

Frequency (n)

The number of vibrations (complete waves or cycles) produced in one second is called frequency of the wave. It is denoted as n. The SI unit of frequency is s^{-1} (or) hertz (Hz). Human ear can hear sound of frequency from 20 Hz to 20,000 Hz. Sound with frequency less than 20 Hz is called infrasonic sound. Sound with frequency greater than 20,000 Hz is called ultrasonic sound. Human beings cannot hear infrasonic and ultrasonic sounds.

Time period (T)

The time required to produce one complete vibration (wave or cycle) is called time period of the wave. It is denoted as T. The SI unit of time period is second (s). Frequency and time period are reciprocal to each other.

DO YOU KNOW?

Heinrich Rudolph Hertz was born on 22 February 1857 in Hamburg, Germany and educated at the University of Berlin. He confirmed J. C. Maxwell's electromagnetic theory by his experiments. He laid the foundation for future development of radio, telephone, telegraph and even television. He also discovered the photoelectric effect which was later explained by Albert Einstein. The SI unit of frequency was named as hertz in his honour.

Wavelength (λ)

The minimum distance in which a sound wave repeats itself is called its wavelength. In a sound wave, the distance between the centers of two consecutive compressions or two consecutive rarefactions is also called wavelength. The wavelength is usually denoted as λ (Greek letter lambda). The SI unit of wavelength is metre (m).

Velocity or speed (v)

The distance travelled by the sound wave in one second is called velocity of the sound. The SI unit of velocity of sound is m s^{-1}.

2.4 Distinguishing different sounds

Sounds can be distinguished from one another in terms of the following three different factors.

1. Loudness
2. Pitch
3. Timbre (or quality)

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1. Loudness and Intensity

Loudness is a quantity by virtue of which a sound can be distinguished from another one, both having the same frequency. Loudness or softness of sound depends on the amplitude of the wave. If we strike a table lightly, we hear a soft sound because we produce a sound wave of less amplitude. If we hit the table hard we hear a louder sound. Loud sound can travel a longer distance as loudness is associated with higher energy. A sound wave spreads out from its source. As it move away from the source its amplitude decreases and thus its loudness decreases. Figure 2.5 shows the wave shapes of a soft and loud sound of the same frequency.

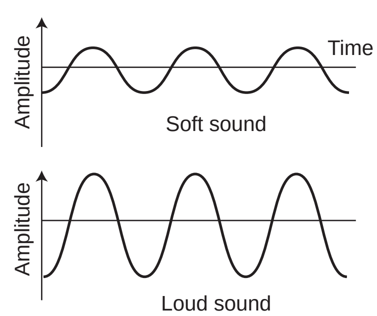

Figure 2.5 Soft and loud sound

The loudness of a sound depends on the intensity of sound wave. Intensity is defined as the amount of energy crossing per unit area per unit time perpendicular to the direction of propagation of the wave.

The intensity of sound heard at a place depends on the following five factors.

i. Amplitude of the source.
ii. Distance of the observer from the source.
iii. Surface area of the source.
iv. Density of the medium.
v. Frequency of the source.

The unit of intensity of sound is decibel (dB). It is named in honour of the Scottish-born scientist Alexander Graham Bell who invented telephone.

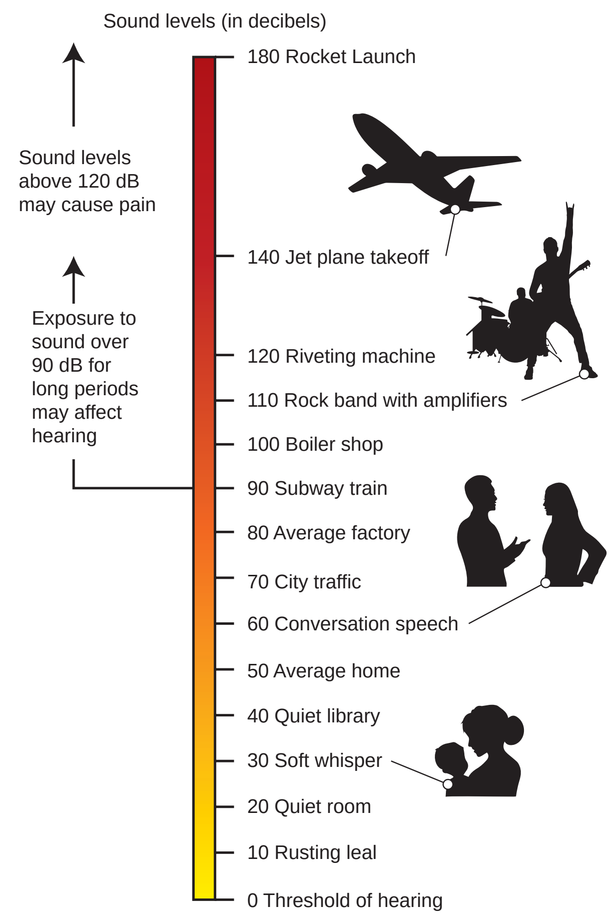

Figure 2.6 Intensity level of sound

2. Pitch

Pitch is the characteristics of sound by which we can distinguish whether a sound is shrill or base. High pitch sound is shrill and low pitch sound is flat. Two music sounds produced by the same instrument with same amplitude, will differ when their vibrations are of different frequencies. Figure 2.7 consists of two waves representing low pitch and high pitch sounds.

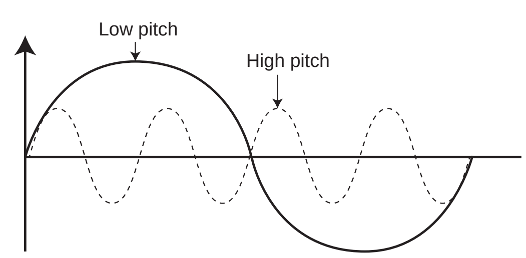

Figure 2.7 Longitudinal nature of sound

3. Timbre or Quality

Timbre is the characteristic which distinguishes two sounds of same loudness and pitch emitted by two different instruments. A sound of single frequency is called a tone and a collection of tones is called a note. Timbre is then a general term for the distinguishable characteristics of a tone.

2.5 Speed of sound

The speed of sound is defined as the distance travelled by a sound wave per unit time as it propagates through an elastic medium.

$$\text{Speed (v)} = \frac{\text{Distance}}{\text{Time}}$$

If the distance traveled by one wave is taken as one wavelength (λ), and the time taken for this propagation is one time period (T), then

$$\text{Speed (v)} = \frac{\text{one wavelength } (\lambda)}{\text{one time period (T)}} \quad \text{(or)} \quad v = \frac{\lambda}{T}$$

As, $T = \frac{1}{n}$ the speed (v) of sound is also written as, $v = n\lambda$

The speed of sound remains almost the same for all frequencies in a given medium under the same physical conditions.

Example 1

A sound wave has a frequency of 2 kHz and wavelength of 15 cm. How much time will it take to travel 1.5 km?

Solution:

Given, Frequency, n = 2 kHz = 2000Hz

Wavelength, λ = 15 cm = 0.15 m

Speed, $v = n\lambda$

$= 0.15 \times 2000 = 300 \text{ m s}^{-1}$

The time taken (t) by the wave to travel a distance (d) of 1.5 km is calculated as, d = 1.5 km = 1500 m

$$\text{Time (t)} = \frac{\text{Distance (d)}}{\text{Velocity (v)}}$$

$$t = \frac{1500}{300} = 5 \text{ s}$$

The sound will take 5 s to travel a distance of 1.5 km.

Example 2

What is the wavelength of a sound wave in air at 20° C with a frequency of 22 MHz?

Solution:

The speed of sound at 20° C is $v = 344 \text{ m s}^{-1}$.

The frequency of sound n = 22 MHz

$= 22 \times 10^6$ Hz

To find the wavelength λ, we use the wave equation with speed of sound.

$\lambda = v/n$

$\lambda = 344/22 \times 10^6$

$\lambda = 15.64 \times 10^{-6}$ m

Ans. $\lambda = 15.64\ \mu\text{m}$.

2.5.1 Speed of sound in different media

Sound propagates through a medium at a finite speed. The sound of thunder is heard a little later than the flash of light is seen. So we can make out that sound travels with a speed which is much less than the speed of light. The speed of sound depends on the properties of the medium through which it travels.

The speed of sound in a gaseous medium depends on,

- pressure of the medium
- temperature of the medium
- density of the medium
- nature of gas

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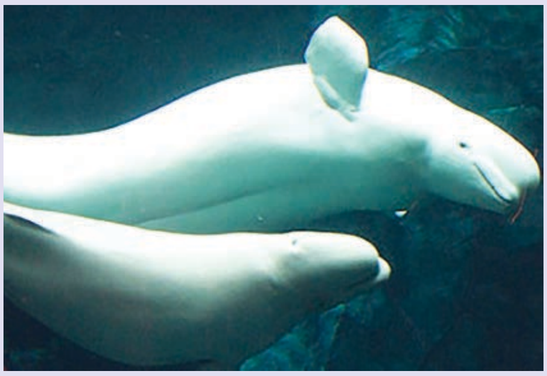
More to Know

Sound travels about 5 times faster in water than in air. Since the speed of sound in sea water is very large (being about 1530 m s^{-1} which is more than 5500 km h^{-1}), two whales in the sea which are even hundreds of kilometres away from each other can talk to each other very easily through the sea water.



The speed of sound in solid medium depends on,

- elastic property of the medium
- temperature of the medium
- density of the medium

The speed of sound is less in gaseous medium compared to solid medium. In any medium the speed of sound increases if we increase the temperature of the medium. For example the speed of sound in air is 330 m s^{-1} at 0°C and 340 m s^{-1} at 25°C. The speed of sound at a particular temperature in various media is listed in Table 2.1.

Table 2.1 Speed of sound in different media at 25° C.

State	Medium	Speed in m s^{-1}
Solids	Aluminum	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass	3980
Liquids	Water (Sea)	1531
	Water (distilled)	1498
	Ethanol	1207
	Methanol	1103
Gases	Hydrogen	1284
	Helium	965
	Air	340
	Oxygen	316
	Sulphur dioxide	213

More to Know

Sonic boom: When the speed of any object exceeds the speed of sound in air (330 m s^{-1}) it is said to be travelling at supersonic speed. Bullets, jet, aircrafts etc., can travel at supersonic speeds. When an object travels at a speed higher than that of sound in air, it produces shock waves. These shock waves carry a large amount of energy. The air pressure variations associated with this type of shock waves produce a very sharp and loud sound called the 'sonic boom'. The shock waves produced by an aircraft have energy to shatter glass and even damage buildings.

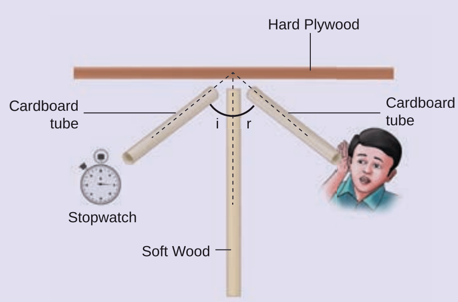
2.6 Reflection of sound

Sound bounces off a surface of solid or a liquid medium like a rubber ball that bounces off from a wall. An obstacle of large size which may be polished or rough is needed for the reflection of sound waves. The laws of reflection are:

- The angle in which the sound is incident is equal to the angle in which sound is reflected.
- Direction of incident sound, direction of the reflected sound and the normal are in the same plane.

Activity 5

Take two identical pipes as shown in below. You can make the pipes using chart paper. The length of the pipes should be sufficiently long as shown in figure. Arrange them on a table near wall. Keep a clock near the open end of one of the pipes and try to hear the sound of the clock through the other pipe. Adjust the position of the pipes so that you can best hear the sound of the clock. Now, measure the angle of incidence and reflection and see the relationship between the angles. Lift the pipes on the right vertically to a small height, and observe what happens.



2.6.1 Uses of multiple reflections of sound

Musical instruments

Megaphones, loud speakers, horns, musical instruments such as nathaswaram, shehnai and trumpets are all designed to send sound in a particular direction without spreading it in all directions. In these instruments, a tube followed by a conical opening reflects sound successively to guide most of the sound waves from the source in the forward direction towards the audience.

Figure 2.8 Megaphone or horn

Stethoscope

Stethoscope is a medical instrument used for listening to sounds produced in the body. In stethoscopes these sounds reach doctor's ears by multiple reflections that happen in the connecting tube.

Figure 2.9 Stethoscope

DO YOU KNOW?

Noise pollution: Noise is an unwanted sound. Sounds with loudness of 120 dB (decibel) and higher can be painful to the ear. Even brief exposures to higher sound levels can rupture eardrum and can cause permanent hearing loss. However, long exposure to relatively lower sound level can also cause hearing problems. Such exposures may lead to psychological damages too. For some jobs, ear protectors must be worn in work places. You may have experienced a temporary hearing loss after being exposed to a loud band for long time or a loud bang for a short time. Ear protectors are commercially available at medical stores and hardware stores.

2.7 Echo

When we shout or clap near a suitable reflecting surface such as a tall building or a mountain, we will hear the same sound again a little later. This sound which we hear is called an echo. The sensation of sound persists in our brain for about 0.1s.

More to Know

Use of ear phones for long hours can cause infection in the inner parts of the ears, apart from damage to the ear drum. Your safety is in danger if you wear ear phones while crossing signals, walking on the roads and travelling. Using earphones while sleeping is all the more dangerous as current is passing in the wires. It may even lead to mental irritation. Hence, you are advised to deter from using earphones as far as possible.

Hence, to hear a distinct echo the time interval between the original sound and the reflected sound must be at least 0.1s. Let us consider the speed of sound to be 340 m s^{-1} at 25° C. The sound must go to the obstacle and return to the ear of the listener on reflection after 0.1 s. Thus, the total distance covered by the sound from the point of generation to the reflecting surface and back should be at least 340 m s^{-1} × 0.1 s = 34 m.

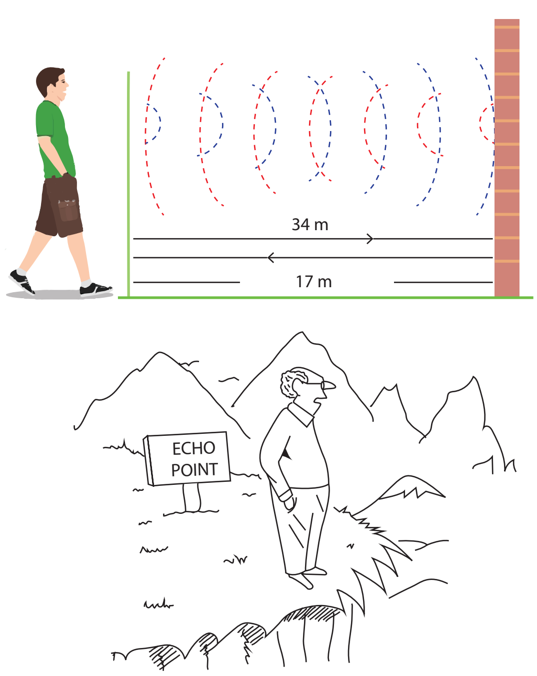


Figure 2.10 Echo

Thus, for hearing distinct echoes, the minimum distance of the obstacle from the source of sound must be half of this distance i.e. 17 m. This distance will change with the temperature of air. Echoes may be heard more than once due to successive or multiple reflections. The roaring of thunder is due to the successive reflections of the sound from a number of reflecting surfaces, such as the clouds at different heights and the land.

Example 3

A person claps his hands near a cliff and hears the echo after 5 s. What is the distance of the cliff from the person if the speed of the sound is taken as 330 m s^{-1}?

Solution:

Speed of sound, v = 330 m s^{-1}

Time taken to hear the echo, t = 5 s

Distance travelled by the sound, d = v × t

= 330 × 5

= 1650 m (or) 1.65 km

In 5s sound travels twice the distance between the cliff and person. Hence the distance between the cliff and the person $= \frac{1650}{2} = 825$ m.

Example 4

A man fires a gun and hears its echo after 5 s. The man then moves 310 m towards the hill and fires his gun again. If he hears the echo after 3 s, calculate the speed of sound.

Solution:

Distance (d) = velocity (v) × time (t)

Distance travelled by sound when gun fires first time, $2d = v \times 5$ (1)

Distance travelled by sound when gun fires second time, $2d - 620 = v \times 3$ (2)

Rewriting equation (2) as,
$2d = (v \times 3) + 620$ (3)

Equating (1) and (3), $5v = 3v + 620$

$2v = 620$

Velocity of sound, $v = 310\ \text{m s}^{-1}$

2.8 Reverberation

A sound created in a big hall will persist by repeated reflection from the walls until it is reduced to a value where it is no longer audible. The repeated reflection that results in this persistence of sound is called reverberation. In an auditorium or big hall excessive reverberation is highly undesirable. To reduce reverberation, the roof and walls of the auditorium are generally covered with sound absorbing materials like compressed fiberboard, flannel cloths, rough plaster and draperies. The seat materials are also selected on the basis of their sound absorbing properties.

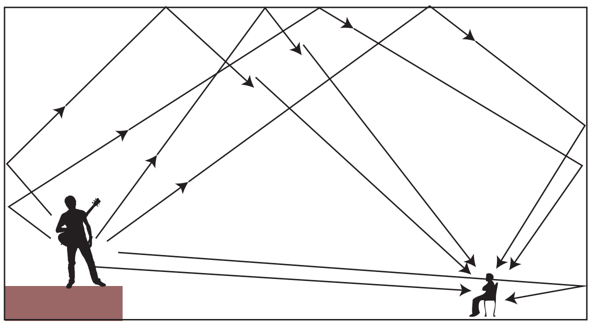


Figure 2.11 Reverberation of sound in a auditorium

There is a separate branch in physics called acoustics which takes these aspects of sound in to account while designing auditoria, opera halls, theaters etc. (You will study about acoustics in class X).

2.9 Ultrasonic sound or Ultrasound

Ultrasonic sound is the term used for sound waves with frequencies greater than 20,000 Hz. These waves cannot be heard by the human ear, but the audible frequency range for other animals includes ultrasound frequencies. For example dogs can hear ultrasonic sound. Ultrasonic whistles are used on cars to alert deer to oncoming traffic so that they will not leap across the road in front of cars.

An important use of ultrasound is in examining inner parts of the body. Thus ultrasound is an alternative to X-rays. The ultrasonic waves allow different tissues such as organs and bones to be 'seen' or distinguished by bouncing of ultrasonic waves by the objects examined. The waves are detected, analysed and stored in a computer. An echogram is an image obtained by the use of reflected ultrasonic waves. It is used as a medical diagnostic tool. Ultrasonic sound is having application in marine surveying also.

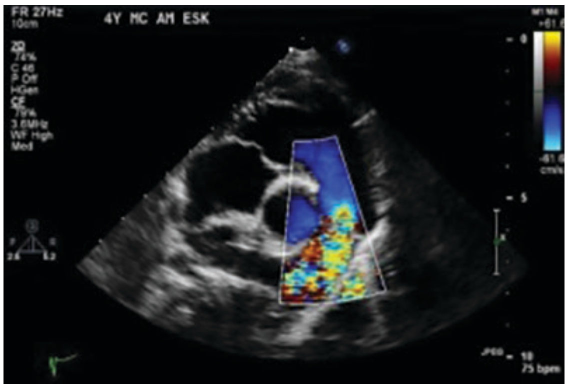
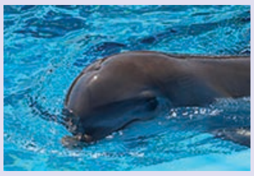


Figure 2.12 Echogram using ultra sound

More to Know

Animals, such as bats, dolphins, rats, whales and oil birds, use ultrasound to navigate or communicate. Bats, dolphins and some toothed whales use echolation, an ultrasound technique that uses echoes to identify and locate objects. Echolation allows bats to navigate through dark caves and find insects for food. Dolphins and whales emit a rapid series of underwater clicks in ultrasonic frequencies to locate their prey and navigate through water. Many nocturnal insects including moths, grasshoppers, praying mantis, beetles and lacewings, have sharp ultrasonic hearing, which helps them escape predators. While oil birds use ultrasound to fly safely and hunt at night, they use lower echolation frequencies compared to bats and other nocturnal insects.



2.9.1 Applications of ultrasonic waves

- Ultra sound can be used in cleaning technology. Minute foreign particles can be removed from objects placed in a liquid bath through which ultrasound is passed.
- Ultrasounds can also be used to detect cracks and flaws in metal blocks.
- Ultrasonic waves are made to reflect from various parts of the heart and form the image of the heart. This technique is called 'echo cardiography'.
- Ultrasound may be employed to break small 'stones' formed in the kidney into fine grains. These grains later get flushed out with urine.

2.10 SONAR

SONAR stands for Sound Navigation And Ranging. Sonar is a device that uses ultrasonic waves to measure the distance, direction and speed of underwater objects. Sonar consists of a transmitter and a detector and is installed at the bottom of boats and ships.

The transmitter produces and transmits ultrasonic waves. These waves travel through water and after striking the object on the seabed, get reflected back and are sensed by the detector. The detector converts the ultrasonic waves into electrical signals which are appropriately interpreted. The distance of the object that reflected the sound wave can be calculated by knowing the speed of sound in water and the time interval between transmission and reception of the ultrasound.

Let the time interval between transmission and reception of ultrasound signal be 't' and

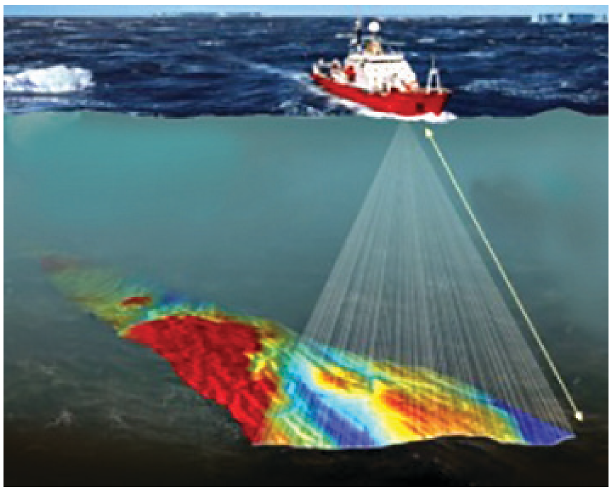


Figure 2.13 Sonar

the speed of sound through sea water be $2d = v \times t$. This method is called echo-ranging. Sonar technique is used to determine the depth of the sea and to locate underwater hills, valleys, submarine, icebergs etc.

Example 5

A ship sends out ultrasound that returns from the seabed and is detected after 3.42 s. If the speed of ultrasound through sea water is 1531m s^{-1}, what is the distance of the seabed from the ship?

Solution

Time between transmission and detection, t = 3.42 s.

Speed of ultrasound in sea water, $v = 1531 \text{m s}^{-1}$

Distance travelled by the ultrasound = 2 × depth of the sea

We know, distance = speed × time

2d = speed of ultrasound × time

$$2d = 1531 \times 3.42$$

$$\therefore d = \frac{5236}{2} m$$

$$d = 2618 \text{ m}$$

Thus, the distance of the seabed from the ship is 2618 m or 2.618 km.

2.11 Electrocardiogram (ECG)

The electrocardiogram (ECG) is one of the simplest and oldest cardiac investigations available. It can provide a wealth of useful information and remains an essential part of the assessment of cardiac patients. In ECG the sound variation produced by heart is converted into electric signals. Thus, an ECG is simply a representation of the electrical activity of the heart muscle as it changes with time. Usually it is printed on paper for easy analysis. The sum of this electrical activity, when amplified and recorded for just a few seconds is known as an ECG (Fig. 2.14).

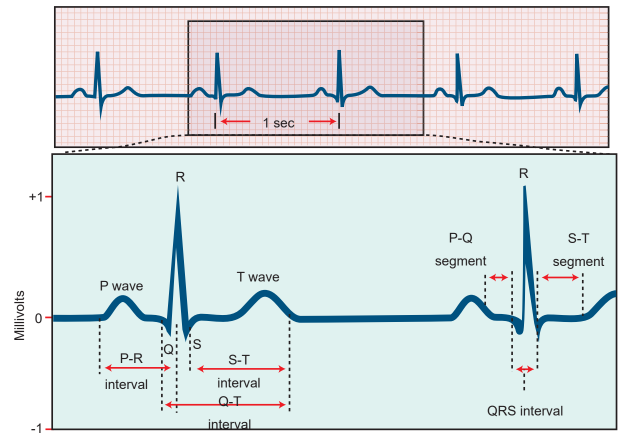


Figure 2.14 ECG diagram

2.12 Structure of human ear

How do we hear? We are able to hear with the help of an extremely sensitive device called the ear. It allows us to convert pressure variations in air with audible frequencies into electric signals that travel to the brain via the auditory nerve. The auditory aspect of human ear is discussed below.

The outer ear is called 'pinna'. It collects the sound from the surroundings. The collected sound passes through the auditory canal. At the end of the ear is eardrum or tympanic membrane. When a compression of the medium reaches the eardrum the pressure on the outside of the membrane increases and forces the eardrum inward. Similarly the eardrum moves outward when a rarefaction reaches it. In this way the eardrum vibrates. The vibrations are amplified several times by three bones (the hammer, anvil and stirrup) in the middle ear. The middle ear transmits the amplified pressure variations received from the sound wave to the inner ear. In the inner ear, the pressure variations are turned into electrical signals by the cochlea. These electrical signals are sent to the brain via the auditory nerve and the brain interrupts them as sound.

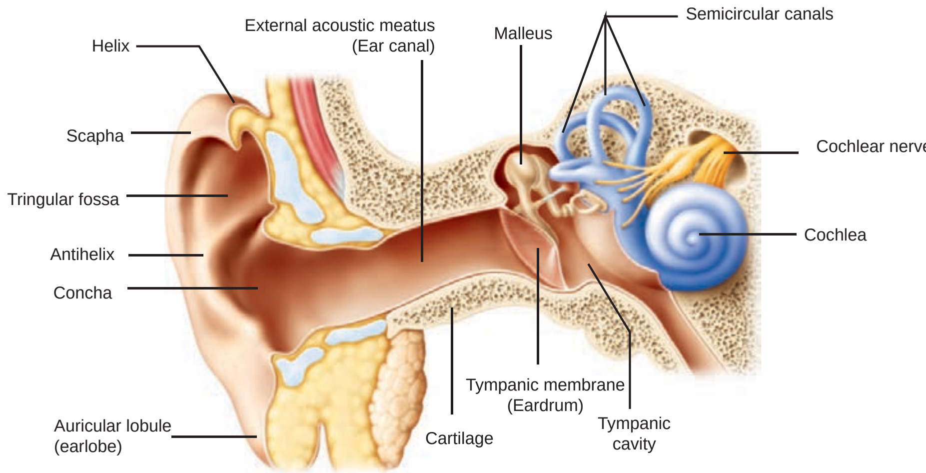


Figure 2.14 Human ear

More to Know

Hearing Aid

People with hearing loss may need a hearing aid. A hearing aid is an electronic, battery operated device. The hearing aid receives sound through a microphone. The microphone converts the sound waves into electrical signals. These electrical signals are amplified by an amplifier. The amplified electrical signals are given to a speaker of the hearing aid. The speaker converts the amplified electrical signals to sound and sends to the ear for clear hearing.

Points to Remember

- Sound is produced due to vibration.
- Sound travels as a longitudinal wave through a material medium.
- Sound travels as successive compressions and rarefactions in the medium.
- In sound propagation, it is the energy of the sound that travels and not the particles of the medium.
- Sound cannot travel through vacuum.
- The distance between two consecutive compressions or two consecutive rarefactions is called the wavelength.
- The time taken by the wave to complete one oscillation.
- The number of oscillations per unit time is called the frequency. $n = 1 / T$
- The speed v, frequency n, and wavelength λ, of sound are related by the equation. $v = n\,\lambda$
- The speed of sound depends primarily on the nature and the temperature of the transmitting medium.
- The law of reflection of sound: (i) The angle of incidence ray, the angle of reflection and normal drawn at the point of incidence all lie in the same plane (ii) The angle of incidence i and the angle of reflection r are always equal.
- For hearing distinct echo sound, the time interval between the original sound and the reflected sound must be at least 0.1 s.
- The persistence of hearing sound in an auditorium is the result of repeated reflections of sound and is called reverberation.
- The amount of sound energy passing each second through unit area is called the intensity of sound.
- The audible range of hearing for average human being is in the frequency range of 20 Hz to 20000 Hz

- Sound waves with frequencies below audible range are termed as 'Infrasonics' and those above audible range are termed as 'Ultrasonics'.
- The SONAR technique is used to determine the depth of the sea and to locate under water hills, valleys, submarines, icebergs, etc.

A-Z GLOSSARY

Amplitude	The maximum displacement of a particle.
Compressions	The region of increased pressure.
ECG	Electrocardiogram.
Echo	The repetition of sound caused by the reflection of sound.
Frequency	Number of waves produced in one second.
Longitudinal wave	The wave that propagates with compressions and rarefactions are called longitudinal waves.
Loudness	Loudness or softness of sound depends on the amplitude of the wave.
Pitch	Characteristics of sound based on frequency.
Rarefactions	The region of decreased pressure.
Reverberation	The repeated reflection that results in persistence of sound is called reverberation.
SONAR	Sound Navigation And Ranging.
Speed of sound	Distance travelled by a sound wave per unit time.
Timbre (or quality)	Characteristic which distinguishes the two sounds of same loudness and pitch emitted by two different instruments.
Time period	Time taken to produce one wave.
Ultrasonic sound	Sound waves with frequencies greater than 20,000 Hz.
Velocity (or) Speed	Distance travelled by the wave in one second.
Wave	The propagating disturbance that travels in a medium is called a wave.
Wavelength	The minimum distance in which a sound wave repeats itself.

TEXTBOOK EVALUATION

G9L7T4

I. Choose the correct answer:

1. Which of the following vibrates when a musical note is produced by the cymbals in a orchestra?
   a) stretched strings
   b) stretched membranes
   c) air columns
   d) metal plates

2. Sound travels in air:
   a) if there is no moisture in the atmosphere.
   b) if particles of medium travel from one place to another.
   c) if both particles as well as disturbance move from one place to another.
   d) if disturbance moves.

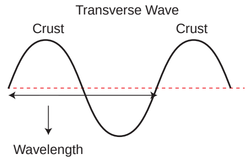
3. A musical instrument is producing continuous note. This note cannot be heard by a person having a normal hearing range. This note must then be passing through
   a) wax b) vacuum
   c) water d) empty vessel

4. If the speed of a wave is 340 ms^{-1} and its frequency is 1700 Hz, then wavelength λ for this wave in cm will be
   a) 34 b) 20 c) 15 d) 0.2

5. Which of the following statement best describes frequency?
   a) the number of complete vibrations per second.
   b) the distance travelled by a wave per second.
   c) the distance between one crest of wave and the next one.
   d) the maximum disturbance caused by a wave.

6. The maximum speed of vibrations which produces audible sound will be in
   a) seawater b) ground glass
   b) dry air d) Human blood

7. In the sound wave produced by a vibrating turning fork as shown in the diagram, half the wave length is represented by:



   a) BD b) AB c) AE d) DE

8. The sound waves travel faster
   a) in liquids b) in gases
   c) in solids d) in vacuum

9. When the pitch of note by a harmonium is lowered, then the wave length of the note
   a) first decreases and then increases
   b) decreases
   c) remains the same
   d) increases

10. The speeds of sound in four different media are given below. Which of the following is the most likely speed in ms^{-1} with which the two under water whales in a sea can talk to each other when separated by a large distance?
    a) 5170 b) 1280
    c) 340 d) 1530

11. Which of the following can produce longitudinal waves as well as transverse waves under different conditions?
    a) TV transmitter b) tuning fork
    c) water d) slinky

12. The velocities of sound waves in four media P, O, Q, R and S are 18,00 km/h, 900 km/h, 0 km/h, and 1200 km/h respectively. Which could be a liquid medium?
    a) R b) Q c) P d) S

II. Fill in the blanks.

1. Vibration of object produces __________ .
2. Sound is a ____________ wave and needs a material medium to travel.
3. Number of vibrations produced in one second is ____________ .
4. The velocity of sound in solid is ____________ than the velocity of sound in air.
5. Loudness is proportional to the square of the ____________ .
6. A sound wave has a frequency of 4 k hz and wavelength 2 m. Then the velocity of sound is ____________ .
7. ____________ is a medical instrument used for listening to sounds produced in the body.
8. The repeated reflection that results in persistence of sound is called ____________ .
9. Ultrasounds can also be used to detect cracks and flows in __________ .
10. In the inner ear, the pressure variations are turned into electrical signals by the _______ .

III. Match the following.

Tuning fork	The point where density of air is maximum
Sound	Maximum displacement from the equilibrium position
Compressions	The sound whose frequency is greater than 20,000 Hz
Amplitude	Longitudinal wave
Ultasonics	Production of sound

IV. Matrix matching.

Loudness	Number of vibrations produced in unit time	decibel
Time period	The amount of sound produced / received	Metre
Amplitude	Distance travelled by sound in unit time	Hertz
Velocity of sound	The time required to produce one complete wave	Metre per second
Frequency	The maximum displacement from the mean position	second

V. Answer in brief.

1. Name the device which is used to produce sound in laboratory experiments.
2. Through which medium sound travels faster, iron or water? Give reason.
3. What should an object do to produce sound?
4. Can sound travel through vacuum?
5. Name the physical quantity whose SI unit is 'hertz'. Define.
6. What is meant by supersonic speed?
7. How does the sound produced by a vibrating object in a medium reach your ears?
8. You and your friend are on the moon. Will you be able to hear any sound produced by your friend?

VI. Answer in detail.

1. Describe with diagram, how compressions and rarefactions are produced.
2. Verify experimentally the laws reflection of sound.
3. List the applications of sound.
4. Explain how does SONAR work?
5. Explain the working of human ear with diagram.

VII. Numerical problems.

1. The frequency of a source of sound is 600 Hz. How many times does it vibrate in a minute?
2. A stone is dropped from the top of a tower 750 m high into a pond of water at the base of the tower. When is the splash heard at the top? (Given g = 10 m s^{-2} and speed of sound = 340 m s^{-1})

REFERENCE BOOKS

1. An Introduction to Physical Science- James T-Shipman, Jerry D. Wilson and Aaron W. Todd.—Houghton Miffin Company, Boston, Newyark.
2. Applied Physics – Rajasekaran S and others – Vikas Publishing House Pvt Ltd.
3. Fundamentals of Physics – Halliday, Resnick and Walker- Sixth Edition – Wiley India Pvt Ltd. NewDelhi.

INTERNET RESOURCES

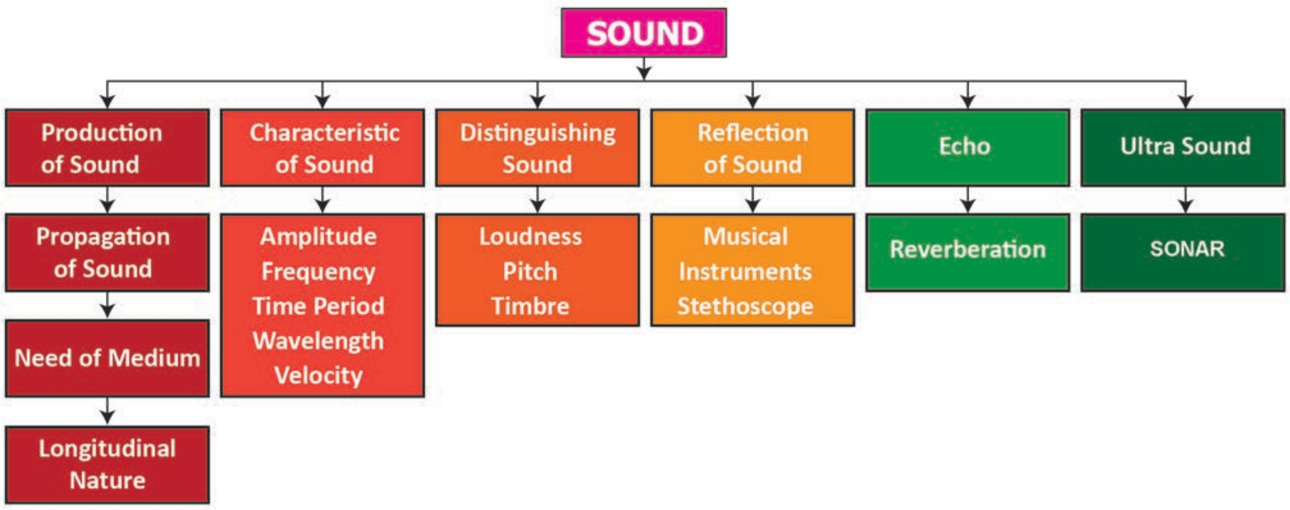
www.britannica.com/science/ultrasonics

www.reference.com/pets-animals/animals-use-ultrasound

https://www.searchencrypt.com

https://www.soundwaves.com/

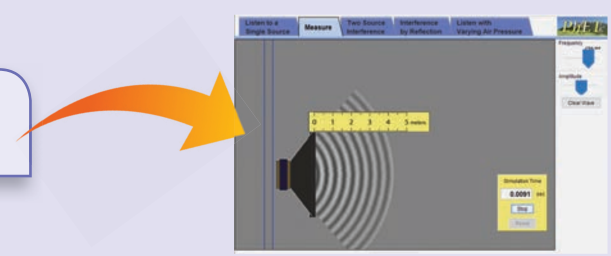
Concept Map



ICT CORNER

Sound

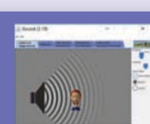
Experiment with *sound waves* using virtual simulator.



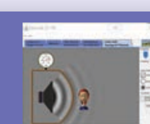
Steps

- Type the given URL to reach "pHET Simulation" page and download the "java" file of Sound.
- Open the "java" file and plug in your headphone. Click "Audio enabled" box from right side to hear the sound waves.
- Switch the tabs from the top to simulate various properties of sound waves. Watch the longitudinal sound waves from different interfaces by altering "Frequency" and "Amplitude".
- Alter "Air Density" and observe its effect on the sound waves. Use "Reset" to repeat the experiment.


Step1


Step2


Step3


Step4

Sound Simulator

URL: https://phet.colorado.edu/en/simulation/legacy/sound or Scan the QR Code.

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*Pictures are indicative only

UNIT 3

Universe

G9V3UR

Learning Objectives

After completing this lesson, students will be able to

- understand the evolution of the universe.
- explain the vastness of the universe.
- interpret Kepler's laws of motion and solve related problems.
- calculate the orbital velocity and the time-period of satellites.
- know more about International Space Station.

Introduction

If you look at the sky, you can see the Sun during daytime; moon and numerous stars during night time. In the earlier days, before the invention of astronomical instruments, people were able to see the Sun, moon and stars only. Based on their observation, they thought that Earth is the centre of all the objects in the space. This was known as the geocentric model, held by Greek astronomer Ptolemy (2nd Century), Indian astronomer Aryabhatta (5th Century) and many astronomers around the world. Later Polish astronomer Nicolaus Copernicus observed the space more keenly and proposed the heliocentric model (helios = Sun), with Sun at the centre of the solar system. The invention of the telescope in the Netherlands, in 1608, created a revolution in astronomy. The improvement of telescopes led astronomers to realize that our Sun is one of hundreds of billions of stars in a galaxy, what we call the Milky Way. We have millions of galaxies in space. The collection of all the things that exist in space is known as the universe. In this lesson we will study how the universe came into existence and all the things in it, how satellites are put into orbit and also about international space station.

3.1 Building Block of the Universe

The basic constituent of the universe is luminous matter i.e., galaxies which are really the collection of billions of stars. The universe contains everything that exists including the Earth, planets, stars, space, and galaxies. This includes all matter, energy and even time. No one knows how big the universe is. It could be infinitely large. Scientists, however, measure the size of the universe by what they can see. This is called the 'observable universe'. The observable universe is around 93 billion light years (1 light year = the distance that light travels in one year, which is 9.4607×10^{12} km) across.

One of the interesting things about the universe is that it is currently expanding. It is growing larger and larger all the time. Not only is it growing larger, but the edge of the universe is expanding at a faster and faster rate. However, most of the universe what we think of is empty space. All the atoms together only make up around four percent of the universe. The majority of the universe consists of something scientists call dark matter and dark energy.

Activity 1

Form a team of three to four students. Prepare a poster about the astronomers.

3.1.1 Age of the universe

Scientists think that the universe began with the start of a massive explosion called the Big Bang. According to Big Bang theory, all the matter in the universe was concentrated in a single point of hot dense matter. About 13.7 billion years ago, an explosion occurred and ejected all the matter in all directions in the form of galaxies. Nearly all of the matter in the universe that we understand is made of hydrogen and helium, the simplest elements, created in the Big Bang. The rest, including the oxygen that we breathe, the carbon, calcium, and iron in our bodies, and the silicon in our computer chips are formed in the cores of stars.

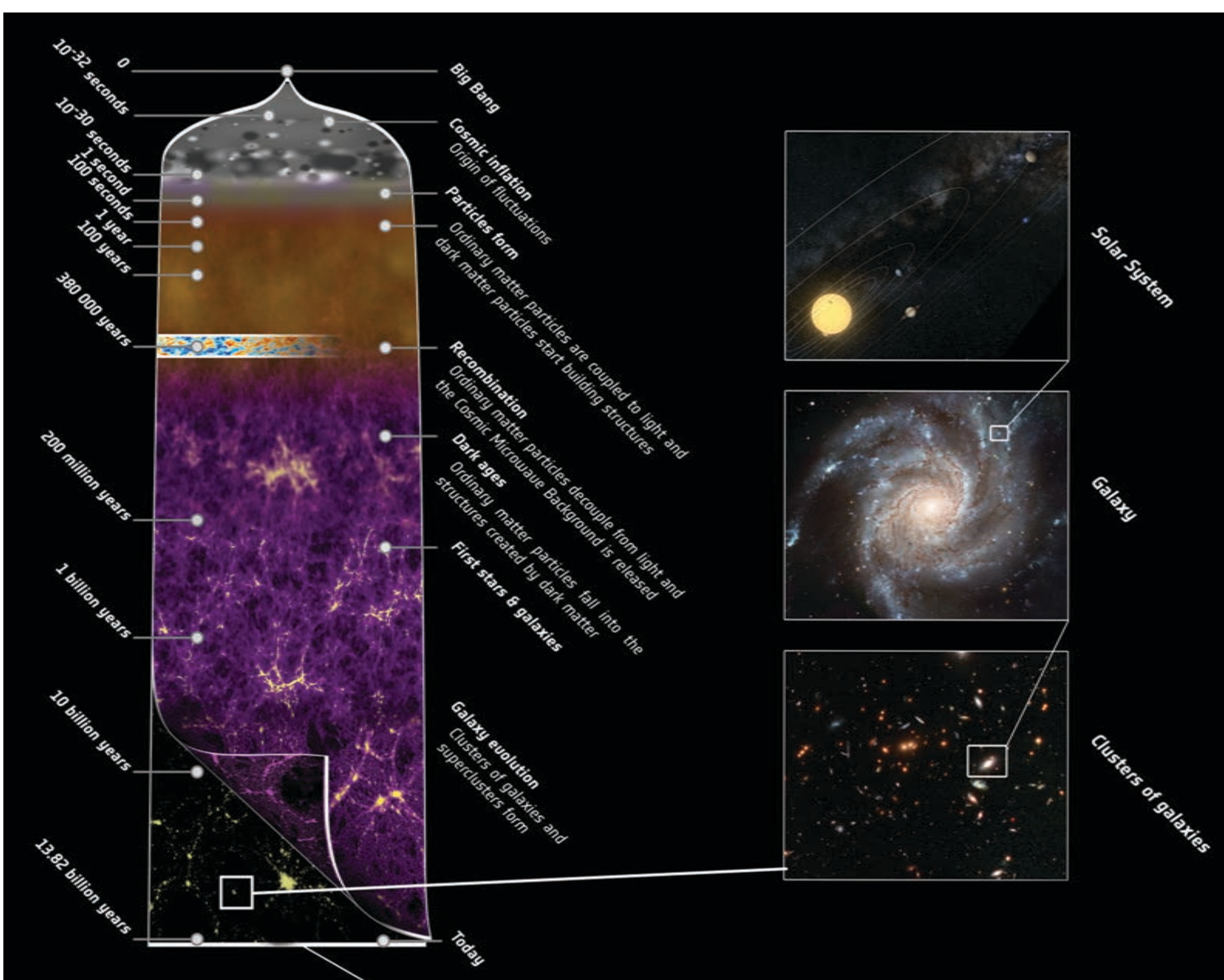


Figure 3.1 Formation of the universe

The gravity that holds these stars together generally keeps these elements deep inside their interiors. When these stars explode, these fundamental building blocks of planetary systems are liberated throughout the universe.

More to Know

DARK MATTER AND DARK ENERGY

Scientists are not sure exactly what dark matter is. Dark matter gets its name because it cannot be seen with any type of instrument that we have today. Around 27% of the universe is made up of dark matter. Dark energy is something that fills all space. The theory of dark energy helps us to explain why the universe is expanding. Around 68% of the universe is dark energy.

3.1.2 Galaxies

According to astronomers galaxies were formed shortly after the Big Bang that happened 10 billion to 13.7 billion years ago. Immediately after the Big Bang, clouds of gases began to compress under gravity to form the building blocks of galaxies. A galaxy is a massive collection of gas, dust, and billions of stars and their solar systems. Scientists believe that there are one hundred billion (10^{11}) galaxies in the observable universe. The size of the galaxies ranges having a few hundred million (10^{8}) stars to one hundred trillion (10^{14}) stars. Galaxies are also in different shapes. Depending on their appearance galaxies are classified as spiral, elliptical, or irregular. Galaxies occur alone or in pairs, but they are more often parts of groups, clusters, and super clusters. Galaxies in such groups often interact and even merge together.

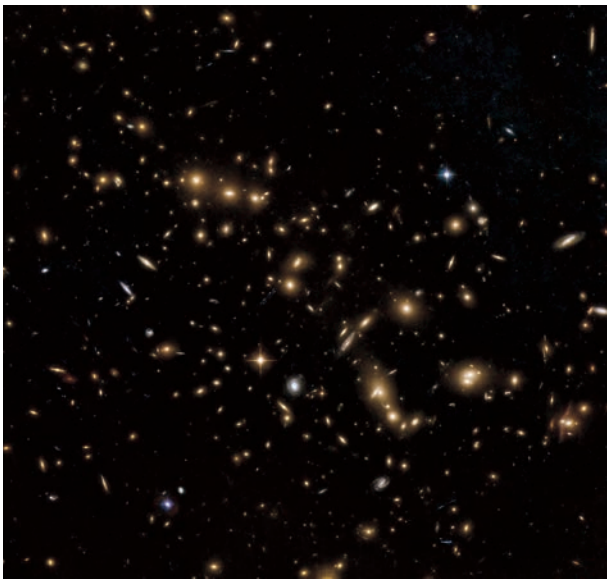


Figure 3.2 Galaxies
(Image from Hubble Space Telescope)

Our Sun and all the planets in the solar system are in the Milky Way galaxy. There are many galaxies besides our Milky Way. Andromeda galaxy is our closest neighboring galaxy. The Milky Way galaxy is spiral in shape. It is called Milky Way because it appears as a milky band of light in the sky. It is made up of approximately 100 billion stars and its diameter is 1,00,000 light years. Our solar system is 25,000 light years away from the centre of our galaxy. Just as the Earth goes around the Sun, the Sun goes around the centre of the galaxy and it takes 250 million years to do that.

Figure 3.3 Milky Way Galaxy

DO YOU KNOW? The distance of Andromeda, our nearest galaxy is ≈ 2.5 million light-years. If we move at the speed of the Earth (30 km/s), it would take us 25 billion years to reach it!

3.1.3 Stars

Stars are the fundamental building blocks of galaxies. Stars were formed when the galaxies were formed during the Big Bang. Stars produce heat, light, ultraviolet rays, x-rays, and other forms of radiation. They are largely composed of gas and plasma (a superheated state of matter). Stars are built by hydrogen gases. Hydrogen atoms fuse together to form helium atoms and in the process they produce large amount of heat. In a dark night we can see nearly 3,000 stars with the naked eye. We don't know how many stars exist. Our universe contains more than 100 billion galaxies, and each of those galaxies may have more than 100 billion stars.

Figure 3.4 Stars

Though the stars appear to be alone, most of the stars exist as pairs. The brightness of a star depends on their intensity and the distance from the Earth. Stars also appear to be in different colours depending on their temperature. Hot stars are white or blue, whereas cooler stars are orange or red in colour. They also occur in many sizes. Some stars have radii a thousand times larger than that of our own Sun.

A group of stars forms an imaginary outline or meaningful pattern on the space. They represent an animal, mythological person or creature, a god, or an object. This group of stars is called constellations. People in different cultures and countries adopted their own sets of constellations outlines. There are 88 formally accepted constellations. Aries, Gemini, Leo, Orion, Scorpius and Cassiopeia are some of the constellations.

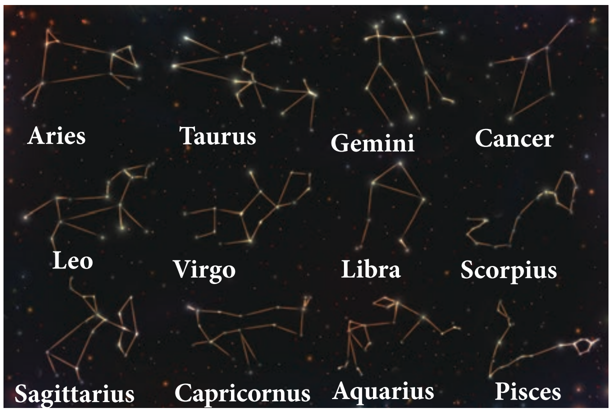


Figure 3.5 Constellations

Activity 2

Observe the sky keenly during night. Can you see a group of stars? Can you figure out any shape? Discuss with your teachers and find out their name.

3.2 The Solar System

The Sun and celestial bodies which revolve around it form the solar system. It consists of large number of bodies such as planets, comets, asteroids and meteors. The gravitational force of attraction between the Sun and these objects keep them revolving around it.

3.2.1 The Sun

The Sun is sometimes referred to by its Latin name Sol or by its Greek name Helios. The ancient Greeks grouped the Sun together with the other celestial bodies which moved across the sky, calling them all planets. But the Sun is a medium sized star, a very fiery spinning ball of hot gases. Three quarters of the Sun has hydrogen gas and one quarter has helium gas. It is over a million times as big as the Earth. Hydrogen atoms combine or fuse together to form helium under enormous pressure. This process, called nuclear fusion releases enormous amount of energy as light and heat. It is this energy which makes Sun shine and provide heat. The Sun is situated at the centre of the solar system. The strong gravitational fields cause other solar matter, mainly planets, asteroids, comets, meteoroids and other debris, to orbit around it. The Sun is believed to be more than 4.6 billion years old.

More to Know

Sun	
Diameter (across equator):	about 1,392,000 km (1 million 392 thousand km)
Volume:	1.3 million times that of Earth
Distance from the Earth:	About 150 million (15 crore) km
Sun's gravity:	28 times that of the Earth
Surface temperature:	From 5500˚C to 6000˚C
Core temperature:	1.5 million˚C
Composition:	75% Hydrogen + 25% helium + 70 elements

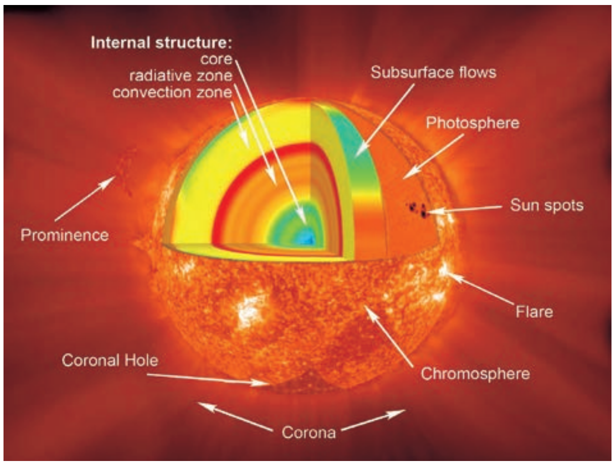


Figure 3.6 Internal view of the Sun

Formation of the Sun

At the time of the Big Bang, hydrogen gas condensed to form huge clouds, which later concentrated and formed the numerous galaxies. Some of the hydrogen gas was left free and started floating around in our galaxy. With time, due to some changes, this free-floating hydrogen gas concentrated and paved way for the formation of the Sun and solar system. Gradually, the Sun and the solar system turned into a slowly spinning molecular cloud, composed of hydrogen and helium molecules, along with dust. The cloud started to undergo the process of compression, as a result of its own gravity. Its excessive and high-speed spinning ultimately resulted in its flattening into a giant disc.

Rotation

The Sun rotates on its axis. Since the Sun is primarily made of very hot gas, the surface at the equator rotates once every 25.4 days. The rotation near the poles takes around 36 days.

Energy output

Most of the energy emitted by the Sun is visible light and a form of radiation known as infrared rays, which we feel as heat.

DO YOU KNOW?

- The Sun travels around the galaxy once every 200 million years – a journey of 100,000 light years.
- The Sun provides our plant with 126,000,000,000,000 horsepower of energy every day!
- For 186 days one cannot see the Sun in the North Pole.
- The amount of energy reaching the Earth's surface from the Sun is 6,000 times the amount of energy used by all human beings worldwide.
- The Sun is one among the 6000 stars which is visible to the naked eye from the Earth.

Colour

It is a common misconception that Sun emits yellow color radiation and it is not true. The radiation coming from the Sun contains all the colors. But the yellow is most intense among all the colors. Sunlight is scattered by the molecules when it passes through the Earth's atmosphere. The scattering of light depends on the color. Blue and violet are scattered more and red is scattered less.

3.2.2 Planets

A planet revolves around the Sun along a definite curved path which is called an orbit. It is elliptical. The time taken by a planet to complete one revolution is called its period of revolution. The period of revolution increases as the distance of the planet from the Sun increases. Thus the period of revolution of the Earth is 365.30 days whereas that of Neptune is 164.80 years.

Besides revolving around the Sun, a planet also rotates on its own axis like a top. The time taken by a planet to complete one rotation is called its period of rotation. The period of rotation of the Earth is 23 hours and 56 minutes and so the length of a day on Earth is taken as 24 hours. Table 3.1 tells about the length of a day on each planet. A day on the planet mercury is 59 Earth days, i.e., 59 × 24 = 1416 hours. Jupiter rotates so fast that a day lasts only less than 10 hours.

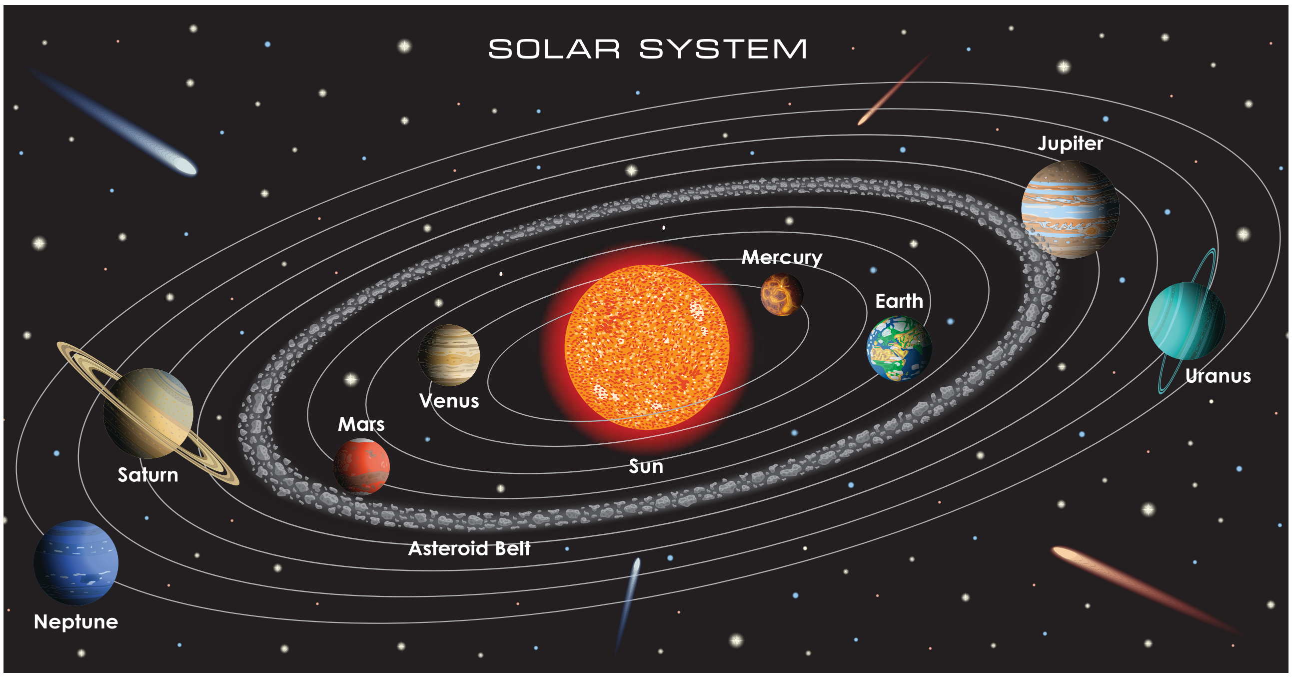


Figure 3.7 Planets in Orbit

Table 3.1 Length of a day on each planet

Planets	Length of a day
Mercury	58.65 days
Venus	243 days
Earth	23.93 hours
Mars	24.62 hours
Jupiter	9.92 hours
Saturn	10.23 hours
Uranus	17 hours
Neptune	18 hours

The planets are spaced unevenly. The first four planets are relatively close together and close to the Sun. They form the inner solar system. Farther from the Sun is the outer solar system, where the planets are much more spread out. Thus the distance between Saturn and Uranus is much greater (about 20 times) than between the Earth and the Mars.

The four planets grouped together in the inner solar system are Mercury, Venus, Earth and Mars. They are called inner planets. They have a surface of solid rock crust and so are called terrestrial or rocky planets. Their insides, surfaces and atmospheres are formed in a similar way and form similar pattern. Our planet, Earth can be taken as a model of the other three planets.

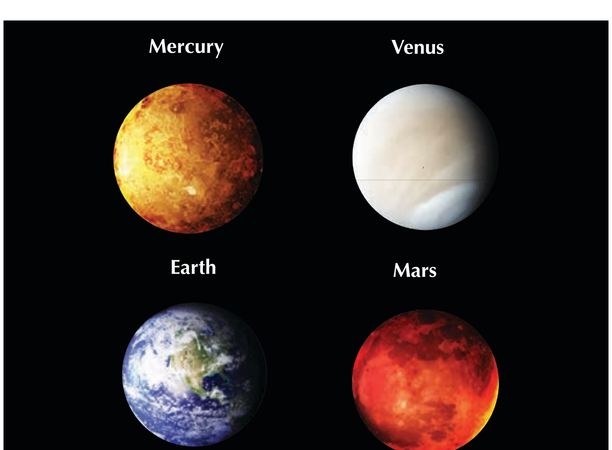


Figure 3.8 Inner Planets

The four large planets Jupiter, Saturn, Uranus and Neptune spread out in the outer solar system that slowly orbit the Sun are called outer planets. They are made of hydrogen, helium and other gases in huge amounts and have very dense atmosphere. They are known as gas giants and are called gaseous planets. The four outer planets Jupiter, Saturn, Uranus and Neptune have rings whereas the four inner planets do not have any rings. The rings are actually tiny pieces of rock covered with ice. Now let us learn about each planet in the solar system.

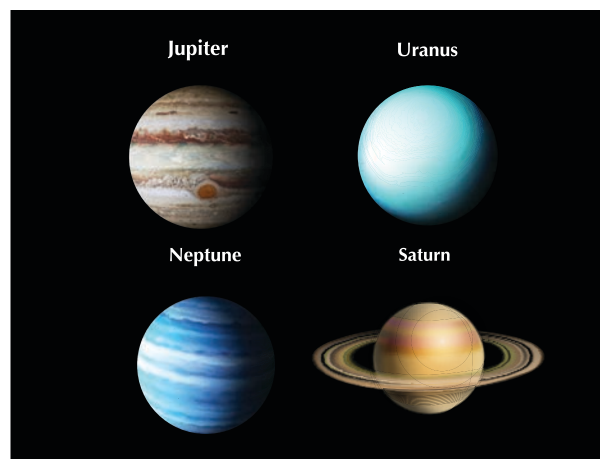


Figure 3.9 Outer Planets

Mercury

Mercury is a rocky planet nearest to the Sun. It is very hot during day but very cold at night. It moves around the Sun faster than any other planet – one year being only 87.97 Earth days and rotates very slowly. One day is equal to 58.65 days. Mercury can be easily observed thorough telescope than naked eye since it is very faint and small. It always appears in the eastern horizon or western horizon of the sky.

Venus

Venus is a special planet from the Sun, almost the same size as the Earth. It is the hottest planet in our solar system. After our moon, it is the brightest heavenly body in our night sky. A day on this planet is longer than its year. A day on this planet is 243 Earth days, and a year is only 224.7 Earth days. This planet spins in the opposite direction to all other planet and so unlike Earth, the Sun rises in the west and sets in the east here. Venus can be seen clearly through naked eye. It always appears in the horizon of eastern or western sky.

Activity 3

Watch the sky in the early morning. Do you see any planet? What is its name? Find out with the help of your teachers.

The Earth

The Earth where we live is the only planet in the solar system which supports life. Due to its right distance from the Sun it has the right temperature, the presence of water and suitable atmosphere and a blanket of ozone. All these have made continuation of life possible on the Earth. It moves around the Sun in 365.25 days and rotation period is 23.93 hours. The axis of rotation of the Earth is not perpendicular to the plane of its orbit. The tilt is responsible for the change of seasons on the Earth. From space, the Earth appears bluish green due to the reflection of light from water and land mass on its surface.

The Earth rotates on its axis from west to east (Fig. 3.10), so the Sun appears to move in its opposite direction that is from east to west. Life on Earth as we know would not be possible without the Sun. The solar energy from the Sun has supported and sustained terrestrial existence on Earth since the beginning of time.

DO YOU KNOW?

More than 1 million Earth would fit inside the Sun! A man weighing 60 kg in the Earth will weigh 1680 kg in the Sun.

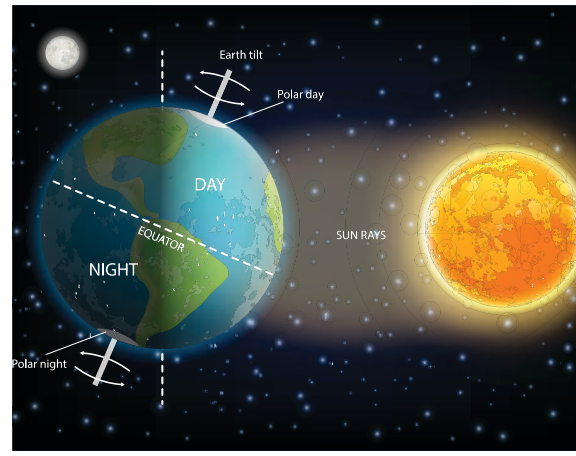
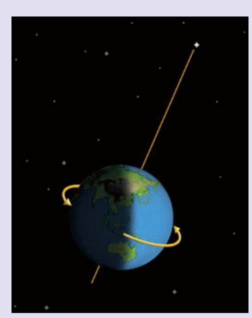


Figure 3.10 The rotation of the Earth on its axis

DO YOU KNOW?

All stars appear to us as moving from east to west, whereas there is one star which appears to us stationary in its position. It has been named as Pole star. The pole star appears to us as fixed in space at the same place in the sky in the north direction because it lies on the axis of rotation of the Earth which itself is fixed and does not change its position in space. It may be noted that the pole star is not visible from the southern hemisphere.



Mars

The first planet outside the orbit of the Earth is Mars. It appears slightly reddish and therefore it is also called the red planet. It has two small natural satellites (Deimos and Phobos). A natural satellite of any planet is called moon. One day on this planet is of 24 hours 37 minutes 22 seconds, and one year is 686.98 days, i.e., 687 Earth days.

Jupiter

Jupiter is called as Giant planet. It is the largest of all planets (about 11 times larger and 318 times heavier than Earth). It has 3 rings and 65 moons. Its moon Ganymede is the largest moon of our solar system. Rotating faster than any other planet, Jupiter has the shortest days - one day lasting only 9 hours 55 minutes 30 seconds. One year in Jupiter equals our 11.862 years.

Saturn

Known for its bright shiny rings, Saturn appears yellowish in colour. It is the second biggest and a giant gas planet in the outer solar system. It rotates very fast - the rotation period being 10.7 hours but revolves slowly around the Sun - the revolution period being 29.46 Earth years. At least 60 moons are present - the largest being Titan. Titan is the only moon in the solar system with clouds. Having least density of all (30 times less than Earth), this planet is so light.

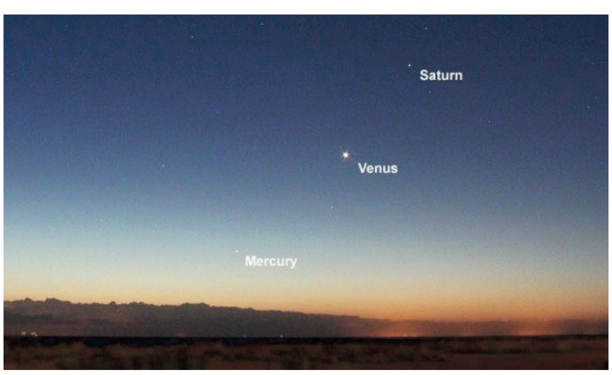


Figure 3.11 Planets seen from Earth

Uranus

Uranus is a cold gas giant and it is the seventh planet from the Sun in the solar system. It can be seen only with the help of large telescope. It has a greatly tilted axis of rotation. As a result, in its orbital motion it appears to roll on its side. Its revolution period is 84 Earth years and the rotation period is 17.2 hours. Due to its peculiar tilt, it has the longest summers and winters each lasting 42 years.

Neptune

It appears as Greenish star. It is the eighth planet from the Sun and is the windiest planet. Every 248 years, Pluto crosses its orbit. This situation continues for 20 years. It has 13 moons – Triton being the largest. Triton is the only moon in the solar system that moves in the opposite direction to the direction in which its planet spins.

3.2.3 Other bodies of the solar system

Besides the eight planets, there are some other bodies which revolve around the Sun. They are also members of the solar system.

Asteroids

There is a large gap in between the orbits of Mars and Jupiter. This gap is occupied by a broad belt containing about half a million pieces of rocks that were left over when the planets were formed and now revolve around the Sun. These are called asteroids. The biggest asteroid is Ceres – 946 km across. Every 50 million years, the Earth is hit by an asteroid nearing 10 km across. Asteroids can only be seen through large telescope.

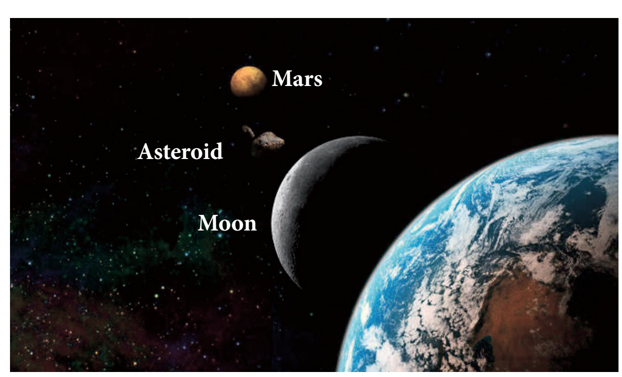


Figure 3.12 Asteroids

Comets

Comets are lumps of dust and ice that revolve around the Sun in highly elliptical orbits. Their period of revolution is very long.

When approaching the Sun, a comet vaporizes and forms a head and tail. Some of the biggest comets even seen had tails 160 million (16 crores) km long. This is more than the distance between the Earth and the Sun. Many comets are known to appear periodically. One such comet is Halley's Comet, which appears after nearly every 76 years. It was last seen in 1986. It will next be seen in 2062.

Figure 3.13 Comet

> **DO YOU KNOW?**
>
> **Cosmic year**
>
> The Sun travelling at a speed of 250 km per second (9 lakh km/h) takes about 225 million years to complete one revolution around the Milky Way. This period is called a cosmic year.

Meteors and Meteorites

Meteors are small piece of rocks scattered throughout the solar system. Traveling with high speed, these small pieces come closer to the Earth's atmosphere and are attracted by the gravitational force of Earth. Most of them are burnt up by the heat generated due to friction in the Earth's atmosphere. They are called meteors. Some of the bigger meteors may not be burnt completely and they fall on the surface of Earth. These are called meteorites.

Figure 3.14 Meteors and Meteorites

Satellites

A body moving in an orbit around a planet is called satellite. In order to distinguish them from the man made satellites (called as artificial satellites), they are called as natural satellites or moons. Satellite of the Earth is called Moon (other satellites are written as moon). It moves around the Earth once in 27.3 days in an approximate circular orbit of radius 3.85×10^5 km. Natural satellites do not make their own light. We can see the Earth's satellite Moon, because it reflects the light of the Sun. Satellite moves around the planets due to gravity, and the centripetal force. Among the planets in the solar system all the planets have moons except Mercury and Venus.

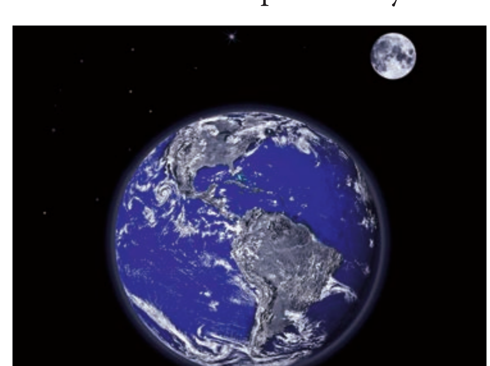


Figure 3.15 Moon revolving around Earth

3.3 Orbital Velocity

We saw that there are natural satellites moving around the planets. There will be gravitational force between the planet and satellites. Nowadays many artificial satellites are launched into the Earth's orbit. The first artificial satellite Sputnik was launched in 1956. India launched its first satellite Aryabhatta on April 19, 1975. Artificial satellites are made to revolve in an orbit at a height of few hundred kilometres. At this altitude, the friction due to air is negligible. The satellite is carried by a rocket to the desired height and released horizontally with a high velocity, so that it remains moving in a nearly circular orbit.

The horizontal velocity that has to be imparted to a satellite at the determined height so that it makes a circular orbit around the planet is called orbital velocity.

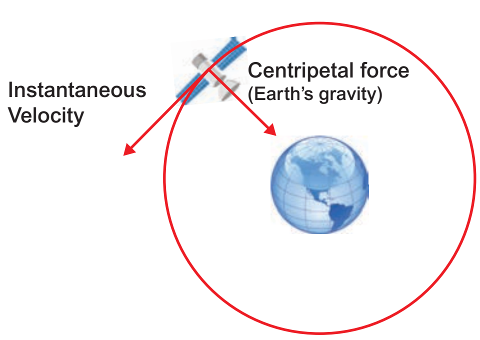


Figure 3.16 Orbital velocity

The orbital velocity of the satellite depends on its altitude above Earth. Nearer the object to the Earth, the faster is the required orbital velocity. At an altitude of 200 kilometres, the required orbital velocity is little more than 27,400 kph. That orbital speed and distance permit the satellite to make one revolution in 24 hours. Since Earth also rotates once in 24 hours, a satellite stays in a fixed position relative to a point on Earth's surface. Because the satellite stays over the same spot all the time, this kind of orbit is called 'geostationary'. Orbital velocity can be calculated using the following formula.

$$v = \sqrt{\frac{GM}{(R+h)}} \quad \text{where}$$

G = Gravitational constant (6.673×10^{-11} Nm^{2}kg^{-2})

M = Mass of the Earth (5.972×10^{24} kg)

R = Radius of the Earth (6371 km)

h = Height of the satellite from the surface of the Earth.

Example 1

Can you calculate the orbital velocity of a satellite orbiting at an altitude of 500 km?

Data: G = 6.673×10^{-11} SI units;

M = 5.972×10^{24} kg; R = 6371000 m;

h = 500000 m.

Solution:

$$v = \sqrt{\frac{6.67 \times 10^{-11} \times 5.972 \times 10^{24}}{(6371000 + 500000)}}$$

Ans: $v = 7613$ ms^{-1} or 7.613 kms^{-1}

DO YOU KNOW?

Microgravity is the condition in which people or objects appear to be weightless. The effects of microgravity can be seen when astronauts and objects float in space. Micro- means very small, so microgravity refers to the condition where gravity 'seems' to be very small. Many things seem to act differently in microgravity. Fire burns differently. Without the pull of gravity, flames are mere round. NASA performs science experiments in microgravity. These experiments help NASA to learn things that would be hard or perhaps impossible to learn on Earth.

3.4 Time period of a Satellite

Time taken by the satellite to complete one revolution round the Earth is called time period.

$$\text{Time period, } T = \frac{\text{Distance covered}}{\text{Orbital velocity}}.$$

$$T = \frac{2\pi r}{v}$$

Substituting the value of v, we get

$$T = \frac{2\pi(R+h)}{\sqrt{\dfrac{GM}{(R+h)}}}.$$

Example 2

At an orbital height of 500 km, find the orbital period of the satellite.

Solution

$h = 500\text{x}10^3\text{m}$, $R = 6371\text{x}10^3\text{m}$,

$v = 7616\text{x}10^3\,\text{kms}^{-1}$.

Substituting the values,

$$T = \frac{2\pi(R+h)}{v} = 2 \times \frac{22}{7} \times \frac{(6371+500)}{7616}$$

$= 5.6677\text{x}10^3\text{s} = 5667$ s.

This is $T \approx 95$ min

Activity 2

Prepare a list of Indian satellites from Aryabhatta to the latest along with their purposes.

3.5 Kepler's Laws

In the early 1600s, Johannes Kepler proposed three laws of planetary motion. Kepler was able to summarize the carefully collected data of his mentor - Tycho Brahe - with three statements that described the motion of planets in a Sun-centered solar system. Kepler's efforts to explain the underlying reasons for such motions are no longer accepted; nonetheless, the actual laws themselves are still considered an accurate description of the motion of any planet and any satellite. Kepler's three laws of planetary motion can be described as below.

First Law – The Law of Ellipses

The path of the planets about the Sun is elliptical in shape, with the center of the Sun being located at one of the foci.

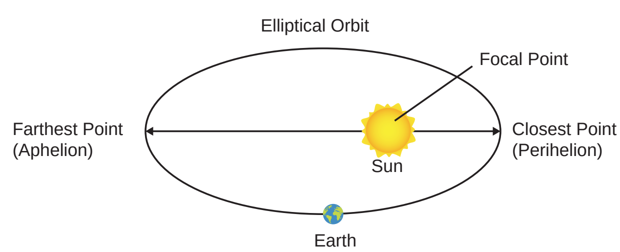


Figure 3.17 The Law of Ellipses

Second Law – The Law of Equal Areas

An imaginary line drawn from the center of the Sun to the center of the planet will sweep out equal areas in equal intervals of time.

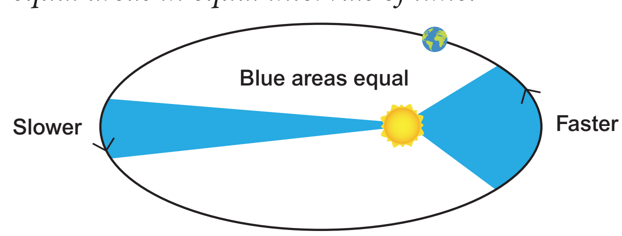


Figure 3.18 The Law of Equal area

Third Law – The Law of Harmonies

The ratio of the squares of the periods of any two planets is equal to the ratio of the cubes of their semi major axis from the Sun.

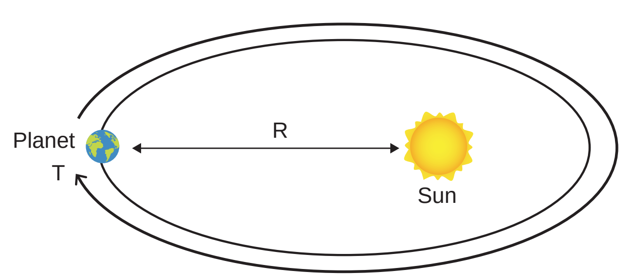


Figure 3.19 The Law of Harmonics

3.6 International Space Station

ISS is a large spacecraft which can house astronauts. It goes around in low Earth orbit at approximately 400 km distance. It is also a science laboratory. Its very first part was placed in orbit in 1998 and its core construction was completed by 2011. It is the largest man-made object in space which can also be seen from the Earth through the naked eye. The first human crew went to the ISS in 2000. Ever since that, it has never been unoccupied by humans. At any given instant, at least six humans will be present in the ISS. According to the current plan ISS will be operated until 2024, with a possible extension until 2028. After that, it could be deorbited, or recycled for future space stations.

Figure 3.20 International Space Station

3.6.1 Purpose of International Space Station

The ISS is intended to act as a scientific laboratory and observatory. Its main purpose is to provide an international lab for conducting experiments in space, as the space environment is nearly impossible to reproduce here on Earth. The microgravity environment present in the ISS provides ideal conditions for doing many scientific researches especially in biology, human biology, physics, astronomy and meteorology.

More to Know

Some facts about ISS

Mass/Power	420 000 kg / 75 kW to 90 kW
Length/Width/ Height	73 m / 108 m / 31 m
Operating Altitude	407 km
Orbital velocity/ Period	7.67 km s^{-1} (27 600 km hr^{-1}) / 93 min
Humans visited	227 (as of July 2018)
Food needed to support three for six months	3,630 kg
Total length of wire for electrical connections	13 km
Most no. of days spent in ISS	665 days by astronaut Peggy Wilson

3.6.2 Benefits of ISS

According to NASA, the following are some of the ways in which the ISS is already benefitting us or will benefit us in the future.

Supporting water-purification efforts

Using the technology developed for the ISS, areas having water scarcity can gain access to advanced water filtration and purification systems. This could very well be a life-saving difference for the people in such hazardous locations. The water recovery system (WRS) and the oxygen generation system (OGS) developed for the ISS have already saved a village in Iraq from being deserted due to lack of clean water.

Eye tracking technology

The Eye Tracking Device, built for a microgravity experiment, has proved ideal to be used in many laser surgeries. This device tracks the eye's position very accurately without interfering with the surgeon's work. Also, eye tracking technology is helping disabled people with limited movement and speech. For example, a kid who has severe disability in body movements can use his eye-movements alone and do routine tasks and lead an independent life.

Robotic arms and surgeries

Robotic arms developed for research in the ISS are providing significant help to the surgeons in removing inoperable tumours (e.g., brain tumours) and taking biopsies with great accuracies. The same technology designed for huge robotic arms that help astronauts in space is being brought back to Earth to do some heavy lifting in cancer treatment - in the form of a surgical robot. Its inventors say that the robot could take biopsies with remarkable precision and consistency.

Figure 3.21 Robotic arm

Apart from the above-mentioned applications there are many other ways in which the researches that take place in the ISS are helpful. They are: development of improved vaccines, breast cancer detection and treatment, ultrasound machines for remote regions etc,.

3.6.3 ISS and international cooperation

As great as the ISS' scientific achievements are, no less in accomplishment is the international co-operation which resulted in the construction of the ISS. An international collaboration of five different space agencies of 16 countries provides, maintains and operates the ISS. They are: NASA (USA), Roskosmos (Russia), ESA (Europe), JAXA (Japan) and CSA (Cananda). Belgium, Brazil, Denmark, France, Germany, Italy, Holland, Norway, Spain, Sweden, Switzerland and the UK are also part of the consortium. In fact, in the late 1950s, the idea of international space missions was unthinkable. The first part of the ISS was launched by the Russian Zarya module, which was funded by America. The first crew sailed on board was Russian Soyuz spaceship. Even as the ISS has sections split into US Orbital Segment, Russian Orbital Segment etc., on the whole it is jointly-owned by all the participating agencies and their nations. Cooperative international agreements between the world powers have made the largest international scientific undertaking a possibility. The many significant researches and functions of the ISS could only have been possible with the full co-operation of these nations.

DO YOU KNOW?

The Indian Space Research Organisation (ISRO) had proposed its Indian Human Spaceflight Programme to be done by 2021/2022 according to ISRO Chairman, K. Sivan. The first crew is to consist of three astronauts to be taken to space with a spacecraft called *Gaganyaan* on a GSLV-III rocket. V.R. Lalithambika, a specialist in advanced launcher technologies, will help the project as Director of the Human Space Flight Project.

Points to Remember

- ❖ The basic constituent of universe is galaxies which are really the collection of billions of stars.
- ❖ Scientists think that the universe began with the start of a massive explosion called the Big Bang.
- ❖ The universe contains everything that exists including the Earth, planets, stars, space, and galaxies.
- ❖ Depending on their appearance, galaxies are classified as spiral, elliptical, or irregular.
- ❖ Our Sun and all the planets in the solar system are in the Milky Way galaxy.
- ❖ Stars are the fundamental building blocks of galaxies.
- ❖ A group of stars forms an imaginary outline or meaningful pattern on the space, called constellations.
- ❖ The Sun and celestial bodies which revolve around it form the solar system.
- ❖ The first four planets are relatively close together and close to the Sun. They form the inner solar system. Farther from the Sun is the outer solar system, where the planets are much more spread out.
- ❖ Due to its right distance from the Sun, Earth has the right temperature, the presence of water and suitable atmosphere and a blanket of ozone.
- ❖ Million pieces of rocks that were left over when the planets were formed and now revolve around the Sun are called asteroids.
- ❖ Comets are lumps of dust and ice that revolve around the Sun in a highly elliptical orbits.
- ❖ A body moving in an orbit around a planet is called satellite.
- ❖ The ISS is intended to act as a scientific laboratory and observatory. Its main purpose is to provide an international lab for conducting experiments in space.

A-Z GLOSSARY

Asteroid	Small, rocky object orbiting the Sun.
Astronomy	The scientific study of the universe and the objects in it.
Big Bang Theory	A theory which states that the universe began in an enormous explosion.
Comet	A chunk of dirty, dark ice, mixed with dust and grit which revolves around the Sun in an oval orbit.
Constellation	A group of stars that can be seen as a pattern from Earth. There are 88 constellations.
Galaxy	A group of stars, nebulae, star clusters, globular clusters and other matter. There are millions of galaxies in the universe.
Meteor	A meteoroid that travels through the Earth's atmosphere. As it falls toward Earth, it burns up, making a streak of light. Also known as a shooting star.
Meteorite	A meteor that hits the Earth's surface.
Milky Way	A broad band of light that looks like a trail of spilled milk in the night sky. Created by the millions of faint stars that form part of our galaxy.
Moon	Any natural object which orbits a planet.

Orbit	The path of one object as it revolves around another
Planet	A relatively large object that revolves around a star, but which is not itself a star.
Satellite	Any object in outer space that orbits another object. Manmade satellites are launched into space to orbit a planet or moon.
Solar System	The Sun and all the objects that orbit it.
Space station	A large, manned satellite in space used as a base for space exploration over a long period of time.
Star	A ball of constantly exploding gases, giving off light and heat. The Sun is a star.
Universe	The word used to describe everything that exists in space, including the galaxies and stars, the Milky Way and the Solar System.

TEXTBOOK EVALUATION

I. Choose the correct answer.

1. Which of the following statements is correct?
   A. There are eight planets in our Solar System.
   B. Except Mars, all other planets revolve around the Sun in elliptical orbits
   (a) A only (b) B only
   (c) Both A and B (d) None

2. Who proposed the heliocentric model of the universe?
   (a) Tycho Brahe (b) Nicolaus Copernicus
   (c) Ptolemy (d) Archimedes

3. Which of the following is not a part of outer solar system?
   (a) Mercury (b) Saturn
   (c) Uranus (d) Neptune

4. Ceres is a ________.
   (a) Meteor (b) Star
   (c) Planet (d) Astroid

5. The period of revolution of planet A around the Sun is 8 times that of planet B. How many times is the distance of planet A as great as that of planet B?
   (a) 4 (b) 5
   (c) 2 (d) 3

6. The Big Bang occurred ________ years ago.
   (a) 13.7 billion (b) 15 million
   (c) 15 billion (d) 20 million

II. Fill in the blanks.

1. The speed of Sun in km/s is ________.
2. The rotational period of the Sun near its poles is ________.
3. India's first satellite is ________.
4. The third law of Kepler is also known as the Law of ________.
5. ________ is the only moon in the solar system that moves in the opposite direction to the direction in which its planet spins.
6. The number of planets in our Solar System is ________.

III. True or false.

1. The distance between Saturn and Uranus is about 10 times as that between Earth and Mars.
2. ISS is a proof for international cooperation.

3. Halley's comet appears after nearly 67 hours.
4. Satellites nearer to the Earth should have lesser orbital velocity.
5. Mars is called the red planet.

IV. Match the following.

1. Jupiter	a. 17.2 hours
2. Mercury	b. 10.7 hours
3. Venus	c. 87.97 days
4. Saturn	d. 9 hours 55 min
5. Mars	e. 243 days
	f. 87.97 days
	g. 24 hours 37 min

V. Answer very briefly.

1. What is solar system?
2. What is a cosmic year?
3. Define orbital velocity.
4. Define time period of a satellite.
5. What is a satellite? What are the two types of satellites?

VI. Answer in brief.

1. Write a note on the inner planets.
2. Write about comets in brief.
3. State Kepler's laws.
4. Write short notes on Gaganyaan.
5. What factors have made life on Earth possible?

VII. Answer in detail.

1. Give an account of all the planets in the solar system.
2. Discuss the benefits of ISS.
3. Write a note on orbital velocity.

VIII. Conceptual questions

1. Why do some stars appear blue and some red?
2. Why are we able to see the Moon even though it is not a luminous body?
3. How is a satellite maintained in nearly circular orbit?
4. Why are some satellites called geostationary?
5. A man weighing 60 kg in the Earth will weigh 1680 kg in the Sun. Why?

IX. Numerical problems

1. Calculate the speed with which a satellite moves if it is at a height of 36,000 km from the Earth's surface and has an orbital period of 24 hr (Take R = 6370 km)
   [Hint: Convert hr into seconds before doing calculation]
2. At an orbital height of 400 km, find the orbital period of the satellite.

REFERENCE BOOKS

1. Big Bang - By Simon Singh.
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Learning Objectives

At the end of this lesson students will be able to:

- Understand the concepts of force and motion.
- Explain inertia and its types.
- State the three laws of Newton.
- Apply Newtonian concept of force and motion.
- Define force, momentum and impulse.
- Distinguish between mass and weight
- Analyze weightlessness and the principle of conservation of momentum.
- Explain the law of gravitation and its applications.
- Understand the variations in 'g' due to height and depth.
- Solve numerical problems related to force and motion

INTRODUCTION

Human beings are so curious about things around them. Things around us are related to one another. Some bodies are at rest and some are in motion. Rest and motion are interrelated terms.

In the previous classes you have learnt about various types of motion such as linear motion, circular motion, oscillatory motion, and so on. So far, you have discussed the motion of bodies in terms of their displacement, velocity, and acceleration. In this unit, let us investigate the cause of motion.

When a body is at rest, starts moving, a question that arises in our mind is 'what causes the body to move?' Similarly, when a moving object comes to rest, you would like to know what brings it to rest? If a moving object speeds up or slows down or changes its direction. what speeds up or slows down the body? What changes the direction of motion?

One answer for all the above questions is 'Force'. In a common man's understanding of motion, a body needs a 'push' or 'pull' to move, or bring to rest or change its velocity. Hence, this 'push' or 'pull' is called as 'force'.

Let us define force in a more scientific manner using the three laws proposed by Sir Isaac Newton. These laws help you to understand the motion of a body and also to predict the future course of its motion, if you know the forces acting on it. Before Newton formulated his three laws of motion, a different perception about the force and motion of bodies prevailed. Let us first look at these ideas and then eventually learn about Newton's laws in this unit.

Mechanics is the branch of physics that deals with the effect of force on bodies. It is divided into two branches, namely, statics and dynamics.

Statics: It deals with the bodies, which are at rest under the action of forces.

Dynamics: It is the study of moving bodies under the action of forces. Dynamics is further divided as follows.

Kinematics: It deals with the motion of bodies without considering the cause of motion.

Kinetics: It deals with the motion of bodies considering the cause of motion.

1.1 FORCE AND MOTION

According to *Aristotle* a Greek Philosopher and Scientist, the natural state of earthly bodies is 'rest'. He stated that a moving body naturally comes to rest without any external influence of the force. Such motions are termed as **'natural motion' (Force independent).** He also proposed that a force (a push or a pull) is needed to make the bodies to move from their natural state (rest) and behave contrary to their own natural state called as **'violent motion' (Force dependent)**. Further, he said, when two differnt mass bodies are dropped from a height, the heavier body falls faster than the lighter one.

Galileo proposed the following concepts about force, motion and inertia of bodies:

(i) The natural state of all earthly bodies is either the state of rest or the state of uniform motion.

(ii) A body in motion will continue to be in the same state of motion as long as no external force is applied.

(iii) When a force is applied on bodies, they resist any change in their state. This property of bodies is called 'inertia'.

(iv) When dropped from a height in vacuum, bodies of different size, shape and mass fall at the same rate and reach the ground at the same time.

1.2 INERTIA

While you are travelling in a bus or in a car, when a sudden brake is applied, the upper part of your body leans in the forward direction. Similarly, when the vehicle suddenly is move forward from rest, you lean backward. This is due to, any body would like to continue to be in its state of rest or the state of motion. This is known as 'inertia'.

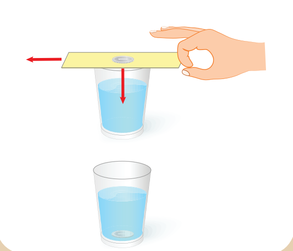
The inherent property of a body to resist any change in its state of rest or the state of uniform motion, unless it is influenced upon by an external unbalanced force, is known as **'inertia'.**

Activity 1

Take a glass tumbler and place a small cardboard on it as shown in the figure. Now, keep a coin at the centre of the cardboard. Then, flick the cardboard quickly. What do you observe?

The cardboard falls off the ground and the coin falls into the glass tumbler.

Inertia of rest



In activity described above, the inertia of the coin keeps it in the state of rest when the cardboard moves. Then, when the cardboard has moved, the coin falls into the tumbler due to gravity. This happen due to 'inertia of rest'.

1.2.1 Types of Inertia

a) **Inertia of rest:** The resistance of a body to change its state of rest is called inertia of rest.

b) **Inertia of motion**: The resistance of a body to

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change its state of motion is called inertia of motion.

c) **Inertia of direction:** The resistance of a body to change its direction of motion is called inertia of direction.

1.2.2 Examples of Inertia

- An athlete runs some distance before jumping. Because, this will help him jump longer and higher. (Inertia of motion)
- When you make a sharp turn while driving a car, you tend to lean sideways, (Inertia of direction).
- When you vigorously shake the branches of a tree, some of the leaves and fruits are detached and they fall down, (Inertia of rest).

Figure 1.1 Inertia of motion

1.3 LINEAR MOMENTUM

The impact of a force is more if the velocity and the mass of the body is more. To quantify the impact of a force exactly, a new physical quantity known as linear momentum is defined. The linear momentum measures the impact of a force on a body.

The product of mass and velocity of a moving body gives the magnitude of linear momentum. It acts in the direction of the velocity of the object. Linear momentum is a vector quantity.

Linear Momentum = mass × velocity

$$p = m\,v \quad \ldots\ldots\ldots\ldots (1.1)$$

It helps to measure the magnitude of a force. Unit of momentum in SI system is kg m s^{-1} and in C.G.S system its unit is g cm s^{-1}.

1.4 NEWTON'S LAWS OF MOTION

1.4.1 Newton's First Law

This law states that **every body continues to be in its state of rest or the state of uniform motion along a straight line unless it is acted upon by some external force.** It gives the definition of force as well as inertia.

1.4.2 Force

Force is an external effort in the form of push or pull, which:

1. produces or tries to produce the motion of a static body.
2. stops or tries to stop a moving body.
3. changes or tries to change the direction of motion of a moving body.

Force has both magnitude and direction. So, it is a vector quantity.

1.4.3 Types of forces

Based on the direction in which the forces act, they can be classified into two types as: (a) Like parallel forces and (b) Unlike parallel forces.

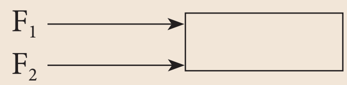
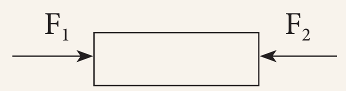
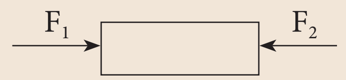
(a) **Like parallel forces:** Two or more forces of equal or unequal magnitude acting along the same direction, parallel to each other are called like parallel forces.

(b) **Unlike parallel forces:** If two or more equal forces or unequal forces act along opposite directions parallel to each other, then they are called unlike parallel forces. Action of forces are given in Table 1.1.

1.4.4 Resultant Force

When several forces act simultaneously on the same body, then the combined effect of the multiple forces can be represented by a single force, which is termed as '*resultant force*'. It is equal to the vector sum (adding the magnitude of the forces with their direction) of all the forces.

Table 1.1 Action of forces

Action of forces	Diagram	Resultant force (F_{net})
Parallel forces are acting in the same direction		$F_{net} = F_1 + F_2$
Parallel unequal forces are acting in opposite directions		$F_{net} = F_1 - F_2$ (if $F_1 > F_2$) $F_{net} = F_2 - F_1$ (if $F_2 > F_1$) F_{net} is directed along the greater force.
Parallel equal forces are acting in opposite directions in the same line of action ($F_1 = F_2$)		$F_{net} = F_1 - F_2$ ($F_1 = F_2$) $F_{net} = 0$

(a) Unlike parallel forces – Tug of war

(b) Unbalanced forces - Action of a lever

(c) Like parallel forces

Figure 1.2 Combined effect of forces

If the resultant force of all the forces acting on a body is equal to zero, then the body will be in equilibrium. Such forces are called **balanced forces**. If the resultant force is not equal to zero, then it causes the motion of the body due to **unbalanced forces**

Examples: Drawing water from a well, force applied with a crow bar, forces on a weight balance, etc.

A system can be brought to equilibrium by applying another force, which is equal to the resultant force in magnitude, but opposite in direction. Such force is called as '**Equilibrant**'.

1.4.5 Rotating Effect of Force

Have you observed the position of the handle in a door? It is always placed at the edge of door and not at some other place. Why? Have you tried to push a door by placing your hand closer to the hinges or the fixed edge? What do you observe?

The door can be easily opened or closed when you apply the force at a point far away from the fixed edge. In this case, the effect of the force you apply is to turn the door about the fixed edge. This turning effect of the applied force is more when the distance between the fixed edge and the point of application of force is more.

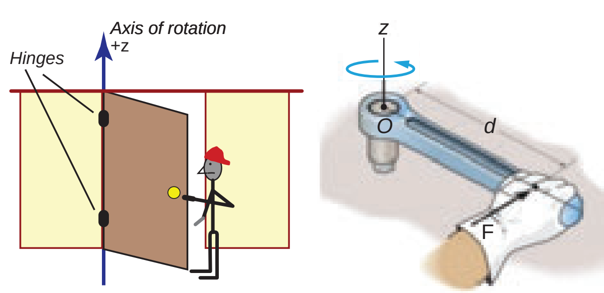


Figure 1.3 Rotating effect of a force

The axis of the fixed edge about which the door is rotated is called as the '*axis of rotation*'. Fix one end of a rod to the floor/wall, and apply a force at the other end tangentially.

The rod will be turned about the fixed point is called as '*point of rotation*'.

1.4.6 Moment of the Force

The rotating or turning effect of a force about a fixed point or fixed axis is called **moment of the force** about that point or **torque (τ)**. It is measured by the product of the force (F) and the perpendicular distance (d) between the fixed point or the fixed axis and the line of action of the force.

$$\tau = F \times d \quad \ldots\ldots\ldots\ldots (1.2)$$

Torque is a vector quantity. It is acting along the direction, perpendicular to the plane containing the line of action of force and the distance. Its SI unit is N m.

Couple: Two equal and unlike parallel forces applied simultaneously at two distinct points constitute a couple. The line of action of the two forces does not coincide. It does not produce any translatory motion since the resultant is zero. But, a couple results in causes the rotation of the body. Rotating effect of a couple is known as **moment of a couple**.

Examples: Turning a tap, winding or unwinding a screw, spinning of a top, etc.

Moment of a couple is measured by the product of any one of the forces and the perpendicular distance between the line of action of two forces. The turning effect of a couple is measured by the magnitude of its moment.

Moment of a couple = Force × perpendicular distance between the line of action of forces

$$M = F \times S \quad \ldots\ldots\ldots\ldots (1.3)$$

The unit of moment of a couple is newton metre (N m) in SI system and dyne cm in CGS system.

By convention, the direction of moment of a force or couple is taken as positive if the body is rotated in the anti-clockwise direction and negative if it is rotate in the clockwise direction. They are shown in Figures 1.4 (a and b)

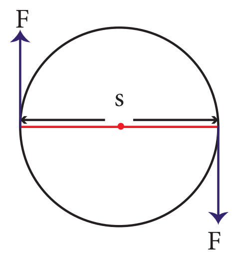


Figure 1.4 (a)
Clockwise moment

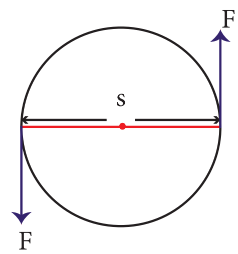


Figure 1.4 (b)
Anticlockwise moment

1.4.7 Application of Torque

1. Gears:

A gear is a circular wheel with teeth around its rim. It helps to change the speed of rotation of a wheel by changing the torque and helps to transmit power.

2. Seasaw

Most of you have played on the seasaw. Since there is a difference in the weight of the persons sitting on it, the heavier person lifts the lighter person. When the heavier person comes closer to the pivot point (fulcrum) the distance of the line of action of the force decreases. It causes less amount of torque to act on it. This enables the lighter person to lift the heavier person.

3. Steering Wheel

A small steering wheel enables you to manoeuore a car easily by transferring a torque to the wheels with less effort.

1.4.8 Principle of Moments

When a number of like or unlike parallel forces act on a rigid body and the body is in equilibrium, then the algebraic sum of the moments in the clockwise direction is equal to the algebraic sum of the moments in the anticlockwise direction. In other words, at equilibrium, the algebraic sum of the moments of all the individual forces about any point is equal to zero.

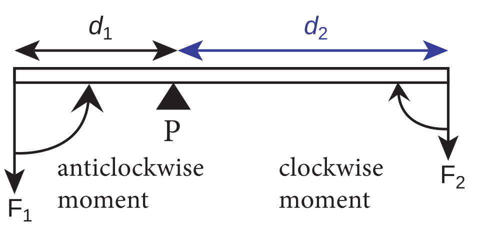


Figure 1.5 Principle of moments

In the illustration given in figure 1.5, the force F_1 produces an anticlockwise rotation at a distance d_1 from the point of pivot P (called fulcrum) and the force F_2 produces a clockwise rotation at a distance d_2 from the point of pivot P. The principle of moments can be written as follows:

Moment in clockwise direction = Moment in anticlockwise direction

$$F_1 \times d_1 = F_2 \times d_2 \; \ldots\ldots\ldots \; (1.4)$$

1.5 NEWTON'S SECOND LAW OF MOTION

According to this law, "**the force acting on a body is directly proportional to the rate of change of linear momentum of the body and the change in momentum takes place in the direction of the force**".

This law helps us to measure the amount of force. So, it is also called as '*law of force*'. Let, 'm' be the mass of a moving body, moving along a straight line with an initial speed 'u' After a time interval of 't', the velocity of the body changes to 'v' due to the impact of an unbalanced external force F.

Initial momentum of the body $P_i = mu$

Final momentum of the body $P_f = mv$

Change in momentum $\Delta p = P_f - P_i = mv - mu$

By Newton's second law of motion,

Force, F $\propto$ rate of change of momentum

F $\propto$ change in momentum / time

$$F \propto \frac{mv - mu}{t}$$

$$F = \frac{km(v - u)}{t}$$

Here, k is the proportionality constant. k = 1 in all systems of units. Hence,

$$\mathbf{F = \frac{m(v - u)}{t}} \qquad (1.5)$$

Since, acceleration = change in velocity/time, a=(v-u)/t. Hence, we have

$$\mathbf{F = m \times a} \qquad (1.6)$$

Force = mass × acceleration

No external force is required to maintain the motion of a body moving with uniform velocity. When the net force acting on a body is not equal to zero, then definitely the velocity of the body will change. Thus, change in momentum takes place in the direction of the force. The change may take place either in magnitude or in direction or in both.

Force is required to produce the acceleration of a body. In a uniform circular motion, even though the speed (magnitude of velocity) remains constant, the direction of the velocity changes at every point on the circular path. So, the acceleration is produced along the radius called as *centripetal acceleration*. The force, which produces this acceleration is called as centripetal force, about which you have learnt in class IX.

Units of force: SI unit of force is newton (N) and in C.G.S system its unit is dyne.

Definition of 1 newton (N): The amount of force required for a body of mass 1 kg produces an acceleration of 1 m s^{-2}, **1 N = 1 kg m s^{-2}**

Definition of 1 dyne: The amount of force required for a body of mass 1 gram produces an acceleration of 1 cm s^{-2}, **1 dyne = 1 g cm s^{-2}**; also **1 N = 10^5 dyne.**

Unit force:

The amount of force required to produce an acceleration of 1 m s^{-2} in a body of mass 1 kg is called '*unit force*'.

Gravitational unit of force:

In the SI system of units, gravitational unit of force is kilogram force, represented by kg f. In the CGS system its unit is gram force, represented by g f.

1 kg f = 1 kg × 9.8 m s^{-2} = 9.8 N;

1 g f = 1 g × 980 cm s^{-2} = 980 dyne

1.6 Impulse

A large force acting for a very short interval of time is called as '**Impulsive force**'. When a force F acts on a body for a period of time t, then the product of force and time is known as '**impulse**' represented by 'J'

Impulse, $J = F \times t$ (1.7)

By Newton's second law

$F = \Delta p / t$ (Δ refers to change)

$\Delta p = F \times t$ (1.8)

From 1.7 and 1.8

$$\mathbf{J = \Delta p}$$

Impulse is also equal to the magnitude of change in momentum. Its unit is kg m s^{-1} or N s.

Change in momentum can be achieved in two ways. They are:

i. a large force acting for a short period of time and

ii. a smaller force acting for a longer period of time.

Examples:

- Automobiles are fitted with springs and shock absorbers to reduce jerks while moving on uneven roads.
- In cricket, a fielder pulls back his hands while catching the ball. He experiences a smaller force for a longer interval of time to catch the ball, resulting in a lesser impulse on his hands.

Figure 1.6 Example of impulsive force

1.7 NEWTON'S THIRD LAW OF MOTION

Newton's third law states that '**for every action, there is an equal and opposite reaction. They always act on two different bodies**'.

If a body A applies a force F_A on a body B, then the body B reacts with force F_B on the body A, which is equal to F_A in magnitude, but opposite in direction. $F_B = -F_A$

Examples:

- When birds fly they push the air downwards with their wings (Action) and the air pushes the bird upwards (Reaction).
- When a person swims he pushes the water using the hands backwards (Action), and the water pushes the swimmer in the forward direction (Reaction).
- When you fire a bullet, the gun recoils backward and the bullet is moving forward (Action) and the gun equalises this forward action by moving backward (Reaction).

1.8 PRINCIPLE OF CONSERVATION OF LINEAR MOMENTUM

There is no change in the linear momentum of a system of bodies as long as no net external force acts on them.

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Let us prove the law of conservation of linear momentum with the following illustration:

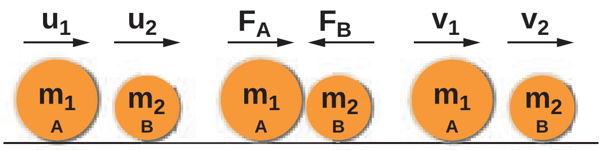


Figure 1.7 Conservation of linear momentum

Proof:

Let two bodies A and B having masses m_1 and m_2 move with initial velocity u_1 and u_2 in a straight line. Let the velocity of the first body be higher than that of the second body. i.e., $u_1 > u_2$. During an interval of time t second, they tend to have a collision. After the impact, both of them move along the same straight line with a velocity v_1 and v_2 respectively.

Force on body B due to A,

$$F_B = m_2 (v_2 - u_2)/t$$

Force on body A due to B,

$$F_A = m_1 (v_1 - u_1)/t$$

By Newton's III law of motion,

Action force = Reaction force

$$F_A = -F_B$$

$$m_1 (v_1 - u_1)/t = -m_2 (v_2 - u_2)/t$$

$$\mathbf{m_1 v_1 + m_2 v_2 = m_1 u_1 + m_2 u_2} \text{ ------ } \mathbf{(1.9)}$$

The above equation confirms **in the absence of an external force, the algebraic sum of the momentum after collision is numerically equal to the algebraic sum of the momentum before collision.**

Hence the law of conservation linear momentum is proved.

1.9 ROCKET PROPULSION

Propulsion of rockets is based on the law of conservation of linear momentum as well as Newton's III law of motion. Rockets are filled with a fuel (either liquid or solid) in the propellant tank. When the rocket is fired, this fuel is burnt and a hot gas is ejected with a high speed from the nozzle of the rocket, producing a huge momentum. To balance this momentum, an equal and opposite reaction force is produced in the combustion chamber, which makes the rocket project forward.

While in motion, the mass of the rocket gradually decreases, until the fuel is completely burnt out. Since, there is no net external force acting on it, the linear momentum of the system is conserved. The mass of the rocket decreases with altitude, which results in the gradual increase in velocity of the rocket. At one stage, it reaches a velocity, which is sufficient to just escape from the gravitational pull of the Earth. This velocity is called *escape velocity*. (This topic will be discussed in detail in higher classes).

1.10 GRAVITATION

1.10.1 Newton's universal law of gravitation

This law states that **every particle of matter in this universe attracts every other particle with a force. This force is directly proportional to the product of their masses and inversely proportional to the square of the distance between the centers of these masses. The direction of the force acts along the line joining the masses**.

Force between the masses is always attractive and it does not depend on the medium where they are placed.

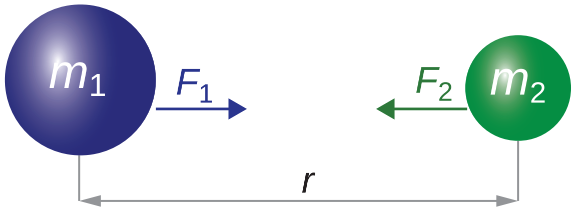


Figure 1.8 Gravitational force between two masses

Let, m_1 and m_2 be the masses of two bodies A and B placed *r* metre apart in space

Force $F \propto m_1 \times m_2$

$F \propto 1/r^2$

On combining the above two expressions

$$F \propto \frac{m_1 \times m_2}{r^2}$$

$$\mathbf{F} = \frac{\mathbf{G\,m_1\,m_2}}{\mathbf{r^2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1.10)$$

Where G is the universal gravitational constant. Its value in SI unit is 6.674×10^{-11} N $m^2\,kg^{-2}$.

1.10.2 Acceleration due to gravity (g)

When you throw any object upwards, its velocity ceases at a particular height and then it falls down due to the gravitational force of the Earth.

The velocity of the object keeps changing as it falls down. This change in velocity must be due to the force acting on the object. The acceleration of the body is due to the Earth's gravitational force. So, it is called as 'acceleration due to the gravitational force of the Earth' or **'acceleration due to gravity of the Earth'**. It is represented as 'g'. Its unit is m s^{-2}

Mean value of the acceleration due to gravity is taken as 9.8 m s^{-2} on the surface of the Earth. This means that the velocity of a body during the downward free fall motion varies by 9.8 m s^{-1} for every 1 second. However, the value of 'g' is not the same at all points on the surface of the earth.

1.10.3 Relation between g and G

When a body is at rests on the surface of the Earth, it is acted upon by the gravitational force of the Earth. Let us compute the magnitude of this force in two ways. Let, M be the mass of the Earth and m be the mass of the body. The entire mass of the Earth is assumed to be concentrated at its centre. The radius of the Earth is R = 6378 km (= 6400 km approximately). By Newton's law of gravitation, the force acting on the body is given by

$$F = \frac{G\,M\,m}{R^2} \qquad (1.11)$$

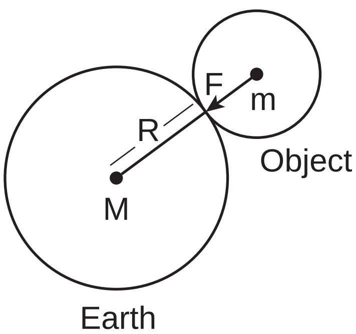


Figure 1.9 Relation between g and G

Here, the radius of the body considered is negligible when compared with the Earth's radius. Now, the same force can be obtained from Newton's second law of motion. According to this law, the force acting on the body is given by the product of its mass and acceleration (called as weight). Here, acceleration of the body is under the action of gravity hence a = g

$F = m\,a = m\,g$

$F = \text{weight} = mg$ ------------------ (1.12)

Comparing equations (1.7) and (1.8), we get

$$\mathbf{mg} = \frac{\mathbf{GMm}}{\mathbf{R^2}} \quad \text{------------------------} \quad (1.13)$$

Acceleration due to gravity

$$\mathbf{g} = \frac{\mathbf{GM}}{\mathbf{R^2}} \quad \text{------------------------------} \quad (1.14)$$

1.10.4 Mass of the Earth (M)

Rearranging the equation (1.14), the mass of the Earth is obtained as follows:

Mass of the Earth $M = g\,R^2/G$

Substituting the known values of g, R and G, you can calculate the mass of the Earth as

$\mathbf{M = 5.972 \times 10^{24}\ kg}$

1.10.5 Variation of acceleration due to gravity (g):

Since, g depends on the geometric radius of the Earth, ($g \propto 1/R^2$), its value changes from one place to another on the surface of the Earth. Since, the geometric radius of the Earth is maximum in the equatorial region and minimum in the polar region, the value of g is maximum in the polar region and minimum at the equatorial region.

When you move to a higher altitude from the surface of the Earth, the value of g reduces. In the same way, when you move deep below the surface of the Earth, the value of g reduces. (This topic will be discussed in detail in the higher classes). Value of g is zero at the centre of the Earth.

1.11 MASS AND WEIGHT

Mass: Mass is the basic property of a body. Mass of a body is defined as the quantity of matter contained in the body. Its SI unit is kilogram (kg).

Weight: Weight of a body is defined as the gravitational force exerted on it due to the Earth's gravity alone.

Weight = Gravitational Force

= mass (m)× acceleration due to gravity(g).

g = acceleration due to gravity for Earth (at sea level) = 9.8 m s^{-2}.

Weight is a vector quantity. Direction of weight is always towards the centre of the Earth. SI unit of weight is newton (N). Weight of a body varies from one place to another place on the Earth since it depends on the acceleration due to gravity of the Earth (g) weight of a body is more at the poles than at the equatorial region.

The value of acceleration due to gravity on the surface of the moon is 1.625 ms^{-2}. This is about 0.1654 times the acceleration due to gravity of the Earth. If a person whose mass is 60 kg stands on the surface of Earth, his weight would be 588 N (W = mg = 60 × 9.8). If the same person goes to the surface of the Moon, he would weigh only 97.5 N (W = 60 × 1.625). But, his mass remains the same (60 kg) on both the Earth and the Moon.

1.12 APPARENT WEIGHT

The weight that you feel to possess during up and down motion, is not same as your actual weight. Apparent weight is the weight of the body acquired due to the action of gravity and other external forces acting on the body.

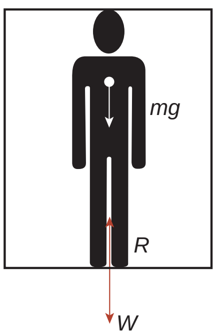


Figure 1.10
A person in a moving lift

Let us see this from the following illustration:

Let us consider a person of mass m, who is travelling in lift. The actual weight of the person is W = mg, which is acting vertically downwards. **The reaction force exerted by the lift's surface 'R', taken as apparent weight** is acting vertically upwards.

Let us see different possibilities of the apparent weight 'R' of the person that arise, depending on the motion of the lift; upwards or downwards which are given in Table 1.2

1.12.1 Weightlessness

Have you gone to an amusement park and taken a ride in a roller coaster? or in a giant wheel? During the fast downward and upward movement, how did you feel?

4PATFE

Table 1.2 Apparent weight of a person in a moving lift

Case 1: Lift is moving **upward** with an acceleration 'a'	Case 2: Lift is moving **downward** with an acceleration 'a'	Case 3: Lift is at **rest**.	Case 4: Lift is **falling down freely**
$R - W = F_{net} = ma$ $R = W + ma$ $R = mg + ma$ $\mathbf{R = m(g+a)}$	$W - R = F_{net} = ma$ $R = W - ma$ $R = mg - ma$ $\mathbf{R = m(g-a)}$	Here, the acceleration is zero $a = 0$ $R = W$ $\mathbf{R = mg}$	Here, the acceleration is equal to g $a = g$ $\mathbf{R = m(g-g)}$
$R > W$	$R < W$	$R = W$	$R = 0$
Apparent weight is **greater** than the actual weight.	Apparent weight is **lesser** than the actual weight.	Apparent weight is **equal** to the actual weight.	Apparent weight is equal to **zero**.

Figure 1.11 Weightlessness in a roller coaster

Its amazing!!. You actually feel as if you are falling freely without having any weight. This is due to the phenomenon of 'weightlessness'. You seem to have lost your weight when you move down with a certain acceleration. Sometimes, you experience the same feeling while travelling in a lift.

When the person in a lift moves down with an acceleration (a) equal to the acceleration due to gravity (g), i.e., when $a = g$, this motion is called as '*free fall*'. Here, the apparent weight ($R = m(g-g) = 0$) of the person is zero. This condition or state refers to the state of weightlessness. (Refer case 4 from Table 1.2).

The same effect takes place while falling freely in a roller coaster or on a swing or in a vertical giant wheel. You feel an apparent weight loss and weight gain when you are moving up and down in such rides.

1.12.2 Weightlessness of the astronauts

Some of us believe that the astronauts in the orbiting spacestation do not experience any gravitational force of the Earth. So they float. But this is absolutely wrong.

Astronauts are not floating but falling freely around the earth due to their huge oribital velocity. Since spacestation and astronauts have equal acceleration, they are under free fall condition. ($R = 0$ refer case 4 in Table 1.2). Hence, both the astronauts and the spacestation are in the state of weightlessness.

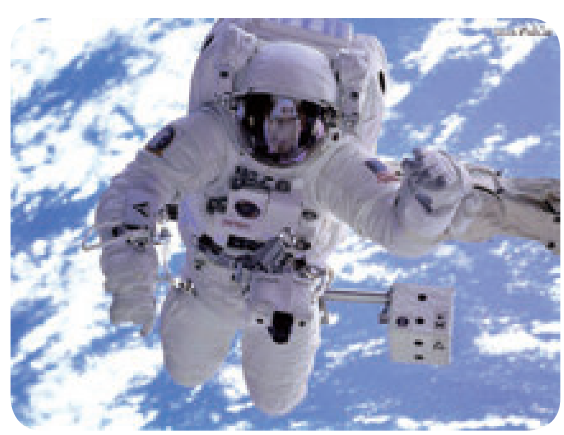


Figure 1.12 Weightlessness of astronauts

1.12.3 Application of Newton's law of gravitation

1) Dimensions of the heavenly bodies can be measured using the gravitation law. Mass of the Earth, radius of the Earth, acceleration due to gravity, etc. can be calculated with a higher accuracy.
2) Helps in discovering new stars and planets.
3) One of the irregularities in the motion of stars is called 'Wobble' lead to the disturbance in the motion of a planet nearby. In this condition the mass of the star can be calculated using the law of gravitation.
4) Helps to explain germination of roots is due to the property of geotropism which is the property of a root responding to the gravity.
5) Helps to predict the path of the astronomical bodies.

Points to Remember

- Mechanics is divided into statics and dynamics.
- Ability of a body to maintain its state of rest or motion is called Inertia.
- Moment of the couple is measured by the product of any one of the forces and the perpendicular distance between two forces.
- SI unit of force is newton (N). C.G.S unit is dyne.
- When a force F acts on a body for a period of time t, then the product of force and time is known as 'impulse'.
- The unit of weight is newton or kg f
- The weight of a body is more at the poles than at the equatorial region.
- Mass of a body is defined as the quantity of matter contained in the object. Its SI unit is kilogram (kg).
- Apparent weight is the weight of the body acquired due to the action of gravity and other external forces on the body.
- Whenever a body or a person falls freely under the action of Earth's gravitational force alone, it appears to have zero weight. This state is referred to as 'weightlessness'.

SOLVED PROBLEMS

Problem-1: Calculate the velocity of a moving body of mass 5 kg whose linear momentum is 2.5 $kg\,m\,s^{-1}$.

Solution: Linear momentum = mass × velocity

Velocity = linear momentum / mass.
$V = 2.5 / 5 = 0.5\ m\ s^{-1}$

Problem 2: A door is pushed, at a point whose distance from the hinges is 90 cm, with a force of 40 N. Calculate the moment of the force about the hinges.

Solution:

Formula: The moment of a force M = F × d

Given: F = 40 N and d = 90 cm = 0.9 m.

Hence, moment of the force = 40 × 0.9 = 36 N m.

Problem 3 : At what height from the centre of the Earth the acceleration due to gravity will be ¼th of its value as at the Earth.

Solution:
Data: Height from the centre of the Earth, $R' = R + h$
The acceleration due to gravity at that height, $g' = g/4$

Formula: $g = GM/R^2$

$$\frac{g}{g'} = \left(\frac{R'}{R}\right)^2 = \left(\frac{R+h}{R}\right)^2 = \left(1 + \frac{h}{R}\right)^2$$

$$4 = \left(1 + \frac{h}{R}\right)^2,$$

$$2 = 1 + \frac{h}{R} \qquad \text{or } h = R. \qquad R' = 2R$$

From the centre of the Earth, the object is placed at twice the radius of the earth.

TEXTBOOK EVALUATION

5J3MGE

I. Choose the correct answer

1) Inertia of a body depends on
   a) weight of the object
   b) acceleration due to gravity of the planet
   c) mass of the object
   d) Both a & b
2) Impulse is equals to
   a) rate of change of momentum
   b) rate of force and time
   c) change of momentum
   d) rate of change of mass
3) Newton's III law is applicable
   a) for a body is at rest
   b) for a body in motion
   c) both a & b
   d) only for bodies with equal masses
4) Plotting a graph for momentum on the X-axis and time on Y-axis. slope of momentum-time graph gives
   a) Impulsive force b) Acceleration
   c) Force d) Rate of force
5) In which of the following sport the turning of effect of force used
   a) swimming b) tennis
   c) cycling d) hockey
6) The unit of 'g' is m s^{-2}. It can be also expressed as
   a) cm s^{-1} b) N kg^{-1}
   c) N m^2 kg^{-1} d) cm^2 s^{-2}
7) One kilogram force equals to
   a) 9.8 dyne b) 9.8×10^4 N
   c) 98×10^4 dyne d) 980 dyne
8) The mass of a body is measured on planet Earth as M kg. When it is taken to a planet of radius half that of the Earth then its value will be____kg
   a) 4 M b) 2M c) M/4 d) M
9) If the Earth shrinks to 50% of its real radius its mass remaining the same, the weight of a body on the Earth will
   a) decrease by 50% b) increase by 50%
   c) decrease by 25% d) increase by 300%
10) To project the rockets which of the following principle(s) is /(are) required?
    a) Newton's third law of motion
    b) Newton's law of gravitation
    c) law of conservation of linear momentum
    d) both a and c

II. Fill in the blanks

1. To produce a displacement ____________ is required
2. Passengers lean forward when sudden brake is applied in a moving vehicle. This can be explained by ____________
3. By convention, the clockwise moments are taken as ____________ and the anticlockwise moments are taken as____________
4. ____________ is used to change the speed of car.
5. A man of mass 100 kg has a weight of ____________ at the surface of the Earth

III. State whether the following statements are true or false. Correct the statement if it is false:

1. The linear momentum of a system of particles is always conserved.
2. Apparent weight of a person is always equal to his actual weight
3. Weight of a body is greater at the equator and less at the polar region.
4. Turning a nut with a spanner having a short handle is so easy than one with a long handle.
5. There is no gravity in the orbiting space station around the Earth. So the astronauts feel weightlessness.

IV. Match the following

Column I		Column II
a. Newton's I law	-	propulsion of a rocket
b. Newton's II law	-	Stable equilibrium of a body
c. Newton's III law	-	Law of force
d. Law of conservation of Linear momentum	-	Flying nature of bird

V. Assertion & Reasoning

Mark the correct choice as

(a) If both the assertion and the reason are true and the reason is the correct explanation of assertion.

(b) If both the assertion and the reason are true, but the reason is not the correct explanation of the assertion.

(c) Assertion is true, but the reason is false.

(d) Assertion is false, but the reason is true.

1. **Assertion:** The sum of the clockwise moments is equal to the sum of the anticlockwise moments.

   Reason: The principle of conservation of momentum is valid if the external force on the system is zero.

2. **Assertion:** The value of 'g' decreases as height and depth increases from the surface of the Earth.

   Reason: 'g' depends on the mass of the object and the Earth.

VI. Answer briefly.

1. Define inertia. Give its classification.
2. Classify the types of force based on their application.
3. If a 5 N and a 15 N forces are acting opposite to one another. Find the resultant force and the direction of action of the resultant force
4. Differentiate mass and weight.
5. Define moment of a couple.
6. State the principle of moments.
7. State Newton's second law.
8. Why a spanner with a long handle is preferred to tighten screws in heavy vehicles?
9. While catching a cricket ball the fielder lowers his hands backwards. Why?
10. How does an astronaut float in a space shuttle?

VII. Solve the given problems

1. Two bodies have a mass ratio of 3:4 The force applied on the bigger mass produces an acceleration of 12 ms^{-2}.What could be the acceleration of the other body, if the same force acts on it.
2. A ball of mass 1 kg moving with a speed of 10 ms^{-1} rebounds after a perfect elastic collision with the floor. Calculate the change in linear momentum of the ball.
3. A mechanic unscrew a nut by applying a force of 140 N with a spanner of length 40 cm. What should be the length of the spanner if a force of 40 N is applied to unscrew the same nut?
4. The ratio of masses of two planets is 2:3 and the ratio of their radii is 4:7 Find the ratio of their accelerations due to gravity.

VIII. Answer in detail.

1. What are the types of inertia? Give an example for each type.
2. State Newton's laws of motion?
3. Deduce the equation of a force using Newton's second law of motion.
4. State and prove the law of conservation of linear momentum.
5. Describe rocket propulsion.
6. State the universal law of gravitation and derive its mathematical expression
7. Give the applications of universal law gravitation.

IX. HOT Questions

1. Two blocks of masses 8 kg and 2 kg respectively lie on a smooth horizontal surface in contact with one other. They are pushed by a horizontally applied force of 15 N. Calculate the force exerted on the 2 kg mass.
2. A heavy truck and bike are moving with the same kinetic energy. If the mass of the truck is four times that of the bike, then calculate the ratio of their momenta. (Ratio of momenta = 1:2
3. "Wearing helmet and fastening the seat belt is highly recommended for safe journey" Justify your answer using Newton's laws of motion.

REFERENCE BOOKS

- Concept of physics-HC verma
- Interactive physics(Newton's law)MTG learning.

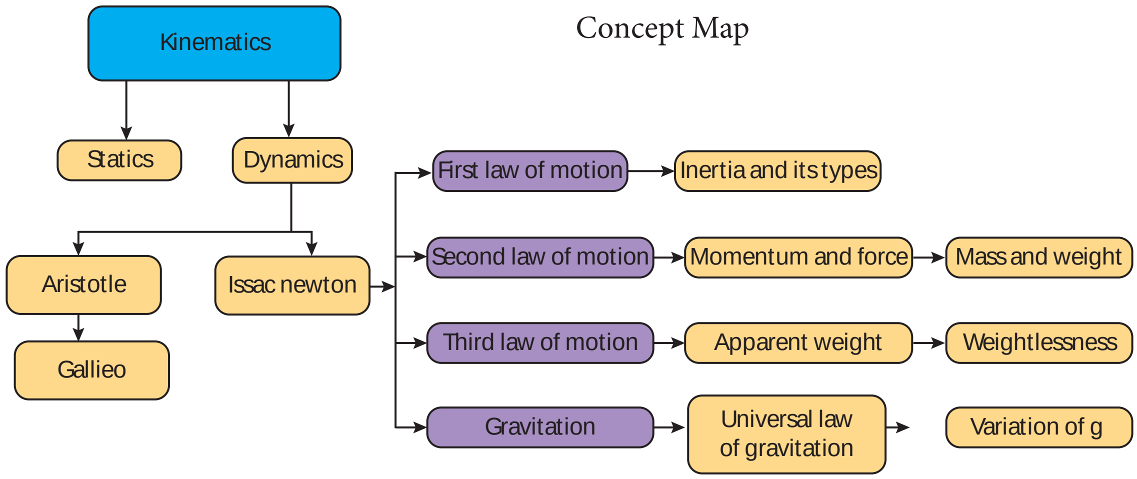
INTERNET RESOURCES

https://www.grc.nasa.gov

https://www.physicsclassroom.com

https://www.britannica.com/science/Newtons-law-of-gravitation

Concept Map



ICT CORNER

Newton's second law

Steps

- Open the browser and type "olabs.edu.in" in the address bar. Click physics tab and then click "Newton's second " under class 9 section. Go to "simulator" tab to do the experiment.
- Select the desired Cart mass (M_1) and vertical mass (M_2) using respective slider. Also select the desired distance (s) by moving the slider. Click on the "Start" button to start the experiment.
- Observe the time and note it down. Calculate acceleration (a) of the cart using the formula $a = 2s/t^2$. Find the fore due to rate of change of momentum using (M_1+M_2) a.
- Calculate force $F = M_2$ g.
- You will observe $(M_1+M_2)a = M_2 g$. Hence Newton's Second Law is verified. Repeat the experiment with different masses. Also do this in different environment like Earth, Moon, Uranus and Jupiter. Click reset to restart the experiment.

Link

http://amrita.olabs.edu.in/?sub=1&brch=1&sim=44&cnt=4

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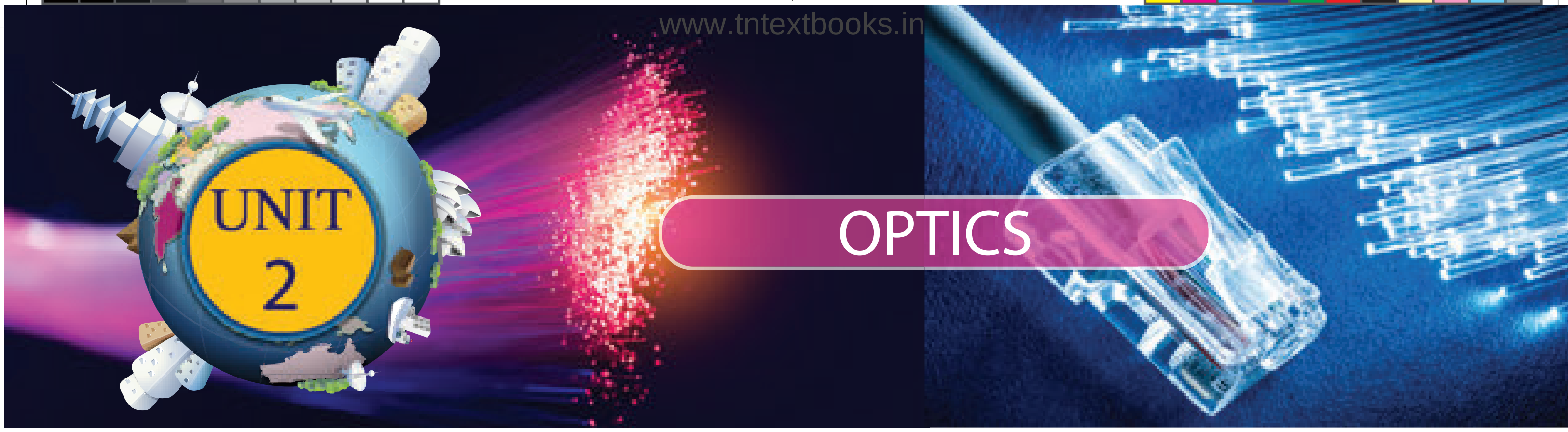

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Learning Objectives

At the end of this lesson, students will be able to:

- state the laws of refraction.
- list the properties of light.
- explain the scattering of light and its various kinds.
- understand the images formed by concave and convex lens.
- analyze the ray diagram of concave and convex lens.
- understand the working of human eye and optical instruments
- solve numerical problems

INTRODUCTION

Light is a form of energy which travels in the form of waves. The path of light is called ray of light and group of these rays are called as beam of light. Any object which gives out light are termed as source of light. Some of the sources emit their own light and they are called as luminous objects. All the stars, including the Sun, are examples for luminous objects. We all know that we are able to see objects with the help of our eyes. But, we cannot see any object in a dark room. Can you explain why? If your answer is 'we need light to see objects', the next question is 'if you make the light from a torch to fall on your eyes, will you be able to see the objects?' Definitely, 'NO'. We can see the objects only when the light is made to fall on the objects and the light reflected from the objects is viewed by our eyes. You would have studied about the reflection and refraction of light elaborately in your previous classes. In this chapter, we shall discuss about the scattering of light, images formed by convex and concave lenses, human eye and optical instruments such as telescopes and microscopes.

2.1 PROPERTIES OF LIGHT

Let us recall the properties of light and the important aspects on refraction of light.

1. Light is a form of energy.
2. Light always travels along a straight line.
3. Light does not need any medium for its propagation. It can even travel through vacuum.
4. The speed of light in vacuum or air is, $c = 3 \times 10^8\ ms^{-1}$.
5. Since, light is in the form of waves, it is characterized by a wavelength (λ) and a frequency (ν), which are related by the following equation: $c = \nu\lambda$ (c - velocity of light).

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6. Different coloured light has different wavelength and frequency.
7. Among the visible light, violet light has the lowest wavelength and red light has the highest wavelength.
8. When light is incident on the interface between two media, it is partly reflected and partly refracted.

2.2 REFRACTION OF LIGHT

When a ray of light travels from one transparent medium into another obliquely, the path of the light undergoes deviation. This deviation of ray of light is called refraction. Refraction takes place due to the difference in the velocity of light in different media. The velocity of light is more in a rarer medium and less in a denser medium. Refraction of light obeys two laws of refraction.

2.2.1 First law of refraction:

The incident ray, the refracted ray of light and the normal to the refracting surface all lie in the same plane.

2.2.2 Second law of refraction:

The ratio of the sine of the angle of incidence and sine of the angle of refraction is equal to the ratio of refractive indices of the two media. This law is also known as Snell's law.

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \quad \cdots\cdots\cdots\cdots \quad (2.1)$$

- Refractive index gives us an idea of how fast or how slow light travels in a medium. The ratio of speed of light in vacuum to the speed of light in a medium is defined as refractive index 'μ' of that medium.
- The speed of light in a medium is low if the refractive index of the medium is high and vice versa.
- When light travels from a denser medium into a rarer medium, the refracted ray is bent away from the normal drawn to the interface.
- When light travels from a rarer medium into a denser medium, the refracted ray is bent towards the normal drawn to the interface.

2.3 REFRACTION OF A COMPOSITE LIGHT-DISPERSION OF LIGHT

We know that Sun is the fundamental and natural source of light. If a source of light produces a light of single colour, it is known as a monochromatic source. On the other hand, a composite source of light produces a white light which contains light of different colours. Sun light is a composite light which consists of light of various colours or wavelengths. Another example for a composite source is a mercury vapour lamp. What do you observe when a white light is refracted through a glass prism?

When a beam of white light or composite light is refracted through any transparent media such as glass or water, it is split into its component colours. This phenomenon is called as 'dispersion of light'.

The band of colours is termed as spectrum. This spectrum consists of following colours: Violet, Indigo, Blue, Green, Yellow, Orange, and Red. These colours are represented by the acronym "VIBGYOR". Why do we get the spectrum when white light is refracted by a transparent medium? This is because, different coloured lights are bent through different angles. That is the angle of refraction is different for different colours.

Angle of refraction is the smallest for red and the highest for violet. From Snell's law, we know that the angle of refraction is determined in terms of the refractive index of the medium. Hence, the refractive index of the medium is different for different coloured lights. This indicates that the refractive index of a medium is dependent on the wavelength of the light.

2.4 SCATTERING OF LIGHT

When sunlight enters the Earth's atmosphere, the atoms and molecules of different gases present in the atmosphere refract the light in all possible directions. This is called as 'Scattering of light'. In this phenomenon, the beam of light is redirected in all directions when it interacts with a particle of medium. The interacting particle of the medium is called as 'scatterer'.

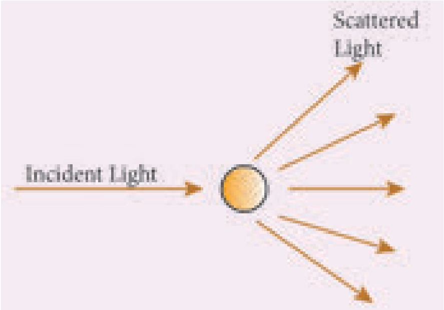

Figure 2.1 Scattering of light

2.4.1 Types of scattering

When a beam of light, interacts with a constituent particle of the medium, it undergoes many kinds of scattering. Based on initial and final energy of the light beam, scattering can be classified as,

1) Elastic scattering 2) Inelastic scattering

1) Elastic scattering

If the energy of the incident beam of light and the scattered beam of light are same, then it is called as 'elastic scattering'.

2) Inelastic scattering

If the energy of the incident beam of light and the scattered beam of light are not same, then it is called as 'inelastic scattering'. The nature and size of the scatterer results in different types of scattering. They are

- Rayleigh scattering
- Mie scattering
- Tyndall scattering
- Raman scattering

Rayleigh scattering

The scattering of sunlight by the atoms or molecules of the gases in the earth's atmosphere is known as Rayleigh scattering.

Rayleigh's scattering law

Rayleigh's scattering law states that, "The amount of scattering of light is inversely proportional to the fourth power of its wavelength".

Amount of scattering 'S' $\propto \frac{1}{\lambda^4}$

According to this law, the shorter wavelength colours are scattered much more than the longer wavelength colours.

When sunlight passes through the atmosphere, the blue colour (shorter wavelength) is scattered to a greater extent than the red colour (longer wavelength). This scattering causes the sky to appear in blue colour.

At sunrise and sunset, the light rays from the Sun have to travel a larger distance in the atmosphere than at noon. Hence, most of the blue lights are scattered away and only the red light which gets least scattered reaches us. Therefore, the colour of the Sun is red at sunrise and sunset.

Mie scattering

Mie scattering takes place when the diameter of the scatterer is similar to or larger than the wavelength of the incident light. It is also an elastic scattering. The amount of scattering is independent of wave length.

Mie scattering is caused by pollen, dust, smoke, water droplets, and other particles in the lower portion of the atmosphere.

Mie scattering is responsible for the white appearance of the clouds. When white light falls on the water drop, all the colours are equally scattered which together form the white light.

Tyndall Scattering

When a beam of sunlight, enters into a dusty room through a window, then its path becomes visible to us. This is because, the tiny dust particles present in the air of the room scatter the beam of light. This is an example of Tyndall Scattering

The scattering of light rays by the colloidal particles in the colloidal solution is called Tyndall Scattering or Tyndall Effect.

> **Do you Know**
>
> **Colloid** is a microscopically small substance that is equally dispersed throughout another material. Example: Milk, Ice cream, muddy water, smoke

Raman scattering

When a parallel beam of monochromatic (single coloured) light passes through a gas or liquid or transparent solid, a part of light rays are scattered.

The scattered light contains some additional frequencies (or wavelengths) other than that of incident frequency (or wavelength). This is known as Raman scattering or Raman Effect.

Raman Scattering is defined as *"The interaction of light ray with the particles of pure liquids or transparent solids, which leads to a change in wavelength or frequency."*

The spectral lines having frequency equal to the incident ray frequency is called 'Rayleigh line' and the spectral lines which are having frequencies other than the incident ray frequency are called 'Raman lines'. The lines having frequencies lower than the incident frequency is called stokes lines and the lines having frequencies higher than the incident frequency are called Antistokes lines.

You will study more about Raman Effect in higher classes.

2.5 LENSES

A lens is an optically transparent medium bounded by two spherical refracting surfaces or one plane and one spherical surface.

Lens is basically classified into two types. They are: (i) Convex Lens (ii) Concave Lens

(i) **Convex or bi-convex lens:** It is a lens bounded by two spherical surfaces such that it is thicker at the centre than at the edges. A beam of light passing through it, is converged to a point. So, a convex lens is also called as converging lens.

(ii) **Concave or bi-concave Lens:** It is a lens bounded by two spherical surfaces such that it is thinner at the centre than at the edges. A parallel beam of light passing through it, is diverged or spread out. So, a concave lens is also called as diverging lens.

2.5.1 Other types of Lenses

Plano-convex lens: If one of the faces of a bi-convex lens is plane, it is known as a plano-convex lens.

Plano-concave lens: If one of the faces of a bi-concave lens is plane, it is known as a plano-concave lens.

All these lenses are shown in Figure 2.2 given below:

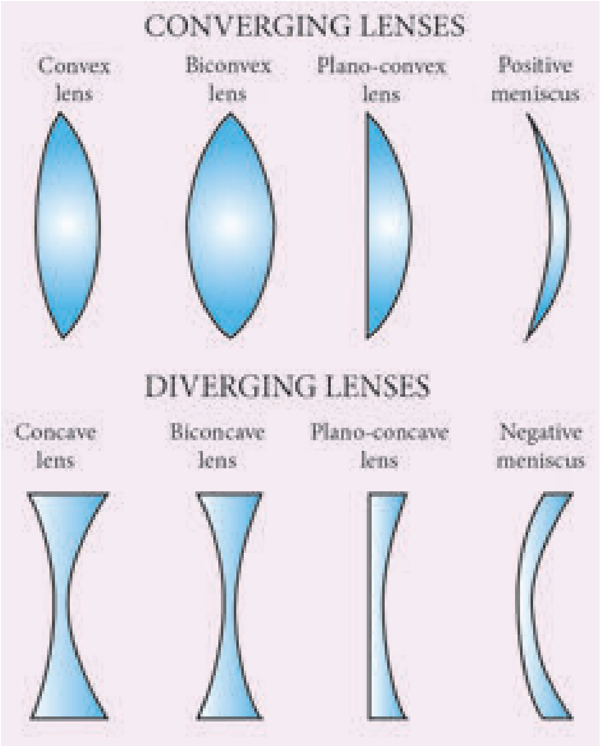

Figure 2.2 Types of lenses

2.6 IMAGES FORMED DUE TO REFRACTION THROUGH A CONVEX AND CONCAVE LENS

When an object is placed in front of a lens, the light rays from the object fall on the lens. The position, size and nature of the image formed can be understood only if we know certain basic rules.

Rule-1: When a ray of light strikes the convex or concave lens obliquely at its optical centre, it continues to follow its path without any deviation (Figure 2.3).

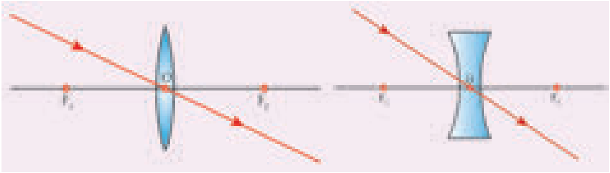

Figure 2.3 Rays passing through the optical centre

Rule-2: When rays parallel to the principal axis strikes a convex or concave lens, the refracted rays are converged to (convex lens) or appear to diverge from (concave lens) the principal focus (Figure 2.4).

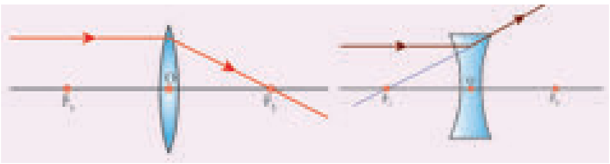

Figure 2.4 Rays passing parallel to the optic axis

Rule-3: When a ray passing through (convex lens) or directed towards (concave lens) the principal focus strikes a convex or concave lens, the refracted ray will be parallel to the principal axis (Figure 2.5).

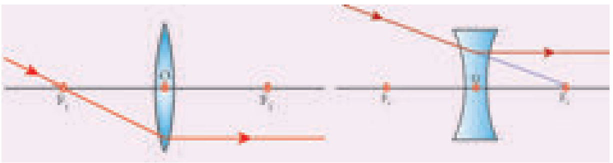

Figure 2.5 Rays passing through or directed towards the principal focus

2.7 REFRACTION THROUGH A CONVEX LENS

Let us discuss the formation of images by a convex lens when the object is placed at various positions.

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Object at infinity

When an object is placed at infinity, a real image is formed at the principal focus. The size of the image is much smaller than that of the object (Figure 2.6).

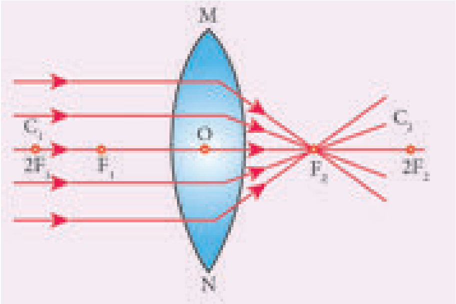


Figure 2.6 Object at infinity

Object placed beyond C (>2F)

When an object is placed behind the center of curvature(beyond C), a real and inverted image is formed between the center of curvature and the principal focus. The size of the image is the same as that of the object (Figure 2.7).

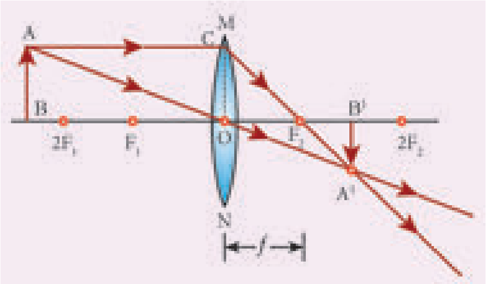


Figure 2.7 Object placed beyond C (>2F)

Object placed at C

When an object is placed at the center of curvature, a real and inverted image is formed at the other center of curvature. The size of the image is the same as that of the object (Figure 2.8).

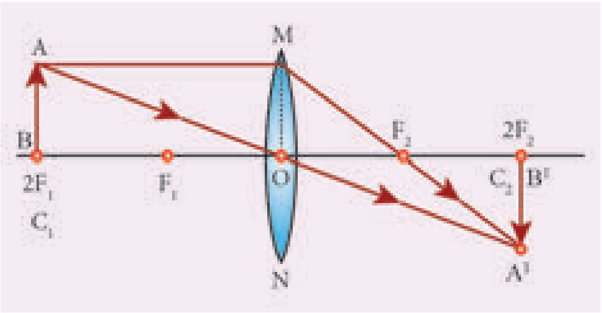


Figure.2.8 Object placed at C

Object placed between F and C

When an object is placed in between the center of curvature and principal focus, a real and inverted image is formed behind the center of curvature. The size of the image is bigger than that of the object (Figure 2.9).

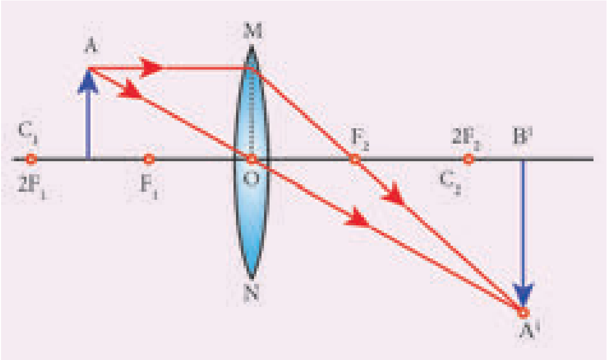


Figure 2.9 Object placed between F and C

Object placed at the principal focus F

When an object is placed at the focus, a real image is formed at infinity. The size of the image is much larger than that of the object (Figure 2.10).

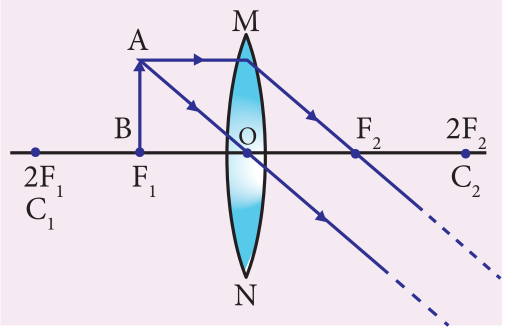


Figure 2.10 Object placed at the principal focus F

Object placed between the principal focus F and optical centre O

When an object is placed in between principal focus and optical centre, a virtual image is formed. The size of the image is larger than that of the object (Figure 2.11).

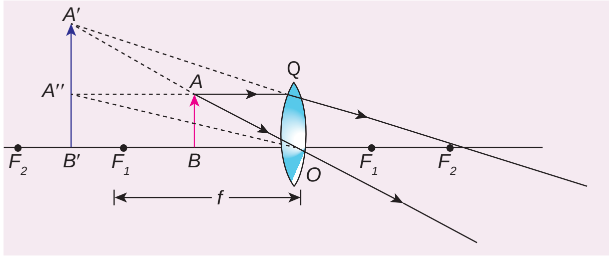


Figure 2.11 Object placed between the principal focus F and optical centre O

2.8 APPLICATIONS OF CONVEX LENSES

1. Convex lenses are used as camera lenses
2. They are used as magnifying lenses
3. They are used in making microscope, telescope and slide projectors
4. They are used to correct the defect of vision called hypermetropia

2.9 REFRACTION THROUGH A CONCAVE LENS

Let us discuss the formation of images by a concave lens when the object is placed at two possible positions.

Object at Infinity

When an object is placed at infinity, a virtual image is formed at the focus. The size of the image is much smaller than that of the object (Figure 2.12).

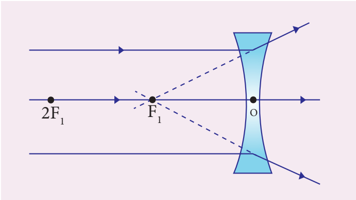


Figure 2.12 Concave lens-Object at infinity

Object anywhere on the principal axis at a finite distance

When an object is placed at a finite distance from the lens, a virtual image is formed between optical center and focus of the concave lens. The size of the image is smaller than that of the object (Figure 2.13).

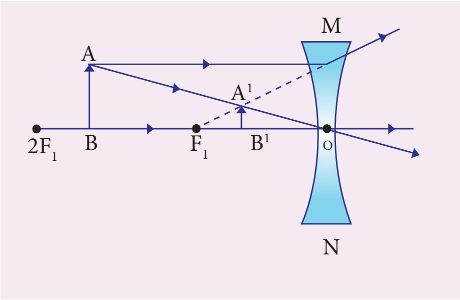


Figure 2.13 Concave lens-Object at a finite distance

But, as the distance between the object and the lens is decreased, the distance between the image and the lens also keeps decreasing. Further, the size of the image formed increases as the distance between the object and the lens is decreased. This is shown in (figure 2.14).

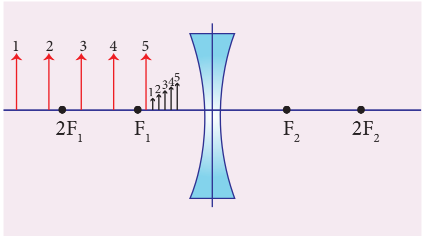


Figure 2.14 Concave lens-Variation in position and size of image with object distance

2.10 APPLICATIONS OF CONCAVE LENSES

1. Concave lenses are used as eye lens of 'Galilean Telescope'
2. They are used in wide angle spy hole in doors.
3. They are are used to correct the defect of vision called 'myopia'

2.11 LENS FORMULA

Like spherical mirrors, we have lens formula for spherical lenses. The lens formula gives the relationship among distance of the object (u), distance of the image (v) and the focal length (f) of the lens. It is expressed as

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \quad \ldots\ldots\ldots\ldots \quad 2.2$$

It is applicable to both convex and concave lenses. We need to give an at most care while solving numerical problems related to lenses in taking proper signs of different quantities.

2.12 SIGN CONVENTION

Cartesian sign conventions are used for measuring the various distances in the ray diagrams of spherical lenses. According to cartesian sign convention,

1. The object is always placed on the left side of the lens.
2. All the distances are measured from the optical centre of the lens.
3. The distances measured in the same direction as that of incident light are taken as positive.
4. The distances measured against the direction of incident light are taken as negative.
5. The distances measured upward and perpendicular to the principal axis is taken as positive.
6. The distances measured downward and perpendicular to the principal axis is taken as negative.

2.13 MAGNIFICATION OF A LENS

Like spherical mirrors, we have magnification for spherical lenses. Spherical lenses produce magnification and it is defined as the ratio of the height of the image to the height of an object. Magnification is denoted by the letter 'm'. If height of the object is h and height of the image is h' , the magnification produced by lens is,

$$m = \frac{\textit{height of the image}}{\textit{height of the object}} = \frac{h'}{h} \quad \ldots\ldots (2.3)$$

Also it is related to the distance of the object (u) and the distance of the image (v) as follows:

$$m = \frac{\textit{Distance of the image}}{\textit{Distance of the object}} = \frac{v}{u} \quad \ldots\ldots (2.4)$$

If the magnification is greater than 1, then we get an enlarged image. On the other hand, if the magnification is less than 1, then we get a diminished image.

2.14 LENS MAKER'S FORMULA

All lenses are made up of transparent materials. Any optically transparent material will have a refractive index. The lens formula relates the focal length of a lens with the distance of object and image. For a maker of any lens, knowledge of radii of curvature of the lens is required. This clearly indicates the need for an equation relating the radii of curvature of the lens, the refractive index of the given material of the lens and the required focal length of the lens. The lens maker's formula is one such equation. It is given as

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \cdots\cdots\cdots (2.5)$$

where μ is the refractive index of the material of the lens; R_1 and R_2 are the radii of curvature of the two faces of the lens; f is the focal length of the lens.

2.15 POWER OF A LENS

When a ray of light falls on a lens, the ability to converge or diverge these light rays depends on the focal length of the lens. This ability of a lens to converge (convex lens) or diverge (concave lens) is called as its power. Hence, the power of a lens can be defined as the degree of convergence or divergence of light rays. Power of a lens is numerically defined as the reciprocal of its focal length.

$$P = \frac{1}{f} \cdots\cdots\cdots\cdots\cdots (2.6)$$

The SI unit of power of a lens is dioptre. It is represented by the symbol D. If focal length is expressed in 'm', then the power of lens is expressed in 'D'. Thus 1D is the power of a lens, whose focal length is 1metre. $1D = 1m^{-1}$.

By convention, the power of a convex lens is taken as positive whereas the power of a concave lens is taken, as negative.

More to Know

The lens formula and lens maker's formula are applicable to only thin lenses. In the case of thick lenses, these formulae with little modifications are used.

Table 2.1 Differences between a Convex Lens and a Concave Lens

S. No	Convex Lens	Concave Lens
1	A convex lens is thicker in the middle than at edges.	A concave lens is thinner in the middle than at edges.
2	It is a converging lens.	It is a diverging lens.
3	It produces mostly real images.	It produces virtual images.
4	It is used to treat hypermeteropia.	It is used to treat myopia.

2.16 HUMAN EYE

The human eyes are most valuable and sensitive organs responsible for vision. They are the gateway to the wonderful world.

Structure of the eye

The eye ball is approximately spherical in shape with a diameter of about 2.3 cm. It consists of a tough membrane called sclera, which protects the internal parts of the eye.

Important parts of human eye are

Cornea: This is the thin and transparent layer on the front surface of the eyeball as shown in figure 2.15. It is the main refracting surface. When light enters through the cornea, it refracts or bends the light on to the lens.

Iris: It is the coloured part of the eye. It may be blue, brown or green in colour. Every person has a unique colour, pattern and texture. Iris controls amount of light entering into the pupil like camera aperture.

Pupil: It is the centre part of the Iris. It is the pathway for the light to retina.

Retina: This is the back surface of the eye. It is the most sensitive part of human eye, on which real and inverted image of objects is formed.

Ciliary muscles – Eye lens is fixed between the ciliary muscles. It helps to change the focal length of the eye lens according to the position of the object.

Eye Lens – It is the important part of human eye. It is convex in nature.

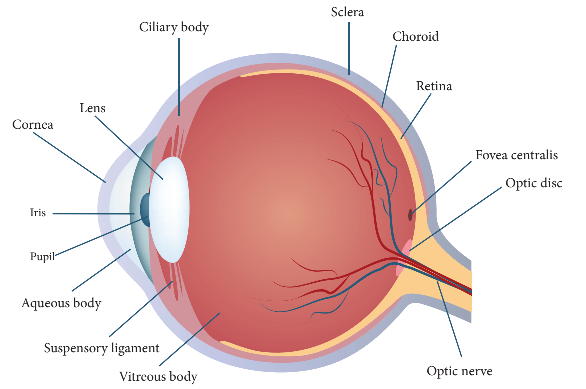


Figure 2.15 Human eye

Working of the eye

The transparent layer cornea bends the light rays through pupil located at the centre part of the Iris. The adjusted light passes through the eye lens. Eye lens is convex in nature. So, the light rays from the objects are converged and a real and inverted image is formed on retina. Then, retina passes the received real and inverted image to the brain through optical nerves. Finally, the brain senses it as erect image.

Power of Accommodation

The ability of the eye lens to focus nearby as well as the distant objects is called power of accommodation of the eye. This is achieved by changing the focal length of the eye lens with the help of ciliary muscles.

Eye lens is made of a flexible, jelly-like material. By relaxing and contracting the ciliary muscle, the curvature and hence the focal length of the eye lens can be altered. When we see distant objects, the ciliary muscle relaxes and makes the eye lens thinner. This increases the focal length of the eye lens. Hence, the distant object can be clearly seen. On the other hand, when we look at a closer object, the focal length of the eye lens is decreased by the contraction of ciliary muscle. Thus, the image of the closer object is clearly formed on the retina.

Persistence of vision

If the time interval between two consecutive light pulses is less than 0.1 second, human eye cannot distinguish them separately. It is called persistence of vision.

The far point and near point of the human eye

The minimum distance required to see the objects distinctly without strain is called least distance of distinct vision. It is called as near point of eye. It is 25 cm for normal human eye.

The maximum distance up to which the eye can see objects clearly is called as far point of the eye. It is infinity for normal eye.

2.17 DEFECTS IN EYE

A normal human eye can clearly see all the objects placed between 25cm and infinity. But, for some people, the eye loses its power of accommodation. This could happen due to many reasons including ageing. Hence, their vision becomes defective. Let us discuss some of the common defects of human eye.

Myopia

Myopia, also known as short sightedness, occurs due to the lengthening of eye ball. With this defect, nearby objects can be seen clearly but distant objects cannot be seen clearly. The focal length of eye lens is reduced or the distance between eye lens and retina increases. Hence, the far point will not be infinity for such eyes and the far point has come closer. Due to this, the image of distant objects are formed before the retina (Figure 2.16-a). This defect can be corrected using a concave lens (Figure 2.16-b). The focal length of the concave lens to be used is computed as follows:

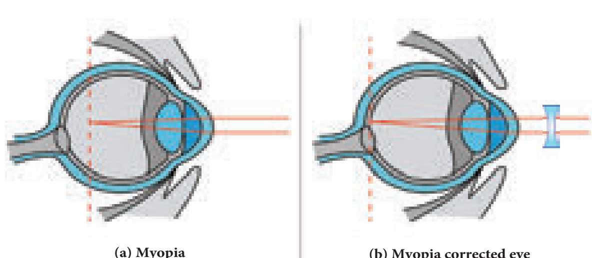


Figure 2.16 (a) Vision with myopia
b) Corrected vision using a concave lens

Let a person with myopia eye can see up to a distance x. Suppose that he wants to see all objects farther than this distance, i.e., up to infinity. Then the focal length of the required concave lens is f = –x. If the person can see up to a distance x and he wants to see up to a distance y, then, the focal length of the required concave lens is,

$$f = \frac{xy}{x-y} \quad \text{..............} (2.7)$$

Hypermeteropia

Hypermeteropia, also known as long sightedness, occurs due to the shortening of eye ball. With this defect, distant objects can be seen clearly but nearby objects cannot be seen clearly. The focal length of eye lens is increased or the distance between eye lens and retina decreases. Hence, the near point will not be at 25cm for such eyes and the near point has moved farther. Due to this, the image of nearby objects are formed behind the retina (Figure 2.17-a). This defect can be corrected using a convex lens (Figure 2.17-b). The focal length of the convex lens to be used is computed as follows:

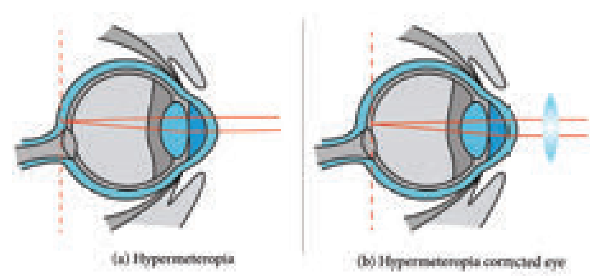


Figure 2.17 (a) Vision with hypermeteropia
(b) Corrected vision using a convex lens

Let a person with hypermeteropia eye can see object beyond a distance d. Suppose that he wants to see all objects closer than this distance up to a distance D. Then, the focal length of the required convex lens is

$$f = \frac{dD}{d-D} \quad \text{..............} (2.8)$$

Presbyopia

Due to ageing, ciliary muscles become weak and the eye-lens become rigid (inflexible) andso the eye loses its power of accommodation.

Because of this, an aged person cannot see the nearby objects clearly. So, it is also called as 'old age hypermetropia'.

Some persons may have both the defects of vision - myopia as well as hypermetropia. This can be corrected by 'bifocal lenses'. In which, upper part consists of concave lens (to correct myopia) used for distant vision and the lower part consists of convex lens (to correct hypermetropia) used for reading purposes.

Astigmatism

In this defect, eye cannot see parallel and horizontal lines clearly. It may be inherited or acquired. It is due to the imperfect structure of eye lens because of the development of cataract on the lens, ulceration of cornea, injury to the refracting surfaces, etc. Astigmatism can be corrected by using cylindrical lenses (Torrid lenses).

2.18 MICROSCOPE

This is an optical instrument, which helps us to see tiny (very small) objects. It is classified as

1. Simple microscope
2. Compound microscope

Simple Microscope

Simple microscope has a convex lens of short focal length. It is held near the eye to get enlarged image of small objects.

Let an object (AB) is placed at a point within the principal focus (u < f) of the convex lens and the observer's eye is placed just behind

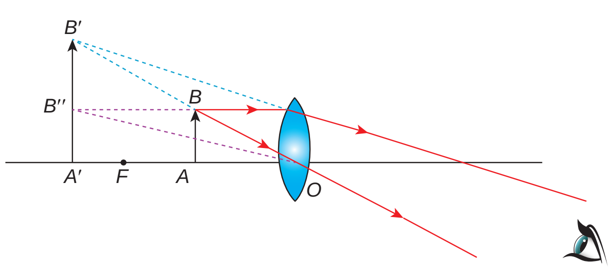


Figure 2.18 Image formation in simple microscope

the lens. As per this position the convex lens produces an erect, virtual and enlarged image (A'B'). The image formed is in the same side of the object and the distance equal to the least distance of distinct vision (D) (For normal human eye D = 25 cm).

Uses of Simple microscope

Simple microscopes are used

a) by watch repairers and jewellers.
b) to read small letters clearly.
c) to observe parts of flower, insects etc.
d) to observe finger prints in the field of forensic science.

Compound microscope

Compound microscope is also used to see the tiny objects. It has better magnification power than simple microscope.

Magnification power of microscopes can be increased by decreasing the focal length of the lens used. Due to constructional limitations, the focal length of the lens cannot be decreased beyond certain limit. This problem can be solved by using two separate biconvex lenses.

Construction

A compound microscope consists of two convex lenses. The lens with the shorter focal length is placed near the object, and is called as 'objective lens' or 'objective piece'. The lens with larger focal length and larger aperture placed near the observer's eye is called as 'eye lens' or 'eye piece'. Both the lenses are fixed in a narrow tube with adjustable provision.

Working

The object (AB) is placed at a distance slightly greater than the focal length of objective lens ($u > f_o$). A real, inverted and magnified image (A'B') is formed at the other

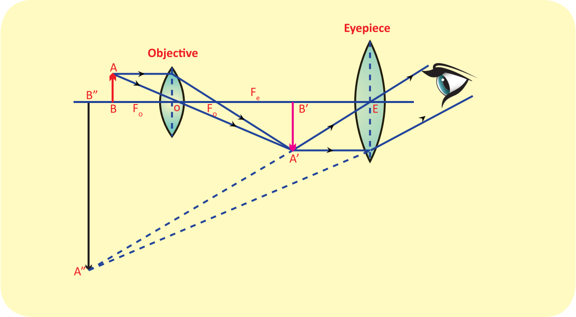


Figure 2.19 Image formation in compound microscope

side of the objective lens. This image behaves as the object for the eye lens. The position of the eye lens is adjusted in such a way, that the image (A'B') falls within the principal focus of the eye piece. This eye piece forms a virtual, enlarged and erect image (A″B″) on the same side of the object

Compound microscope has 50 to 200 times more magnification power than simple microscope

Travelling Microscope

A **travelling microscope** is one of the best instrument for measuring very small length with high degree of accuracy at the order of 0.01mm. It works based on the principle of vernier. Its least count is 0.01 mm.

2.19 TELESCOPE

Have you seen the recent lunar eclipse? With our naked eye we can't visualize the phenomena distinctly. Then, how can we see the distant object in clearer manner? It is possible with telescope.

Telescope is an optical instrument to see the distant objects. The first telescope was invented by Johann Lippershey in 1608. Galileo made a telescope to observe distant stars. He got the idea, from a spectacle maker who one day observed that the distant weather cock appeared magnified through his lens system fitted in his shop. Galileo observed the satellites of Jupiter and the rings of Saturn through his telescope. Kepler invented Telescope in 1611 which was fundamentally similar to the astronomical telescope.

Types of Telescope

According to optical property, it is classified into two groups:

i) refracting telescope ii) reflecting telescope

In **refracting telescope** lenses are used. Galilean telescope, Keplerian telescope, Achromatic refractors, are some refracting telescopes.

In **reflecting telescope** parabolic mirrors are used Gregorian, Newtonian, Cassegrain telescope are some **Reflecting telescopes**

According to the things which are observed, **Astronomical Telescope** and **Terrestrial Telescopes** are the two major types of telescope.

Astronomical Telescope

An astronomical telescope is used to view heavenly bodies like stars, planets galaxies and satellites.

Terrestrial Telescopes

The image in an astronomical telescope is inverted. So, it is not suitable for viewing objects on the surface of the Earth. Therefore, a terrestrial telescope is used. It provides an erect image. The major difference between astronomical and terrestrial telescope is erecting the final image with respect to the object.

Advantages of Telescopes

- Elaborate view of the Galaxies, Planets, stars and other heavenly bodies is possible.
- Camera can be attached for taking photograph for the celestial objects.
- Telescope can be viewed even with the low intensity of light.

Disadvantages

- Frequent maintenances needed.
- It is not easily portable one.

Points to Remember

- Light is a form of energy which travels along a straight line
- The deviation in the path of light ray is called refraction.
- The ratio of speed of light in vacuum to the speed of light in a medium is defined as refractive index 'μ' of that medium.
- Lens formula

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

- Magnification (m) $= \frac{h'}{h} = \frac{v}{u}$
- Power of lens. P $= \frac{1}{f}$
- The ability of the eye to focus nearby as well as the distant objects is called power of accommodation of the eye.
- A microscope is an optical instrument which helps us to see the objects which are very small in dimension.
- Telescope is an optical instrument used to see the distant objects clearly.

SOLVED PROBLEMS

Problem 1

Light rays travel from vacuum into a glass whose refractive index is 1.5. If the angle of incidence is 30°, calculate the angle of refraction inside the glass.

Solution:

accorting to Snell's law,

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1}$$

$$\mu_1 \sin i = \mu_2 \sin r$$

Here $\mu_1 = 1.0$, $\mu_2 = 1.5$, $i = 30°$

$$(1.0) \sin 30° = 1.5 \sin r$$

$$1 \times \frac{1}{2} = 1.5 \sin r$$

$$\sin r = \frac{1}{2 \times 1.5} = \frac{1}{3} = (0.333)$$

$$r = \sin^{-1}(0.333)$$

$$r = 19.45°$$

Problem-2

A beam of light passing through a diverging lens of focal length 0.3m appear to be focused at a distance 0.2m behind the lens. Find the position of the object.

Solution:

f = −0.3 m, v = −0.2 m

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{1}{u} = \frac{1}{v} - \frac{1}{f}$$

$$\frac{1}{u} = \frac{1}{-0.2} - \frac{1}{-0.3} = \frac{-10}{6}$$

$$u = \frac{-6}{10} = -0.6 \text{ m}$$

Problem-3

A person with myopia can see objects placed at a distance of 4m. If he wants to see objects at a distance of 20m, what should be the focal length and power of the concave lens he must wear?

Solution:

Given that x = 4m and y = 20m.

Focal length of the correction lens is

$$f = \frac{xy}{x-y} \quad \text{(Refer eqn.2.7)}$$

$$f = \frac{4 \times 20}{4 - 20} = \frac{80}{-16} = -5 \text{ m}$$

Power of the correction lens

$$= \frac{1}{f} = -\frac{1}{5} = -0.2 \text{ D}$$

Problem-4

For a person with hypermeteropia, the near point has moved to 1.5m. Calculate the focal length of the correction lens in order to make his eyes normal.

Solution:

Given that, d = 1.5m; D = 25cm = 0.25m (For a normal eye).

From equation (2.8), the focal length of the correction lens is

$$f = \frac{d \times D}{d - D} = \frac{1.5 \times 0.25}{1.5 - 0.25} = \frac{0.375}{1.25} = 0.3 \text{ m}$$

6E5CJ2

TEXTBOOK EVALUATION

I. Choose the correct answer

1. The refractive index of four substances A, B, C and D are 1.31, 1.43, 1.33, 2.4 respectively. The speed of light is maximum in

   a) A b) B c) C d) D

2. Where should an object be placed so that a real and inverted image of same size is obtained by a convex lens

   a) f b) 2f
   c) infinity d) between f and 2f

3. A small bulb is placed at the principal focus of a convex lens. When the bulb is switched on, the lens will produce

   a) a convergent beam of light
   b) a divergent beam of light
   c) a parallel beam of light
   d) a coloured beam of light

4. Magnification of a convex lens is

   a) Positive b) negative
   c) either positive or negative d) zero

5. A convex lens forms a real, diminished point sized image at focus. Then the position of the object is at

   a) focus b) infinity
   c) at 2f d) between f and 2f

6. Power of a lens is –4D, then its focal length is

   a) 4m b) –40m
   c) –0.25 m d) –2.5 m

7. In a myopic eye, the image of the object is formed

   a) behind the retina b) on the retina
   c) in front of the retina d) on the blind spot

8. The eye defect 'presbyopia' can be corrected by

   a) convex lens b) concave lens
   c) convex mirror d) Bi focal lenses

9. Which of the following lens would you prefer to use while reading small letters found in a dictionary?

   a) A convex lens of focal length 5 cm
   b) A concave lens of focal length 5 cm
   c) A convex lens of focal length 10 cm
   d) A concave lens of focal length 10 cm

10. If V_B, V_G, V_R be the velocity of blue, green and red light respectively in a glass prism, then which of the following statement gives the correct relation?

    a) $V_B = V_G = V_R$ b) $V_B > V_G > V_R$
    c) $V_B < V_G < V_R$ d) $V_B < V_G > V_R$

II. Fill in the blanks:

1. The path of the light is called as ________
2. The refractive index of a transparent medium is always greater than ________
3. If the energy of incident beam and the scattered beam are same, then the scattering of light is called as ________ scattering.
4. According to Rayleigh's scattering law, the amount of scattering of light is inversely proportional to the fourth power of its ________
5. Amount of light entering into the eye is controlled by ________

III. True or False. If false correct it.

1. Velocity of light is greater in denser medium than in rarer medium
2. The power of lens depends on the focal length of the lens
3. Increase in the converging power of eye lens cause 'hypermetropia'
4. The convex lens always gives small virtual image.

IV. Match the following:

	Column - I		Column - II
1	Retina	a	Path way of light
2	Pupil	b	Far point comes closer
3	Ciliary muscles	c	near point moves away
4	Myopia	d	Screen of the eye
5	Hypermetropia	f	Power of accommodation

V. Assertion and reasoning type

Mark the correct choice as

a) If both assertion and reason are true and reason is the correct explanation of assertion.
b) If both assertion and reason are true but reason is not the correct explanation of assertion.
c) Assertion is true but reason is false.
d) Assertion is false but reason is true.

1. **Assertion:** If the refractive index of the medium is high (denser medium) the velocity of the light in that medium will be small

   Reason: Refractive index of the medium is inversely proportional to the velocity of the light
2. **Assertion:** Myopia is due to the increase in the converging power of eye lens.

   Reason: Myopia can be corrected with the help of concave lens.

VI. Answer Briefly

1. What is refractive index?
2. State Snell's law.
3. Draw a ray diagram to show the image formed by a convex lens when the object is placed between F and 2F.
4. Define dispersion of light
5. State Rayleigh's law of scattering
6. Differentiate convex lens and concave lens.
7. What is power of accommodation of eye?
8. What are the causes of 'Myopia'?
9. Why does the sky appear in blue colour?
10. Why are traffic signals red in colour?

VII. Give the answer in detail

1. List any five properties of light
2. Explain the rules for obtaining images formed by a convex lens with the help of ray diagram.
3. Differentiate the eye defects: Myopia and Hypermetropia
4. Explain the construction and working of a 'Compound Microscope'.

VIII. Numerical Problems:

1. An object is placed at a distance 20cm from a convex lens of focal length 10cm. Find the image distance and nature of the image.
2. An object of height 3cm is placed at 10cm from a concave lens of focal length 15cm. Find the size of the image.

IX. Higher order thinking (HOT) questions:

1. While doing an experiment for the determination of focal length of a convex lens, Raja Suddenly dropped the lens. It got broken into two halves along the axis. If he continues his experiment with the same lens, (a) can he get the image? (b) Is there any change in the focal length?
2. The eyes of the nocturnal birds like owl are having a large cornea and a large pupil. How does it help them?

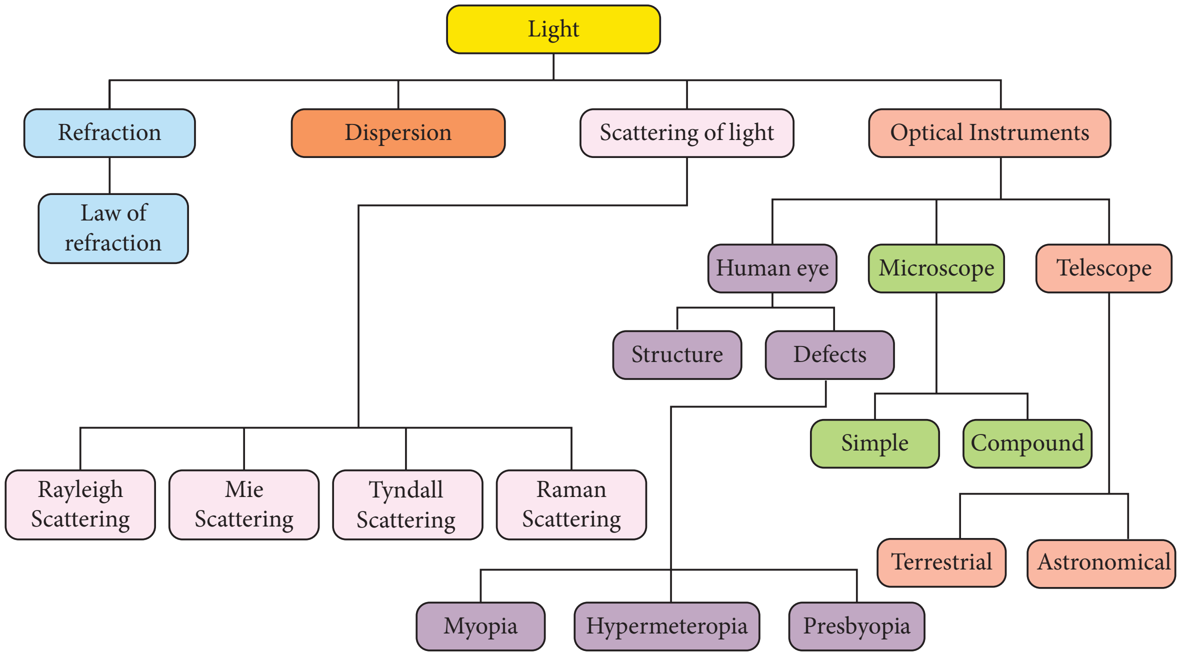
REFERENCE BOOKS

1. Fundamentals of optics by D.R. Khanna and H.R. Gulati, R. Chand & Co.
2. Principles of Physics – Halliday, Resnick & Walker, Wiley Publications, New Delhi.

INTERNET RESOURCES

1. www.physicsabout.com
2. www.khanacademy.org

Concept Map



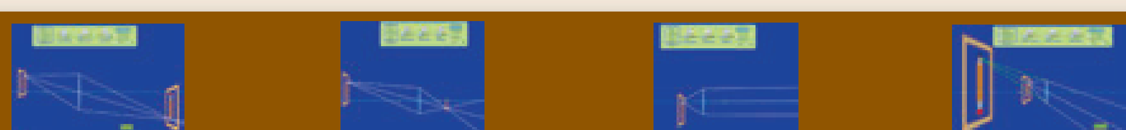
ICT CORNER

Formation of different types of images by a convex lens

In this activity you will be able to understand the images formed by convex lenses.

Steps

- Open the browser and type 'phet.colorado.edu/en/simulation/legacy/geometric-optics' in the address bar.
- Take the pencil and raise it so that the eraser is sitting on the principal axis. Click on the "principal rays" button.
- Place the object at different positions (infinity, beyond 2F, at 2F, between F and 2F, at F, between F and optic centre) from a convex lens and observe different types of images. Explain the result.
- Will the rays ever form an image? Click on "virtual image" to check your answer.



Step1 **Step2** **Step3** **Step4**

Cells alive

URL: https://phet.colorado.edu/en/simulation/legacy/geometric-optics

*Pictures are indicative only

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UNIT 3

THERMAL PHYSICS

Learning Objectives

6TEBIQ

At the end of this lesson, students will be able to

- Understand the concept of heat and temperature
- Know the absolute scale of temperature
- Understand the thermal energy and the thermal equilibrium
- Classification of expansion of substances
- Know the fundamental laws of gases
- Distinguish between real gas and ideal gas
- Derive the ideal gas equation
- Solve the numerical problems

INTRODUCTION

Sun is the primary source of thermal energy for all living organisms. Thermal energy is the cause and temperature is the effect. All living organisms need a particular temperature for their survival. In the kitchen, a container with a steel bottom is placed on the induction stove. Do you know why? All of us have a common man's understanding of thermal energy and temperature. But, in this chapter, you shall learn about thermal energy and temperature in a scientific manner. We shall also discuss about how thermal energy is transferred and the effects of thermal energy.

3.1 TEMPERATURE

Temperature is defined as the degree of hotness of a body. The temperature is higher for a hotter body than for a colder body. It is also be defined as the property which determines whether a body is in equilibrium or not with the surroundings. (or average kinetic enegy of the molecules). Further, temperature is the property, which determines the direction of flow of heat. It is a scalar quantity. The SI unit of temperature is kelvin (K). There are other commonly used units of temperature such as degree celsius (°C) and degree fahrenheit (°F).

3.1.1 Absolute scale (kelvin scale) of temperature

The temperature measured in relation to absolute zero using the kelvin scale is known as absolute temperature. It is also known as the **thermodynamic temperature.** Each unit of the thermodynamic scale of temperature is defined as the fraction of 1/273.16th part of the thermodynamic temperature of the triple point of water. A temperature difference of 1°C is equal to that of 1K. Zero Kelvin is the absolute scale of tempeture of the body.

The relation between the different types of scale of temperature:

Celsius and Kelvin: $K = C + 273$,

Fahrenheit and Kelvin: $[K] = (F + 460) \times \frac{5}{9}$

$0\,K = -273°C$.

3.1.2 Thermal equilibrium

Two or more physical systems or bodies are said to be in thermal equilibrium if there is no net flow of thermal energy between the systems. Heat energy always flows from one body to the other due to a temperature difference between them. Thus, you can define thermal equilibrium in another way. If two bodies are said to be in thermal equilibrium, then, they will be at the same temperature. What will happen if two bodies at different temperatures are brought in contact with one other? There will be a transfer of heat energy from the hot body to the cold body until a thermal equilibrium is established between them. This is depicted in Figure 3.1.

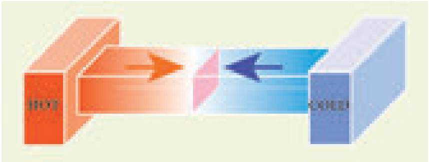

Figure 3.1 Establishing thermal equilibrium

When a cold body is placed in contact with a hot body, some thermal energy is transferred from the hot body to the cold body. As a result, there is some rise in the temperature of the cold body and decrease in the temperature of the hot body. This process will continue until these two bodies attain the same temperature.

3.2 THERMAL ENERGY

If you leave a cup of hot milk on a table for some time, what happens? The hotness of the milk decreases after some time. Similarly, if you keep a bottle of cold water on a table, the water becomes warmer after some time. What do you infer from these observations? In the case of hot milk, there is a flow of energy from the cup of milk to the environment. In the second case, the energy is transferred from the environment to the water bottle. This energy is termed as "thermal energy".

When a hot object is in contact with another cold object, a form of energy flows from the hot object to the cold object, which is known as **thermal energy**. Thus, thermal energy is a form of energy which is transferred between any two bodies due to the difference in their temperatures. Thermal energy is also known as 'heat energy' or simply 'heat'.

Heat energy is the agent, which produces the sensation of warmth and makes bodies hot. The process in which heat energy flows from a body at a higher temperature to another object at lower temperature is known as **heating**. This process of transmission of heat may be done in any of the ways like conduction, convection or radiation. Heat is a scalar quantity. The SI unit of heat energy absorbed or evolved is joule (J) .

During the process of transferring heat energy, the body at lower temperature is heated while the body at higher temperature is cooled. Thus, sometimes, this process of transfer of heat energy is termed as 'cooling'. But, in most of the cases the term 'heating' is used instead of 'cooling'. When the thermal energy is transferred from one body to another, this results in the rise or lowering of the temperature of either of the bodies.

3.2.1 Characteristic features of heat energy transfer

1. Heat always flows from a system at higher temperature to a system at lower temperature.
2. The mass of a system is not altered when it is heated or cooled.
3. For any exchange of heat, the heat gained by the cold system is equal to heat lost by the hot system. *Heat gained = Heat lost*

3.2.2 Other units of Heat energy

Though the SI unit of heat energy is joule, there are some other commonly used units.

Calorie: *One calorie is defined as the amount of heat energy required to rise the temperature of 1 gram of water through 1°C.*

Kilocalorie: *One kilocalorie is defined as the amount of heat energy required to rise the temperature of 1 kilogram of water through 1°C.*

3.3 EFFECT OF HEAT ENERGY

When a certain amount of heat energy is given to a substance, it will undergo one or more of the following changes:

- Temperature of the substance rises.
- The substance may change its state from solid to liquid or from liquid to gas.
- The substance will expand when heated.

The rise in temperature is in proportion to the amount of heat energy supplied. It also depends on the nature and mass of the substance. About the rise in temperature and the change of state, you have studied in previous classes. In the following section, we shall discuss about the expansion of substances due to heat.

3.3.1 Expansion of Substances

When heat energy is supplied to a body, there can be an increase in the dimension of the object. This change in the dimension due to rise in temperature is called thermal expansion of the object. The expansion of liquids (e.g. mercury) can be seen when a thermometer is placed in warm water. All forms of matter (solid, liquid and gas) undergo expansion on heating.

6TN7KD

a) Expansion in solids

When a solid is heated, the atoms gain energy and vibrate more vigorously. This results in the expansion of the solid. For a given change in temperature, the extent of expansion is smaller in solids than in liquids and gases. This is due to the rigid nature of solids.

The different types of expansion of solid are listed and explained below:

1. Linear expansion
2. Superficial expansion
3. Cubical expansion

1. Linear expansion:

When a body is heated or cooled, the length of the body changes due to change in its temperature. Then the expansion is said to be **linear or longitudinal expansion**.

The ratio of increase in length of the body per degree rise in temperature to its unit length is called as the **coefficient of linear expansion**. The SI unit of Coefficient of Linear expansion is K^{-1}. The value of coefficient of linear expansion is different for different materials.

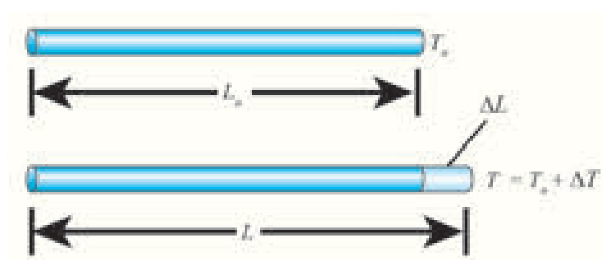

Figure 3.2 Linear expansion

The equation relating the change in length and the change in temperature of a body is given below:

$$\frac{\Delta L}{L_o} = \alpha_L \Delta T$$

ΔL - Change in length (Final length- Original length)

L_o - Original length

ΔT - Change in temperature (Final temperature - Initial temperature)

α_L - Coefficient of linear expansion.

2. Superficial expansion:

If there is an increase in the area of a solid object due to heating, then the expansion is called **superficial or areal expansion.**

Superficial expansion is determined in terms of coefficient of superficial expansion. The ratio of increase in area of the body per degree rise in temperature to its unit area is called as **coefficient of superficial expansion**. Coefficient of superficial expansion is different for different materials. The SI unit of Coefficient of superficial expansion is K^{-1}

The equation relating to the changein area and the change in temperature is given below:

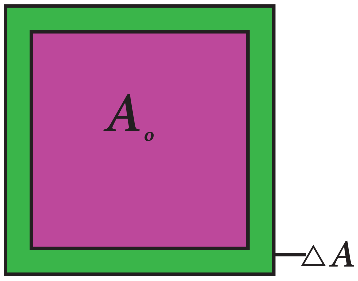

Figure 3.3 Superficial expansion

$$\frac{\Delta A}{A_o} = \alpha_A \Delta T$$

ΔA - Change in area (Final area - Initial area)

A_o - Original area

ΔT - Change in temperature (Final temperature - Initial temperature)

α_A - Coefficient of superficial expansion.

3. Cubical expansion:

If there is an increase in the volume of a solid body due to heating, then the expansion is called **cubical or volumetric expansion.**

As in the cases of linear and areal expansion, cubical expansion is also expressed in terms of coefficient of cubical expansion. The ratio of increase in volume of the body per degree rise in temperature to its unit volume is called as **coefficient of cubical expansion**. This is also measured in K^{-1}.

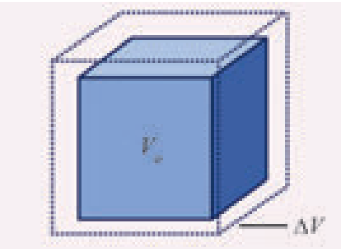

Figure 3.4 Cubical expansion

The equation relating to the change in volume and the change in temperature is given below:

$$\frac{\Delta V}{V_o} = \alpha_V \Delta T$$

ΔV - Change in volume(Final volume - Intial volume)

V_o - Original volume

ΔT - Change in temperature (Final temperature - Initial temperature)

α_V - Coefficient of cubical expansion.

Different materials possess different coefficient of cubical expansion. Table 3.1 gives the coefficient of cubical expansion for some common materials.

Table 3.1 Coefficient of cubical expansion of some materials

S.No.	Name of the material	Coefficient of cubic expansion (K^{-1})
1	Aluminium	7×10^{-5}
2	Brass	6×10^{-5}
3	Glass	2.5×10^{-5}
4	Water	20.7×10^{-5}
5	Mercury	18.2×10^{-5}

b) Expansion in liquids and gases

When heated, the atoms in a liquid or gas gain energy and are forced further apart. The extent of expansion varies from substance to substance. For a given rise in temperature, a liquid will have more expansion than a solid and a gaseous substance has the highest expansion when compared with the other two. The coefficient of cubical expansion of liquid is independent of temperature whereas its value for gases depends on the temperature of gases.

When a liquid is heated, it is done by keeping the liquid in some container and supplying heat energy to the liquid through the container. The thermal energy supplied will be partly used in expanding the container and partly used in expanding the liquid. Thus, what we observe may not be the actual or real expansion of the liquid. Hence, for liquids, we can define real expansion and apparent expansion.

1) Real expansion

If a liquid is heated directly without using any container, then the expansion that you observe is termed as **real expansion** of the liquid.

Coefficient of real expansion is defined as the ratio of the true rise in the volume of the liquid per degree rise in temperature to its unit volume. The SI unit of coefficient of real expansion is K^{-1}.

2) Apparent expansion

Heating a liquid without using a container is not possible. Thus, in practice, you can heat any liquid by pouring it in a container. A part of thermal energy is used in expanding the container and a part is used in expanding the liquid. Thus, what you observe is not the actual or real expansion of the liquid. The expansion of a liquid apparently observed without considering the expansion of the container is called the **apparent expansion** of the liquid.

Coefficient of apparent expansion is defined as the ratio of the apparent rise in the volume of the liquid per degree rise in temperature to its unit volume. The SI unit of coefficient of apparent expansion is K^{-1}.

3.3.2 Experiment to measure real and apparent expansion of liquid

To start with, the liquid whose real and apparent expansion is to be determined is poured in a container up to a level. Mark this level as L_1. Now, heat the container and the liquid using a burner as shown in the Figure 3.5. Initially, the container receives the thermal energy and it expands. As a result, the volume of the liquid appears to have reduced. Mark this reduced level of liquid as L_2.

On further heating, the thermal energy supplied to the liquid through the container results in the expansion of the liquid. Hence, the level of liquid rises to L_3. Now, the difference between the levels L_1 and L_3 is called as **apparent expansion,** and the difference between the levels L_2 and L_3 is called **real expansion**. The real expansion is always more than that of apparent expansion.

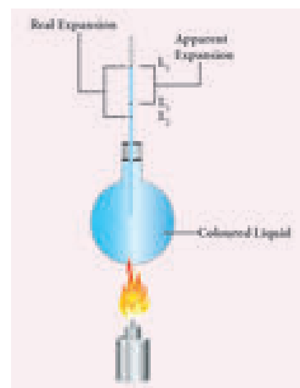

Figure 3.5 Real and apparent expansion of liquid

Real expansion = $L_3 - L_2$

Apparent expansion = $L_3 - L_1$

3.4 FUNDAMENTAL LAWS OF GASES

The three fundamental laws which connect the relation between pressure, volume and temperature are as follows:

1) Boyle's Law
2) Charles's law
3) Avogadro's law

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3.4.1 Boyle's law:

When the temperature of a gas is kept constant, the volume of a fixed mass of gas is inversely proportional to its pressure. This is shown in Figure 3.6.

$$P \propto 1/V$$

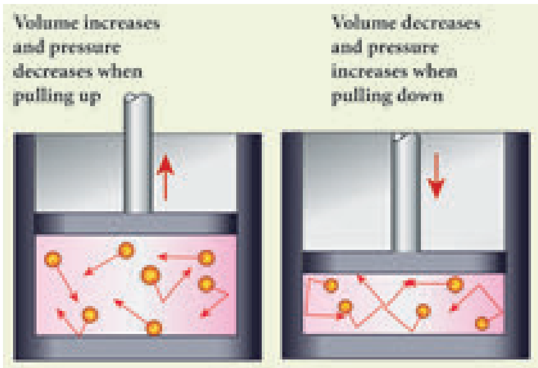


Figure 3.6 Variation of volume with pressure

In other words, for an invariable mass of a perfect gas, at constant temperature, the product of its pressure and volume is a constant.

(i.e) $PV = \text{constant}$

3.4.2 Charles's law (The law of volume)

Charles's law was formulated by a French scientist Jacques Charles. According to this law, *When the pressure of gas is kept constant, the volume of a gas is directly proportional to the temperature of the gas.*

$$V \propto T$$

$$\text{or } \frac{V}{T} = \text{constant}$$

3.4.3 Avogadro's law

Avogadro's law states that at constant pressure and temperature, the volume of a gas is directly proportional to number of atoms or molecules present in it.

8I8UMD

$$\text{i.e. } V \propto n$$

$$\text{(or) } \frac{V}{n} = \text{constant}$$

Avogadro's number (N_A) is the total number of atoms per mole of the substance. It is equal to 6.023×10^{23} /mol.

3.5 GASES

Gases are classified as real gases and ideal gases.

3.5.1 Real Gases

If the molecules or atoms of a gases interact with each other with a definite amount of intermolecular or inter atomic force of attraction, then the gases are said to be **real gases.** At very high temperature or low pressure, a real gases behaves as an ideal gases because in this condition there is no interatomic or intermolecular force of attraction.

3.5.2 Ideal Gases

If the atoms or molecules of a gas do not interact with each other, then the gas is said to be an **ideal gas** or a **perfect gas.**

Actually, in practice, no gas is ideal. The molecules of any gas will have a certain amount of interaction among them. But, these interactions are weaker when the pressure is low or the temperature is high because the interatomic or intermolecular forces of attraction are weak in ideal gas. Hence, a real gas at low pressure or high temperature can be termed as a perfect gas.

Ideal gases obey Boyle's law, Charles's law and Avogadro's law. All these laws state the relationship between various properties of a gas such as pressure (P), volume (V), temperature (T) and number of atoms (n). In a given state of the gas, all these parameters will have a definite set of values. When there is a change in the state of the gas, any one or more of these parameters change its value. The above said laws relate these changes.

3.5.3 Ideal Gas Equation

The ideal gas equation is an equation, which relates all the properties of an ideal gas. An ideal gas obeys Boyle's law and Charles' law and Avogadro's law. According to Boyle's law,

$$PV = constant \qquad (3.1)$$

According to Charles's law,

$$V/T = constant \qquad (3.2)$$

According to Avogadro's law,

$$V/n = constant \qquad (3.3)$$

After combining equations (3.1), (3.2) and (3.3), you can get the following equation.

$$PV/nT = constant \qquad (3.4)$$

The above relation is called the combined law of gases. If you consider a gas, which contains μ moles of the gas, the number of atoms contained will be equal to μ times the Avogadro number, N_A.

$$i.e. \quad n = \mu N_A. \qquad (3.5)$$

Using equation (3.5), equation (3.4) can be written as

$$PV/\mu N_A T = constant$$

The value of the constant in the above equation is taken to be k_B, which is called as **Boltzmann constant (1.38×10^{-23} JK^{-1}).** Hence, we have the following equation:

$$PV/\mu N_A T = k_B$$

$$PV = \mu N_A k_B T$$

Here, $\mu N_A k_B = R$, which is termed as universal gas constant whose value is

$8.31\ J\ mol^{-1} K^{-1}$.

$$PV = RT \qquad (3.6)$$

Ideal gas equation is also called as *equation of state* because it gives the relation between the state variables and it is used to describe the state of any gas.

Points to Remember

- The SI unit of heat energy absorbed or evolved is joule (J)
- Heat always flows from a system at higher temperature to a system at lower temperature.
- **Temperature** is defined as the degree of hotness of a body. The SI unit of temperature is kelvin (K).
- All the substances will undergo one or more of the following changes when heated:
  i) Temperature of the substance rises.
  ii) The substance may change state from solid to liquid or gas.
  iii) The substance will expand when heated.
- All forms of matter (solid, liquid and gas) undergo expansion on heating.
- For a given rise in temperature, a liquid will have more expansion than a solid and a gaseous substance has the highest expansion than the other two.
- If a liquid is heated directly without using any container, then the expansion that you observe is termed as **real expansion** of the liquid.
- The expansion of a liquid apparently observed without considering the expansion of the container is called the **apparent expansion** of liquid.
- For a given heat energy, the real expansion is always more than that of apparent expansion.
- If the atoms or molecules of a gas do not interact with each other, then the gas is said to be an **ideal gas** or a **perfect gas**.
- Ideal gas equation, also called as equation of state is PV = RT. Here, R is known as universal gas constant whose value is $8.31\ J\ mol^{-1}K^{-1}$

Solved Problems

Example 1

A container whose capacity is 70 ml is filled with a liquid up to 50 ml. Then, the liquid in the container is heated. Initially, the level of the liquid falls from 50 ml to 48.5 ml. Then we heat more, the level of the liquid rises to 51.2 ml. Find the apparent and real expansion.

Data:

Level of the liquid L_1 = 50 ml

Level of the liquid L_2 = 48.5 ml

Level of the liquid L_3 = 51.2 ml

$$\text{Apparent expansion} = L_3 - L_1$$
$$= 51.2\,\text{ml} - 50\,\text{ml} = 1.2\,\text{ml}$$
$$\text{Real expansion} = L_3 - L_1$$
$$= 51.2\text{ ml} - 48.5\text{ml} = 2.7\text{ml}$$

So, Real expansion > apparent expansion

Example 2

Keeping the temperature as constant, a gas is compressed four times of its initial pressure. The volume of gas in the container changing from 20cc (V_1 cc) to V_2 cc. Find the final volume V_2.

Data:

Initial pressure (P_1)= P

Final Pressure (P_2) = 4P

Initial volume (V_1) = 20cc = 20cm³

Final volume (V_2) = ?

Using Boyle's Law, PV = constant

$$P_1V_1 = P_2V_2$$
$$V_2 = \frac{P_1}{P_2} \times V_1$$
$$= \frac{P}{4P} \times 20\text{cm}^3$$
$$V_2 = 5\text{ cm}^3$$

8XRPNP

TEXTBOOK EVALUATION

I. Choose the correct answer

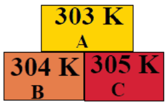
1. The value of universal gas constant
   a) 3.81 $\text{mol}^{-1}\,\text{K}^{-1}$ b) 8.03 $\text{mol}^{-1}\,\text{K}^{-1}$
   c) 1.38 $\text{mol}^{-1}\,\text{K}^{-1}$ d) 8.31 $\text{mol}^{-1}\,\text{K}^{-1}$

2. If a substance is heated or cooled, the change in mass of that substance is
   a) positive b) negative
   c) zero d) none of the above

3. If a substance is heated or cooled, the linear expansion occurs along the axis of
   a) X or −X b) Y or −Y
   c) both (a) and (b) d) (a) or (b)

4. Temperature is the average ___________ of the molecules of a substance
   a) difference in K.E and P.E
   b) sum of P.E and K.E
   c) difference in T.E and P.E
   d) difference in K.E and T.E

5. In the Given diagram, the possible direction of heat energy transformation is



a) $A \leftarrow B$, $A \leftarrow C$, $B \leftarrow C$
b) $A \rightarrow B$, $A \rightarrow C$, $B \rightarrow C$
c) $A \rightarrow B$, $A \leftarrow C$, $B \rightarrow C$
d) $A \leftarrow B$, $A \rightarrow C$, $B \leftarrow C$

II. Fill in the blanks:

1. The value of Avogadro number _________
2. The temperature and heat are __________ quantities
3. One calorie is the amount of heat energy required to raise the temperature of ________ of water through_______.
4. According to Boyle's law, the shape of the graph between pressure and reciprocal of volume is _______________

III. State whether the following statements are true or false, if false explain why?

1. For a given heat in liquid, the apparent expansion is more than that of real expansion.

2. Thermal energy always flows from a system at higher temperature to a system at lower temperature.
3. According to Charles's law, at constant pressure, the temperature is inversely proportional to volume.

IV. Match the items in column-I to the items in column-II

Column-I	Column-II
1. Linear expansion	- (a) change in volume
2. Superficial expansion	- (b) hot body to cold body
3. Cubical expansion	- (c) 1.381 X 10^{-23} JK^{-1}
4. Heat transformation	- (d) change in length
5. Boltzmann constant	- (e) change in area

V. Assertion and reason type questions

a. Both the assertion and the reason are true and the reason is the correct explanation of the assertion.

b. Both the assertion and the reason are true but the reason is not the correct explanation of the assertion.

c. Assertion is true but the reason is false.

d. Assertion is false but the reason is true.

1. **Assertion:** There is no effects on other end when one end of the rod is only heated.

   Reason: Heat always flows from a region of lower temperature to higher temperature of the rod.

2. **Assertion:** Gas is highly compressible than solid and liquid

   Reason: Interatomic or intermolecular distance in the gas is comparably high.

VI. Answer in briefly

1. Define one calorie.
2. Distinguish between linear, arial and superficial expansion.
3. What is co-efficient of cubical expansion?
4. State Boyle's law
5. State-the law of volume
6. Distinguish between ideal gas and real gas.
7. What is co-efficient of real expansion?
8. What is co-efficient of apparent expansion?

VII. Numerical problems

1. Find the final temperature of a copper rod. Whose area of cross section changes from 10 m^2 to 11 m^2 due to heating. The copper rod is initially kept at 90 K. (Coefficient of superficial expansion is 0.0021 /K)
2. Calculate the coefficient of cubical expansion of a zinc bar. Whose volume is increased 0.25 m^3 from 0.3 m^3 due to the change in its temperature of 50 K.

VIII. Answer in detail

1. Derive the ideal gas equation.
2. Explain the experiment of measuring the real and apparent expansion of a liquid with a neat diagram.

IX. HOT question

If you keep ice at 0° C and water at 0° C in either of your hands, in which hand you will feel more chillness? Why?

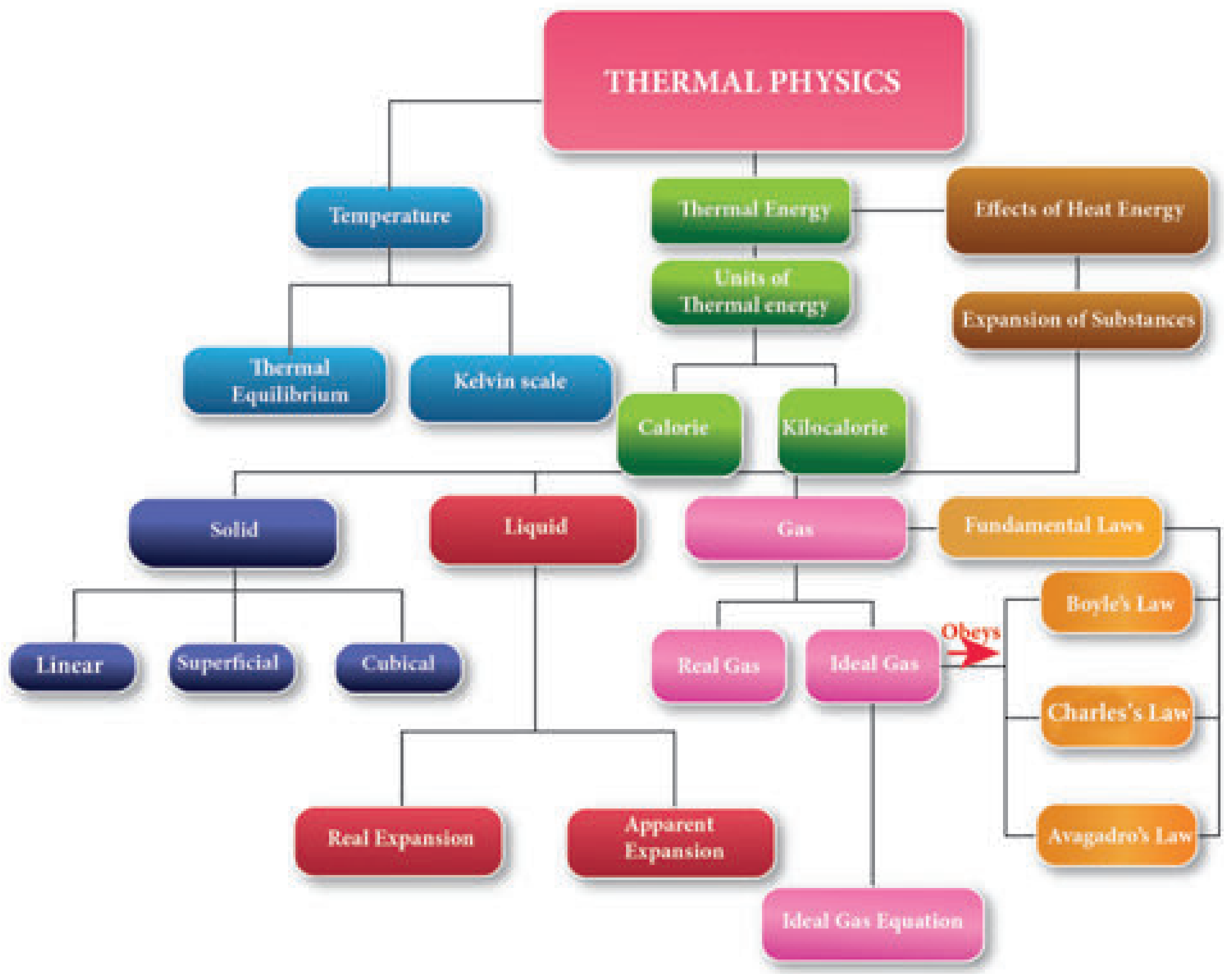
REFERENCE BOOKS

- Thermodynamics and an introduction to thermo statistics by Herbert Hallen
- Fundamentals of Engineering Thermodynamics by Michael Moran.

INTERNET RESOURCE

http://aplusphysics.com/courses/honors/thermo/thermal_physics.html

CONCEPT MAP



ICT CORNER

Boyle's law

In this activity you will be able to verify pressure is proportional to reciprocal of volume (Boyle's law).

Steps

- Open the browser and type "physics-chemistry-interactive-flash-animation.com/matter_change_state_measurement_mass_volume/pressure_volume_boyle_mariotte_law_ideal_gas_closed_system_MCQ.htm" in the address bar. Click enter to start the experiment.
- Change the volume by adjusting the piston of the syringe (between 20 ml to 80 ml) and observe how the pressure changes.
- Tabulate observed values. You will observe when volume decreases pressure inside the syringe gets increased and vice versa. Thus boyle's law (PV = constant) verified.

Cells alive

URL: http://www.physics-chemistry-interactive-flash-animation.com/matter_change_state_measurement_mass_volume/pressure_volume_boyle_mariotte_law_ideal_gas_closed_system_MCQ.htm

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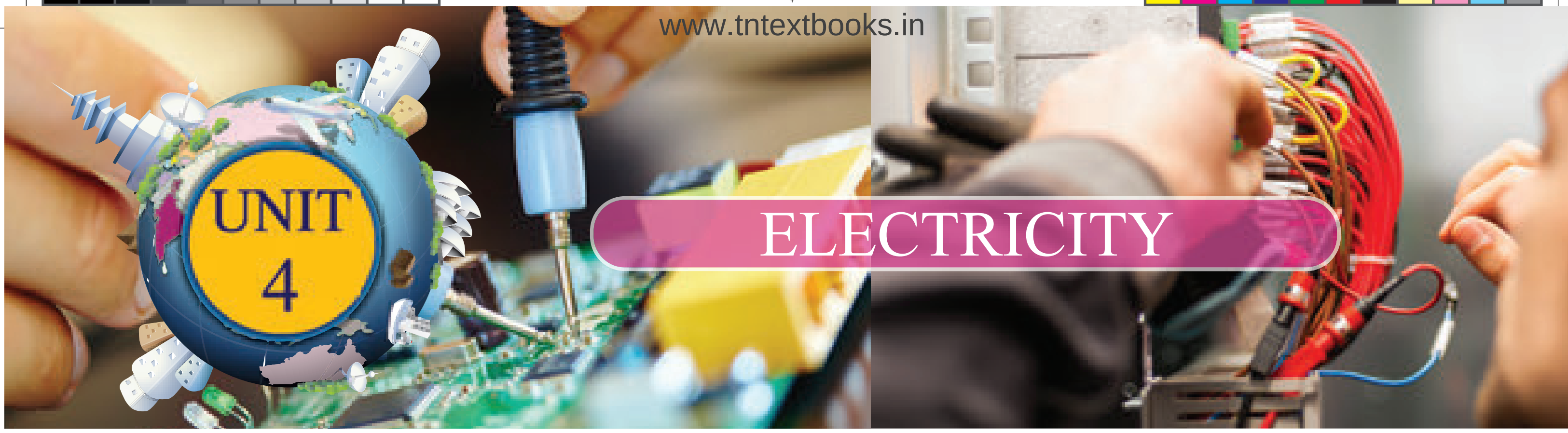

UNIT 4 ELECTRICITY

Learning Objectives

At the end of this lesson, students will be able to:

- Make an electric circuit.
- Differentiate between electric potential and potential difference.
- Infer what electrical resistivity and conductivity mean.
- Know the effective resistance of a system of resistors connected in series and parallel.
- Understand the heating effect of the electric current.
- Define electric power and electric energy and explain domestic electric circuits.
- Know the modern appliances such as LED bulb and LED television.

9DAJQ1

INTRODUCTION

You have already learnt about electricity in your lower classes, haven't you? Well, electricity deals with the flow of electric charges through a conductor. As a common term it refers to a form of energy. The usage of electric current in our day to day life is very important and indispensable. You are already aware of the fact that it is used in houses, educational institutions, hospitals, industries, etc. Therefore, its generation and transmission becomes a very crucial aspect of our life. In this lesson you will learn various terms used in understanding the concept of electricity. Eventually, you will realise the importance of the applications of electricity in day to day situations.

4.1 ELECTRIC CURRENT

The motion of electric charges (electrons) through a conductor (e.g., copper wire) will constitute an electric current. This is similar to the flow of water through a channel or flow of air from a region of high pressure to a region of low pressure.

In a similar manner, the electric current passes from the positive terminal (higher electric potential) of a battery to the negative terminal (lower electric potential) through a wire as shown in the Figure 4.1.

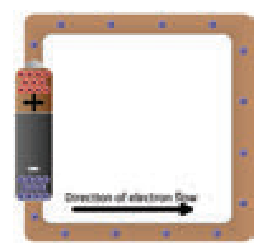

Figure 4.1
Electron flow

4.1.1 Definition of electric current

Electric current is often termed as 'current' and it is represented by the symbol 'I'. It is defined **as the rate of flow of charges in a conductor**. This means that the electric current represents the amount of charges flowing in any cross section of a conductor (say a metal wire) in unit time. If a net charge 'Q' passes through any cross section of a conductor in

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time 't', then the current flowing through the conductor is

$$I = \frac{Q}{t} \qquad (4.1)$$

4.1.2 SI unit of electric current

The SI unit of electric current is ampere (A). The current flowing through a conductor is said to be one ampere, when a charge of one coulomb flows across any cross-section of a conductor, in one second. Hence,

$$1 \text{ ampere} = \frac{1 \text{ coulomb}}{1 \text{ second}}.$$

Solved Problem-1

A charge of 12 coulomb flows through a bulb in 5 second. What is the current through the bulb?

Solution:

Charge Q = 12 C, Time t = 5 s. Therefore,

current $I = \frac{Q}{t} = \frac{12}{5} = 2.4$ A

4.2 ELECTRIC CIRCUIT

An electric circuit is a closed conducting loop (or) path, which has a network of electrical components through which electrons are able to flow. This path is made using electrical wires so as to connect an electric appliance to a source of electric charges (battery). A schematic diagram of an electric circuit comprising of a battery, an electric bulb, and a switch is given in Figure 4.2.

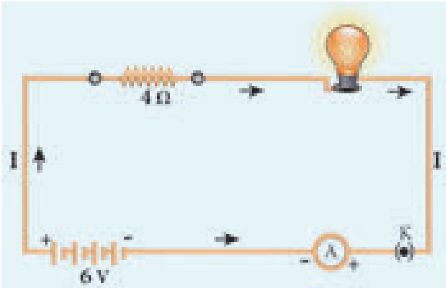
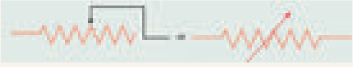
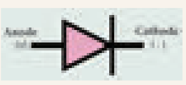
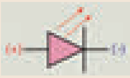


Figure 4.2 A simple electric circuit

Table 4.1 Symbols of some components of a circuit

COMPONENT	USE OF THE COMPONENT	SYMBOL USED
Resistor	Used to fix the magnitude of the current through a circuit	
Variable resistor or Rheostat	Used to select the magnitude of the current through a circuit.	
Ammeter	Used to measure the current.	
Voltmeter	Used to measure the potential difference.	
Galvanometer	Used to indicate the direction of current.	
A diode	A diode has various uses, which you will study in higher classes.	
Light Emitting Diode (LED)	A LED has various uses which you will study in higher classes.	
Ground connection	Used to provide protection to the electrical components. It also serves as a reference point to measure the electric potential.	

In this circuit, if the switch is 'on', the bulb glows. If it is switched off, the bulb does not glow. Therefore, the circuit must be closed in order that the current passes through it. The potential difference required for the flow of charges is provided by the battery. The electrons flow from the negative terminal to the positive terminal of the battery.

By convention, the direction of current is taken as the direction of flow of positive charge (or) opposite to the direction of flow of electrons. Thus, electric current passes in the circuit from the positive terminal to the negative terminal.

4.2.1 Electrical components

The electric circuit given in Figure 4.2 consists of different components, such as a battery, a switch and a bulb. All these components can be represented by using certain symbols. It is easier to represent the components of a circuit using their respective symbols.

The symbols that are used to represent some commonly used components are given in Table 4.1. The uses of these components are also summarized in the table.

4.3 ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE

You are now familiar with the water current and air current. You also know that there must be a difference in temperature between two points in a solid for the heat to flow in it. Similarly, a difference in electric potential is needed for the flow of electric charges in a conductor. In the conductor, the charges will flow from a point in it, which is at a higher electric potential to a point, which is at a lower electric potential.

4.3.1 Electric Potential

The electric potential at a point is defined as the amount of work done in moving a unit positive charge from infinity to that point against the electric force.

4.3.2 Electric Potential Difference

The electric potential difference between two points is defined as the amount of work done in moving a unit positive charge from one point to another point against the electric force.

Figure 4.3 Electric potential

Suppose, you have moved a charge Q from a point A to another point B. Let 'W' be the work done to move the charge from A to B. Then, the potential difference between the points A and B is given by the following expression:

$$\text{Potential Difference (V)} = \frac{\text{Work Done (W)}}{\text{Charge (Q)}} \qquad (4.2)$$

Potential difference is also equal to the difference in the electric potential of these two points. If V_A and V_B represent the electric potential at the points A and B respectively, then, the potential difference between the points A and B is given by:

$$V = V_A - V_B \text{ (if } V_A \text{ is more than } V_B)$$

$$V = V_B - V_A \text{ (if } V_B \text{ is more than } V_A)$$

4.3.3 Volt

The SI unit of electric potential or potential difference is volt (V).

The potential difference between two points is one volt, if one joule of work is done in moving one coulomb of charge from one point to another against the electric force.

$$1\,\text{volt} = \frac{1\ \text{joule}}{1\ \text{coulomb}}$$

Solved Problem-2

The work done in moving a charge of 10 C across two points in a circuit is 100 J. What is the potential difference between the points?

Solution:

Charge, Q = 10 C Work Done, W = 100 J

Potential Difference $V = \frac{W}{Q} = \frac{100}{10}$.

Therefore, V = 10 volt

4.4 OHM'S LAW

A German physicist, Georg Simon Ohm established the relation between the potential difference and current, which is known as Ohm's Law. This relationship can be understood from the following activity.

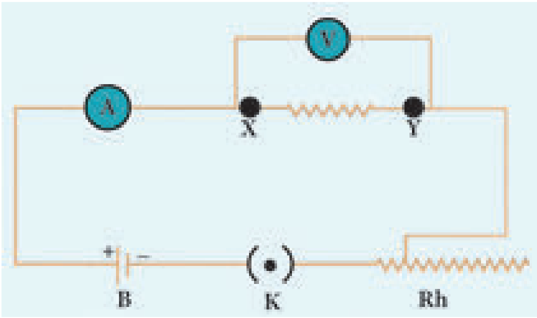


Figure 4.4 Electric circuit to understand Ohm's law

According to Ohm's law, at a constant temperature, the steady current 'I' flowing through a conductor is directly proportional to the potential difference 'V' between the two ends of the conductor.

$I \propto V$. Hence, $\frac{I}{V}$ = constant.

The value of this proportionality constant is found to be $\frac{1}{R}$

Therefore, $I = \left(\frac{1}{R}\right) V$

$$V = I\,R \qquad (4.3)$$

Here, R is a constant for a given material (say Nichrome) at a given temperature and is known as the **resistance** of the material. Since, the potential difference V is proportional to the current I, the graph between V and I is a straight line for a conductor, as shown in the Figure 4.5.

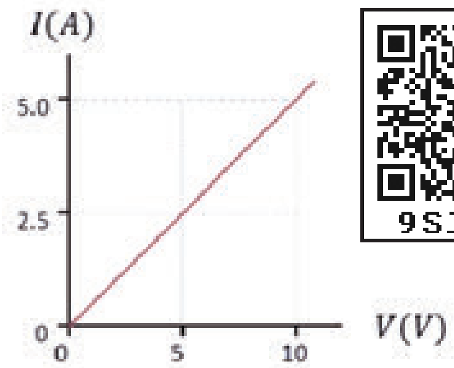


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Figure 4.5 Relation between potential difference and current

4.5 RESISTANCE OF A MATERIAL

In Figure 4.4, a Nichrome wire was connected between X and Y. If you replace the Nichrome wire with a copper wire and conduct the same experiment, you will notice a different current for the same value of the potential difference across the wire. If you again replace the copper wire with an aluminium wire, you will get another value for the current passing through it. From equation (4.3), you have learnt that V/I must be equal to the resistance of the conductor used. The variations in the current for the same values of potential difference indicate that the resistance of different materials is different. Now, the primary question is, "what is resistance?"

Resistance of a material is its property to oppose the flow of charges and hence the passage of current through it. ***It is different for different materials***.

From Ohm's Law, $\frac{V}{I} = R$.

The resistance of a conductor can be defined as the ratio between the potential difference across the ends of the conductor and the current flowing through it.

4.5.1 Unit of Resistance

The SI unit of resistance is ohm and it is represented by the symbol Ω.

Resistance of a conductor is said to be one ohm if a current of one ampere flows through it when a potential difference of one volt is maintained across its ends.

$$1 \text{ ohm} = \frac{1 \text{ volt}}{1 \text{ ampere}}$$

Solved Problem-3

Calculate the resistance of a conductor through which a current of 2 A passes, when the potential difference between its ends is 30 V.

Solution:

Current through the conductor I = 2 A, Potential Difference V = 30 V

From Ohm's Law: $R = \frac{V}{I}$.

Therefore, $R = \frac{30}{2} = 15\ \Omega$

4.6 ELECTRICAL RESISTIVITY & ELECTRICAL CONDUCTIVITY

4.6.1 Electrical Resistivity

You can verify by doing an experiment that the resistance of any conductor 'R' is directly proportional to the length of the conductor 'L' and is inversely proportional to its area of cross section 'A'.

$$R \propto L,\ R \propto \frac{1}{A},$$

$$\text{Hence},\ R \propto \frac{L}{A}$$

$$\text{Therefore, } R = \rho \frac{L}{A} \qquad (4.4)$$

Where, ρ (rho) is a constant, called as electrical resistivity or specific resistance of the material of the conductor.

From equation (4.4), $\rho = \frac{RA}{L}$

If L = 1 m, A = 1 m^2 then, from the above equation $\rho = R$

Hence, the electrical resistivity of a material is ***defined as the resistance of a conductor of unit length and unit area of cross section***. Its unit is **ohm metre**.

Electrical resistivity of a conductor is a measure of the resisting power of a specified material to the passage of an electric current. It is a constant for a given material.

DO YOU KNOW?

Nichrome is a conductor with highest resistivity equal to $1.5 \times 10^{-6}\ \Omega$ m. Hence, it is used in making heating elements.

4.6.2 Conductance and Conductivity

Conductance of a material is the property of a material to aid the flow of charges and hence, the passage of current in it. The conductance of a material is mathematically ***defined as the reciprocal of its resistance*** (R). Hence, the conductance '**G**' of a conductor is given by

$$\mathbf{G} = \frac{1}{R} \qquad (4.5)$$

Its unit is ohm^{-1}. It is also represented as 'mho'.

The reciprocal of electrical resistivity of a material is called its electrical conductivity.

$$\sigma = \frac{1}{\rho} \qquad (4.6)$$

Its unit is ohm^{-1} metre^{-1}. It is also represented as mho metre^{-1}. The conductivity is a constant for a given material. Electrical conductivity of a conductor is a measure of its ability to pass the current through it. Some materials are good conductors of electric current. Example: copper, aluminium, etc. While some other materials are non-conductors of electric current (insulators). Example: glass, wood, rubber, etc.

Conductivity is more for conductors than for insulators. But, the resistivity is less for conductors than for insulators. The resistivity of some commonly used materials is given in Table 4.2.

Table 4.2 Resistivity of some materials

NATURE OF THE MATERIAL	MATERIAL	RESISTIVITY (Ω m)
Conductor	Copper	1.62×10^{-8}
	Nickel	6.84×10^{-8}
	Chromium	12.9×10^{-8}
Insulator	Glass	10^{10} to 10^{14}
	Rubber	10^{13} to 10^{16}

Solved Problem-4

The resistance of a wire of length 10 m is 2 ohm. If the area of cross section of the wire is 2×10^{-7} m^2, determine its (i) resistivity (ii) conductance and (iii) conductivity

Solution:

Given: Length, L = 10 m, Resistance, R = 2 ohm and Area, A = 2×10^{-7} m^2

$$\text{Resistivity, } \rho = \frac{RA}{L} = \frac{2 \times 2 \times 10^{-7}}{10}$$

$$= 4 \times 10^{-8}\ \Omega\ \text{m}$$

$$\text{Conductance, } \mathbf{G} = \frac{1}{R} = \frac{1}{2} = 0.5 \text{ mho}$$

$$\text{Conductivity, } \sigma = \frac{1}{\rho} = \frac{1}{4 \times 10^{-8}}$$

$$= 0.25 \times 10^{-8} \text{ mho m}^{-1}$$

4.7 SYSTEM OF RESISTORS

So far, you have learnt how the resistance of a conductor affects the current through a circuit. You have also studied the case of the simple electric circuit containing a single resistor. Now in practice, you may encounter a complicated circuit, which uses a combination of many resistors. This combination of resistors is known as 'system of resistors' or 'grouping of resistors'. Resistors can be connected in various combinations. The two basic methods of joining resistors together are:

a) Resistors connected in series, and b) Resistors connected in parallel.

In the following sections, you shall compute the effective resistance when many resistors having different resistance values are connected in series and in parallel.

4.7.1 Resistors in series

A series circuit connects the components one after the other to form a 'single loop'. A series circuit has only one loop through which current can pass. If the circuit is interrupted at any point in the loop, no current can pass through the circuit and hence no electric appliances connected in the circuit will work. Series circuits are commonly used in devices such as flashlights. ***Thus, if resistors are connected end to end, so that the same current passes through each of them, then they are said to be connected in series.***

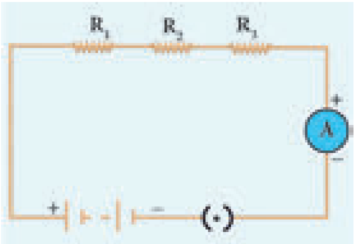

Figure 4.6 Series connection of resistors

Let, three resistances R_1, R_2 and R_3 be connected in series (Figure 4.6). Let the current flowing through them be I. According to Ohm's Law, the potential differences V_1, V_2 and V_3 across R_1, R_2 and R_3 respectively, are given by:

$$V_1 = I R_1 \quad (4.7)$$

$$V_2 = I R_2 \quad (4.8)$$

$$V_3 = I R_3 \quad (4.9)$$

The sum of the potential differences across the ends of each resistor is given by:

$$V = V_1 + V_2 + V_3$$

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Using equations (4.7), (4.8) and (4.9), we get

$$V = I R_1 + I R_2 + I R_3 \quad (4.10)$$

The effective resistor is a single resistor, which can replace the resistors effectively, so as to allow the same current through the electric circuit. Let, the effective resistance of the series-combination of the resistors, be R_S. Then,

$$V = I R_S \quad (4.11)$$

Combining equations (4.10) and (4.11), you get,

$$I R_S = I R_1 + I R_2 + I R_3$$

$$R_S = R_1 + R_2 + R_3 \quad (4.12)$$

Thus, you can understand that when a number of resistors are connected in series, their equivalent resistance or effective resistance is equal to the sum of the individual resistances. When 'n' resistors of equal resistance R are connected in series, the equivalent resistance is 'n R'.

i.e., $R_S = n R$

The equivalent resistance in a series combination is greater than the highest of the individual resistances.

Solved Problem-5

Three resistors of resistances 5 ohm, 3 ohm and 2 ohm are connected in series with 10 V battery. Calculate their effective resistance and the current flowing through the circuit.

Solution:

$R_1 = 5\ \Omega$, $R_2 = 3\ \Omega$, $R_3 = 2\ \Omega$, $V = 10$ V

$R_s = R_1 + R_2 + R_3$, $R_s = 5 + 3 + 2 = 10$, hence $R_s = 10\ \Omega$

The current, $I = \frac{V}{R_S} = \frac{10}{10} = 1$ A

4.7.2 Resistances in Parallel

A parallel circuit has two or more loops through which current can pass. If the circuit is disconnected in one of the loops, the current can still pass through the other loop(s). The wiring in a house consists of parallel circuits.

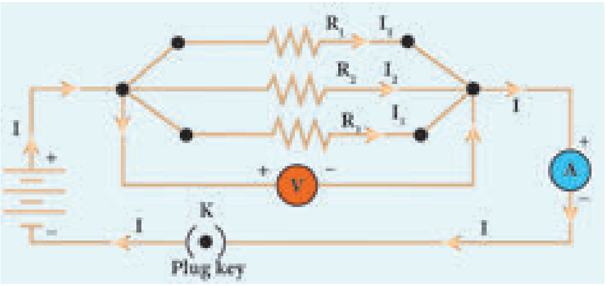

Figure 4.7 Parallel connections of resistors

Consider that three resistors R_1, R_2 and R_3 are connected across two common points A and B. The potential difference across each resistance is the same and equal to the potential difference between A and B. This is measured using the voltmeter. The current I arriving at A divides into three branches I_1, I_2 and I_3 passing through R_1, R_2 and R_3 respectively.

According to the Ohm's law, you have,

$$I_1 = \frac{V}{R_1} \quad (4.13)$$

$$I_2 = \frac{V}{R_2} \quad (4.14)$$

$$I_3 = \frac{V}{R_3} \quad (4.15)$$

The total current through the circuit is given by

$$I = I_1 + I_2 + I_3$$

Using equations (4.13), (4.14) and (4.15), you get

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} \quad (4.16)$$

Let the effective resistance of the parallel combination of resistors be R_P. Then,

$$I = \frac{V}{R_P} \quad (4.17)$$

Combining equations (4.16) and (4.17), you have

$$\frac{V}{R_P} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \quad (4.18)$$

Thus, when a number of resistors are connected in parallel, the sum of the reciprocals of the individual resistances is equal to the reciprocal of the effective or equivalent resistance. When 'n' resistors of equal resistances R are connected in parallel, the equivalent resistance is $\frac{R}{n}$.

i.e., $\frac{1}{R_P} = \frac{1}{R} + \frac{1}{R} + \frac{1}{R} \cdots + \frac{1}{R} = \frac{n}{R}$.

Hence, $R_p = \frac{R}{n}$

The equivalent resistance in a parallel combination is less than the lowest of the individual resistances.

4.7.3 Series Connection of Parallel Resistors

If you consider the connection of a set of parallel resistors that are connected in series, you get a series – parallel circuit. Let R_1 and R_2 be connected in parallel to give an effective resistance of R_{P1}. Similarly, let R_3 and R_4 be connected in parallel to give an effective resistance of R_{P2}. Then, both of these parallel segments are connected in series (Figure 4.8).

Using equation (4.18), you get

$$\frac{1}{R_{P1}} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{R_{P2}} = \frac{1}{R_3} + \frac{1}{R_4}$$

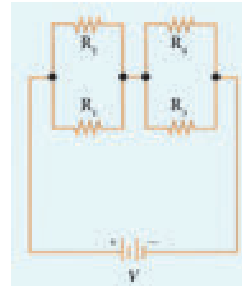

Figure 4.8 Series-parallel combination of resistors

Finally, using equation (4.12), the net effective resistance is given by $R_{total} = R_{P1} + R_{P2}$

4.7.4 Parallel Connection of Series Resistors

If you consider a connection of a set of series resistors connected in a parallel circuit, you get a parallel-series circuit. Let R_1 and R_2 be connected in series to give an effective resistance of R_{S1}. Similarly, let R_3 and R_4 be connected in series to give an effective resistance of R_{S2}. Then, both of these serial segments are connected in parallel (Figure 4.9).

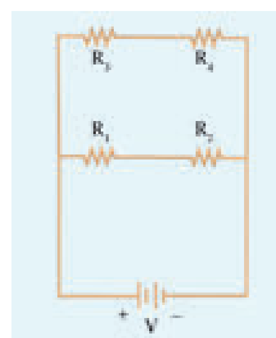

Figure 4.9 Parallel-series combination of resistors

Table 4.3 Difference between series and parallel circuit

S. No.	CRITERIA	SERIES	PARALLEL
1	Equivalent resistance	More than the highest resistance.	Less than the lowest resistance.
2	Amount of current	Current is less as effective resistance is more.	Current is more as effective resistance is less.
3	Switching ON/OFF	If one appliance is disconnected, others also do not work.	If one appliance is discon-nected, others will work independently.

Using equation (4.12), you get

$R_{S1} = R_1 + R_2$, $\quad R_{S2} = R_3 + R_4$

Finally, using equation (4.18), the net effective resistance is given by

$$\frac{1}{R_{total}} = \frac{1}{R_{S1}} + \frac{1}{R_{S2}}$$

4.7.5 Comparison between series and parallel connections

The difference between series and parallel circuits may be summed as follows in Table 4.3

4.8 HEATING EFFECT OF CURRENT

Have you ever touched the motor casing of a fan, which has been used for a few hours continuously? What do you observe? The motor casing is warm. This is due to the heating effect of current. The same can be observed by touching a bulb, which was used for a long duration. Generally, a source of electrical energy can develop a potential difference across a resistor, which is connected to that source. This potential difference constitutes a current through the resistor. For continuous drawing of current, the source has to continuously spend its energy. A part of the energy from the source can be converted into useful work and the rest will be converted into heat energy. Thus, the passage of electric current through a wire, results in the production of heat. This phenomenon is called heating effect of current. This heating effect of current is used in devices like electric heater, electric iron, etc.

4.8.1 Joule's Law of Heating

Let 'I' be the current flowing through a resistor of resistance 'R', and 'V' be the potential difference across the resistor. The charge flowing through the circuit for a time interval 't' is 'Q'.

The work done in moving the charge Q across the ends of the resistor with a potential difference of V is VQ. This energy spent by the source gets dissipated in the resistor as heat. Thus, the heat produced in the resistor is:

$$H = W = VQ$$

You know that the relation between the charge and current is Q = I t. Using this, you get

$$H = V\,I\,t \qquad (4.19)$$

From Ohm's Law, V = I R. Hence, you have

$$\mathbf{H = I^2\,R\,t} \qquad (4.20)$$

This is known as Joule's law of heating.

Joule's law of heating states that the heat produced in any resistor is:

- directly proportional to the square of the current passing through the resistor.
- directly proportional to the resistance of the resistor.
- directly proportional to the time for which the current is passing through the resistor.

4.8.2 Applications of Heating Effect

1. Electric Heating Device:

The heating effect of electric current is used in many home appliances such as electric iron, electric toaster, electric oven, electric heater, geyser, etc. In these appliances Nichrome, which is an alloy of Nickel and Chromium is used as the heating element. Why? Because:

(i) it has high resistivity, (ii) it has a high melting point, (iii) it is not easily oxidized.

2. Fuse Wire:

The fuse wire is connected in series, in an electric circuit. When a large current passes through the circuit, the fuse wire melts due to Joule's heating effect and hence the circuit gets disconnected. Therefore, the circuit and the electric appliances are saved from any damage. The fuse wire is made up of a material whose melting point is relatively low.

3. Filament in bulbs:

In electric bulbs, a small wire is used, known as filament. The filament is made up of a material whose melting point is very high. When current passes through this wire, heat is produced in the filament. When the filament is heated, it glows and gives out light. Tungsten is the commonly used material to make the filament in bulbs.

Solved Problem-6

An electric heater of resistance 5 Ω is connected to an electric source. If a current of 6 A flows through the heater, then find the amount of heat produced in 5 minutes.

Solution:

Given resistance R = 5 Ω, Current I = 6 A, Time t = 5 minutes = 5 × 60 s = 300 s

Amount of heat produced, $H = I^2Rt$, $H = 6^2 \times 5 \times 300$. Hence, H = 54000 J

4.9 ELECTRIC POWER

In general, power is defined as the rate of doing work or rate of spending energy. Similarly, the electric power is defined as the rate of consumption of electrical energy. It represents the rate at which the electrical energy is converted into some other form of energy.

Suppose a current 'I' flows through a conductor of resistance 'R' for a time 't', then the potential difference across the two ends of the conductor is 'V'. The work done 'W' to move the charge across the ends of the conductor is given by the equation (4.19) as follows:

$$W = V\,I\,t,\ \text{Power } P = \frac{\text{Work}}{\text{Time}} = \frac{VIt}{t}$$

$$\mathbf{P = V\,I} \qquad (4.21)$$

Thus, the electric power is the product of the electric current and the potential difference due to which the current passes in a circuit.

4.9.1 Unit of Electric Power

The SI unit of electric power is watt. When a current of 1 ampere passes across the ends of a conductor, which is at a potential difference of 1 volt, then the electric power is

$$P = 1 \text{ volt} \times 1 \text{ ampere} = 1 \text{ watt}$$

Thus, one watt is the power consumed when an electric device is operated at a potential difference of one volt and it carries a current of one ampere. A larger unit of power, which is more commonly used is kilowatt.

DO YOU KNOW?

HORSE POWER:

The horse power (hp) is a unit in the foot-pound-second (fps) or English system, sometimes used to express the electric power. It is equal to 746 watt.

4.9.2 Consumption of electrical energy

Electricity is consumed both in houses and industries. Consumption of electricity is based on two factors: (i) Amount of electric power and (ii) Duration of usage. Electrical energy consumed is taken as the product of electric power and time of usage. For example, if 100 watt of electric power is consumed for two hours, then the power consumed is 100 × 2 = 200 watt hour. Consumption of electrical energy is measured and expressed in watt hour, though its SI unit is watt second. In practice, a larger unit of electrical energy is needed. This larger unit is kilowatt hour (kWh). One kilowatt hour is otherwise known as one unit of electrical energy. One kilowatt hour means that an electric power of 1000 watt has been utilized for an hour. Hence,

1 kWh = 1000 watt hour = 1000 × (60 × 60) watt second = 3.6×10^6 J

4.10 DOMESTIC ELECTRIC CIRCUITS

The electricity produced in power stations is distributed to all the domestic and industrial consumers through overhead and underground cables. The diagram, which shows the general scheme of a domestic electric circuit, is given in Figure 4.10.

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In our homes, electricity is distributed through the domestic electric circuits wired by the electricians. The first stage of the domestic circuit is to bring the power supply to the main-box from a distribution panel, such as a transformer. The important components of the main-box are: (i) a fuse box and (ii) a meter. The meter is used to record the consumption of electrical energy. The fuse box contains either a fuse wire or a miniature circuit breaker (MCB). The function of the fuse wire or a MCB is to protect the house hold electrical appliances from overloading due to excess current.

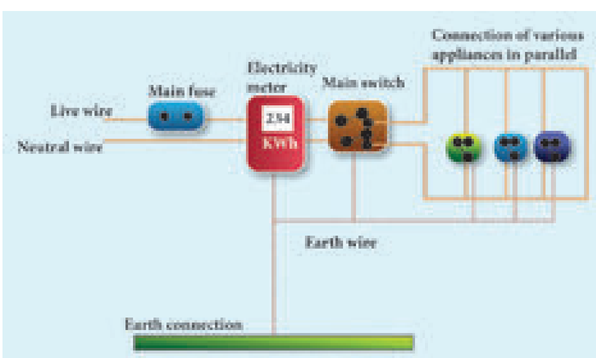


Figure 4.10 Domestic electric circuit

You have learnt about a fuse wire in section 4.8.2. An MCB is a switching device, which can be activated automatically as well as manually. It has a spring attached to the switch, which is attracted by an electromagnet when an excess current passes through the circuit. Hence, the circuit is broken and the protection of the appliance is ensured. Figure 4.11 represents a fuse and an MCB.

Figure 4.11 A fuse and an MCB

The electricity is brought to houses by two insulated wires. Out of these two wires, one wire has a red insulation and is called the 'live wire'. The other wire has a black insulation and is called the 'neutral wire'. The electricity supplied to your house is actually an alternating current having an electric potential of 220 V. Both, the live wire and the neutral wire enter into a box where the main fuse is connected with the live wire. After the electricity meter, these wires enter into the main switch, which is used to discontinue the electricity supply whenever required. After the main switch, these wires are connected to live wires of two separate circuits. Out of these two circuits, one circuit is of a 5 A rating, which is used to run the electric appliances with a lower power rating, such as tube lights, bulbs and fans. The other circuit is of a 15 A rating, which is used to run electric appliances with a high power rating, such as air-conditioners, refrigerators, electric iron and heaters. It should be noted that all the circuits in a house are connected in parallel, so that the disconnection of one circuit does not affect the other circuit. One more advantage of the parallel connection of circuits is that each electric appliance gets an equal voltage.

DO YOU KNOW?

In India, domestic circuits are supplied with an alternating current of potential 220/230V and frequency 50 Hz. In countries like USA and UK, domestic circuits are supplied with an alternating current of potential 110/120 V and frequency 60 Hz.

4.10.1 Overloading and Short circuiting

The fuse wire or MCB will disconnect the circuit in the event of an overloading and short circuiting. Over loading happens when a large number of appliances are connected in series to the same source of electric power. This leads to a flow of excess current in the electric circuit.

When the amount of current passing through a wire exceeds the maximum permissible limit, the wires get heated to such an extent that a fire may be caused. This is known as overloading. When a live wire comes in contact with a neutral wire, it causes a 'short circuit'. This happens when the insulation of the wires get damaged due to temperature changes or some external force. Due to a short circuit, the effective resistance in the circuit becomes very small, which leads to the flow of a large current through the wires. This results in heating of wires to such an extent that a fire may be caused in the building.

4.10.2 Earthing

In domestic circuits, a third wire called the earth wire having a green insulation is usually connected to the body of the metallic electric appliance. The other end of the earth wire is connected to a metal tube or a metal electrode, which is buried into the Earth. This wire provides a low resistance path to the electric current. The earth wire sends the current from the body of the appliance to the Earth, whenever a live wire accidentally touches the body of the metallic electric appliance. Thus, the earth wire serves as a protective conductor, which saves us from electric shocks.

4.11 LED BULB

An LED bulb is a semiconductor device that emits visible light when an electric current passes through it. The colour of the emitted light will depend on the type of materials used. With the help of the chemical compounds like Gallium Arsenide and Gallium Phosphide, the manufacturer can produce LED bulbs that radiates red, green, yellow and orange colours. Displays in digital watches and calculators, traffic signals, street lights, decorative lights, etc., are some examples for the use of LEDs.

4.11.1 Seven Segment Display

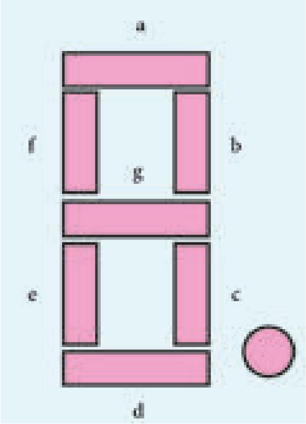


Figure 4.12 Seven segment display

A 'Seven Segment Display' is the display device used to give an output in the form of numbers or text. It is used in digital meters, digital clocks, micro wave ovens, etc. It consists of 7 segments of LEDs in the form of the digit 8. These seven LEDs are named as a, b, c, d, e, f and g (Figure 4.12). An extra 8th LED is used to display a dot.

4.11.2 Merits of a LED bulb

1. As there is no filament, there is no loss of energy in the form of heat. It is cooler than the incandescent bulb.
2. In comparison with the fluorescent light, the LED bulbs have significantly low power requirement.
3. It is not harmful to the environment.
4. A wide range of colours is possible here.
5. It is cost-efficient and energy efficient.
6. Mercury and other toxic materials are not required.

One way of overcoming the energy crisis is to use more LED bulbs.

4.12 LED TELEVISION

LED Television is one of the most important applications of Light Emitting Diodes. An LED TV is actually an LCD TV (Liquid Crystal Display) with LED display. An LED display uses LEDs for backlight and an array of LEDs act as pixels. LEDs emitting white light are used in monochrome (black and white) TV; Red, Green and Blue (RGB) LEDs are used in colour television. The first LED television screen was developed by James P. Mitchell in 1977. It was a monochromatic display. But, after about three decades, in 2009, SONY introduced the first commercial LED Television.

4.12.1 Advantages of LED television

- It has brighter picture quality.
- It is thinner in size.
- It uses less power and consumes very less energy.
- Its life span is more.
- It is more reliable.

Points to Remember

- The magnitude of current is defined as the rate of flow of charges in a conductor.
- The SI unit of electric current is ampere (A).
- The SI unit of electric potential and potential difference is volt (V).
- An electric circuit is a network of electrical components, which forms a continuous and closed path for an electric current to pass through it.
- The parameters of conductors like its length, area of cross-section and material, affect the resistance of the conductor.
- SI unit of electrical resistivity is ohm metre. The resistivity is a constant for a given material.
- The reciprocal of electrical resistivity of a material is called its electrical conductivity.

  $$\sigma = \frac{1}{\rho}$$
- The passage of electric current through a wire results in the production of heat. This phenomenon is called heating effect of current.
- One horse power is equal to 746 watts.
- The function of a fuse wire or a MCB is to protect the house hold electrical appliances from excess current due to overloading or a short circuit.

Solved Problems

1. Two bulbs are having the ratings as 60 W, 220 V and 40 W, 220 V respectively. Which one has a greater resistance?

Solution:

Electric power $P = \frac{V^2}{R}$

For the same value of V, R is inversely proportional to P.

Therefore, lesser the power, greater the resistance

Hence, the bulb with 40 W, 220 V rating has a greater resistance.

2. Calculate the current and the resistance of a 100 W, 200 V electric bulb in an electric circuit.

Solution:

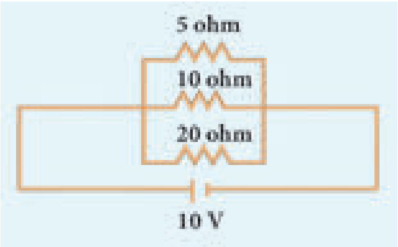
Power P = 100 W and Voltage V = 200 V

Power P = V I

So, Current, $I = \frac{P}{V} = \frac{100}{20} = 0.5$ A

Resistance, $R = \frac{V}{I} = \frac{200}{0.5} = 400\ \Omega$

3. In the circuit diagram given below, three resistors R_1, R_2 and R_3 of 5 Ω, 10 Ω and 20 Ω respectively are connected as shown. Calculate:



A) Current through each resistor
B) Total current in the circuit
C) Total resistance in the circuit

Solution:

A) Since the resistors are connected in parallel, the potential difference across each resistor is same (i.e. V=10V)

Therefore, the current through R_1 is,

$$I_1 = \frac{V}{R_1} = \frac{10}{5} = 2\ A$$

Current through $R_2 = I_2 = \frac{V}{R_2} = \frac{10}{10} = 1\ A$

Current through $R_3 = I_3 = \frac{V}{R_3} = \frac{10}{20} = 0.5\ A$

B) Total current in the circuit, $I = I_1 + I_2 + I_3$

$$= 2 + 1 + 0.5 = 3.5\ A$$

C) Total resistance in the circuit $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

$$= \frac{1}{5} + \frac{1}{10} + \frac{1}{20}$$

$$= \frac{4+2+1}{20}$$

$$\frac{1}{R_P} = \frac{7}{20}$$

Hence, $R_P = \frac{20}{7} = 2.857\ \Omega$

4. Three resistors of 1 Ω, 2 Ω and 4 Ω are connected in parallel in a circuit. If a 1 Ω resistor draws a current of 1 A, find the current through the other two resistors.

Solution:

$R_1 = 1\ \Omega$, $R_2 = 2\ \Omega$, $R_3 = 4\ \Omega$ Current $I_1 = 1\ A$

The potential difference across the 1 Ω resistor $= I_1 R_1 = 1 \times 1 = 1\ V$

Since, the resistors are connected in parallel in the circuit, the same potential difference will exist across the other resistors also.

So, the current in the 2 Ω resistor, $\frac{V}{R_2} = \frac{1}{2} = 0.5\ A$

Similarly, the current in the 4 Ω resistor,

$$\frac{V}{R_3} = \frac{1}{4} = 0.25\ A$$

TEXTBOOK EVALUATION

9STERC

I. Choose the best answer

1. Which of the following is correct?
   a) Rate of change of charge is electrical power.
   b) Rate of change of charge is current.
   c) Rate of change of energy is current.
   d) Rate of change of current is charge.

2. SI unit of resistance is
   a) mho b) joule
   c) ohm d) ohm meter

3. In a simple circuit, why does the bulb glow when you close the switch?
   a) The switch produces electricity.
   b) Closing the switch completes the circuit.
   c) Closing the switch breaks the circuit.
   d) The bulb is getting charged.

4. Kilowatt hour is the unit of
   a) resistivity b) conductivity
   c) electrical energy d) electrical power

II. Fill in the blanks

1. When a circuit is open, ______________ cannot pass through it.
2. The ratio of the potential difference to the current is known as _________.
3. The wiring in a house consists of __________ circuits.
4. The power of an electric device is a product of _________ and ___________.
5. LED stands for ______________________.

III. State whether the following statements are true or false: If false correct the statement.

1. Ohm's law states the relationship between power and voltage.
2. MCB is used to protect house hold electrical appliances.
3. The SI unit for electric current is the coulomb.
4. One unit of electrical energy consumed is equal to 1000 kilowatt hour.
5. The effective resistance of three resistors connected in series is lesser than the lowest of the individual resistances.

IV. Match the items in column-I to the items in column-II:

Column - I	Column - II
(i) electric current	(a) volt
(ii) potential difference	(b) ohm meter
(iii) specific resistance	(c) watt
(iv) electrical power	(d) joule
(v) electrical energy	(e) ampere

V. Assertion and reason type questions:

Mark the correct choice as

a) if both the assertion and the reason are true and the reason is the correct explanation of the assertion.

b) if both the assertion and the reason are true, but the reason is not the correct explanation of the assertion.

c) if the assertion is true, but the reason is false.

d) if the assertion is false, but the reason is true.

1. **Assertion:** Electric appliances with a metallic body have three wire connections.

   Reason: Three pin connections reduce heating of the connecting wires

2. **Assertion:** In a simple battery circuit the point of highest potential is the positive terminal of the battery.

   Reason: The current flows towards the point of the highest potential

3. **Assertion:** LED bulbs are far better than incandescent bulbs.

   Reason: LED bulbs consume less power than incandescent bulbs.

VI. Very short answer questions.

1. Define the unit of current.
2. What happens to the resistance, as the conductor is made thicker?
3. Why is tungsten metal used in bulbs, but not in fuse wires?
4. Name any two devices, which are working on the heating effect of the electric current.

VII. Short answer questions

1. Define electric potential and potential difference.
2. What is the role of the earth wire in domestic circuits?
3. State Ohm's law.
4. Distinguish between the resistivity and conductivity of a conductor.

5. What connection is used in domestic appliances and why?

VIII. Long answer questions.

1. With the help of a circuit diagram derive the formula for the resultant resistance of three resistances connected: a) in series and b) in parallel

2. a) What is meant by electric current?
   b) Name and define its unit.
   c) Which instrument is used to measure the electric current? How should it be connected in a circuit?

3. a) State Joule's law of heating.
   b) An alloy of nickel and chromium is used as the heating element. Why?
   c) How does a fuse wire protect electrical appliances?

4. Explain about domestic electric circuits. (circuit diagram not required)

5. a) What are the advantages of LED TV over the normal TV?
   b) List the merits of LED bulb.

IX. Numerical problems:

1. An electric iron consumes energy at the rate of 420 W when heating is at the maximum rate and 180 W when heating is at the minimum rate. The applied voltage is 220 V. What is the current in each case?

2. A 100 watt electric bulb is used for 5 hours daily and four 60 watt bulbs are used for 5 hours daily. Calculate the energy consumed (in kWh) in the month of January.

3. A torch bulb is rated at 3 V and 600 mA. Calculate it's
   a) power
   b) resistance
   c) energy consumed if it is used for 4 hour.

4 A piece of wire having a resistance R is cut into five equal parts.
   a) How will the resistance of each part of the wire change compared with the original resistance?
   b) If the five parts of the wire are placed in parallel, how will the resistance of the combination change?
   c) What will be ratio of the effective resistance in series connection to that of the parallel connection?

XI. HOTS:

1. Two resistors when connected in parallel give the resultant resistance of 2 ohm; but when connected in series the effective resistance becomes 9 ohm. Calculate the value of each resistance.

2. How many electrons are passing per second in a circuit in which there is a current of 5 A?

3. A piece of wire of resistance 10 ohm is drawn out so that its length is increased to three times its original length. Calculate the new resistance.

REFERENCE BOOKS

1. Electrodynamics by Griffiths

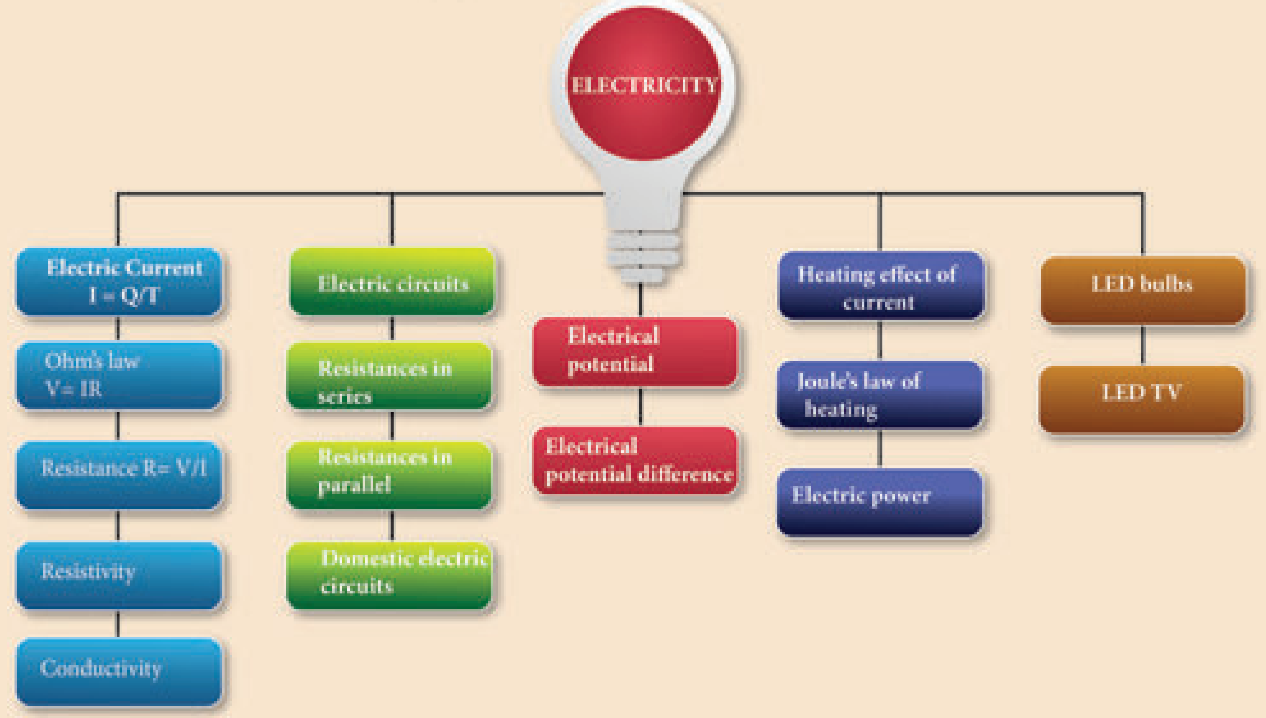
2. Fundamentals of Electric Circuits by Charles Alexander

INTERNET RESOURCES

https://www.elprocus.com/basic-electrical-circuits-and-their-working-for-electrical-engineers/

https://www.physicsclassroom.com/calcpad/circuits

CONCEPT MAP



ICT CORNER — Ohm's Law

In this activity you will be able to (i) verify Ohm's law (ii) understand the relation between current, voltage and resistance.

Steps

- Open the browser and type "olabs.edu.in" in the address bar. Click physics tab and then click "Ohm's law and resistance" under class 10 section. Go to "simulator" tab to do the experiment.
- Construct the electric circuit as per the connection diagram by clicking "show circuit diagram" tab. You can connect wires between electric component by dragging the mouse between the component.
- Switch on the key and note down the voltage (V) and curren (I). Find the value of resistance using the formula $R = \frac{V}{I}$. Repeat the experiment for different values of voltage and current. Check whether the resistance remains constant.
- Find the value of Resistance/(length (in Cm)). Enter the value of resistance and resistance per unit length in the result. Verify the answer.

Note:

1. One time sign up is needed to do simulation. Then login using that username and password.
2. Read theory, procedure and animation to get the theory by clicking the corresponding tab.

Link

URL:http://amrita.olabs.edu.in/?sub=1&brch=4&sim=99&cnt=4

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Learning Objectives

By the end of this section, the students will be able to:

- Understand how sound is produced and transmitted.
- Relate the speed of sound, its frequency, and its wavelength.
- Know the speed of sound in various media.
- Explain the factors affecting the speed of sound in a gaseous medium.
- Demonstrate the phenomenon of reflection of sound.
- Determine the speed of sound using the method of echo.
- Understand Doppler Effect.
- Solve numerical problems related to the above topics.

INTRODUCTION

Sound plays a major role in our lives. We communicate with each other mainly through sound. In our daily life, we hear a variety of sounds produced by different sources like humans, animals, vehicle horns, etc. Hence, it becomes inevitable to understand how sound is produced, how it is propagated and how you hear the sound from various sources. It is sometimes misinterpreted that acoustics only deals with musical instruments and design of auditoria and concert halls. But, acoustics is a branch of physics that deals with production, transmission, reception, control, and effects of sound. You have studied about propagation and properties of sound waves in IX standard. In this lesson we will study about reflection of sound waves, Echo and Doppler effect.

5.1 SOUND WAVES

When you think about sound, the questions that arise in your minds are: How is sound produced? How does sound reach our ears from various sources? What is sound? Is it a force or energy? Let us answer all these questions.

By touching a ringing bell or a musical instrument while it is producing music, you can conclude that sound is produced by vibrations. The vibrating bodies produce energy in the form of waves, which are nothing but sound waves (Figure 5.1).

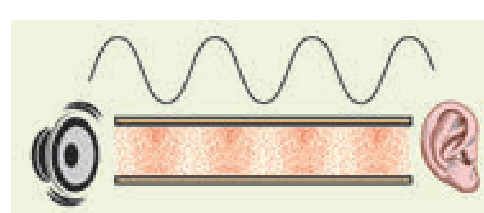

Figure 5.1 Production of sound waves

Suppose you and your friend are on the Moon. Will you be able to hear any sound produced by your friend? As the Moon does not have air, you will not be able to hear any sound produced by your friend. Hence, you understand that the sound produced due to the vibration of different bodies needs a material medium like air, water, steel, etc, for its propagation. Hence, sound can propagate through a gaseous medium or a liquid medium or a solid medium.

ACTIVITY 1

Take a squeaky toy or old mobile phone and put it inside a plastic bag. Seal the bag with the help of a candle or with a thread. Fill a bucket with water and place the bag in the water bucket and squeeze the toy or ring the mobile. You will hear a low sound. Now place your ear against the side of the bucket and squeeze the toy or ring the mobile phone again. You will hear a louder sound.

5.1.1 Longitudinal Waves

Sound waves are longitudinal waves that can travel through any medium (solids, liquids, gases) with a speed that depends on the properties of the medium. As sound travels through a medium, the particles of the medium vibrate along the direction of propagation of the wave. This displacement involves the longitudinal displacements of the individual molecules from their mean positions. This results in a series of high and low pressure regions called compressions and rarefactions as shown in figure 5.2.

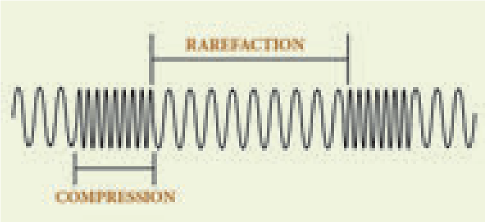

Figure 5.2 Sound propagates as longitudinal waves

5.1.2 Categories of sound waves based on their frequencies

(i) Audible waves – These are sound waves with a frequency ranging between 20 Hz and 20,000 Hz. These are generated by vibrating bodies such as vocal cords, stretched strings etc.

(ii) Infrasonic waves – These are sound waves with a frequency below 20 Hz that cannot be heard by the human ear. e.g., waves produced during earth quake, ocean waves, sound produced by whales, etc.

(iii) Ultrasonic waves – These are sound waves with a frequency greater than 20 kHz, Human ear cannot detect these waves, but certain creatures like mosquito, dogs, bats, dolphins can detect these waves. e.g., waves produced by bats.

5.1.3 Difference between the sound and light waves

S.No.	SOUND	LIGHT
1	Medium is required for the propagation.	Medium is not required for the propagation.
2	Sound waves are longitudinal.	Light waves are transverse.
3	Wavelength ranges from 1.65 cm to 1.65 m.	Wavelength ranges from 4×10^{-7} m to 7×10^{-7} m.
4	Sound waves travel in air with a speed of about 340 m s^{-1} at NTP.	Light waves travel in air with a speed of 3×10^{8} m s^{-1}.

5.1.4 Velocity of sound waves

When you talk about the velocity associated with any wave, there are two velocities, namely particle velocity and wave velocity. SI unit of velocity is metre (m)

Particle velocity:

The velocity with which the particles of the medium vibrate in order to transfer the energy in the form of a wave is called particle velocity.

Wave velocity:

The velocity with which the wave travels through the medium is called wave velocity. In other words, the distance travelled by a sound wave in unit time is called the velocity of a sound wave.

$$\therefore \text{Velocity} = \frac{\text{Distance}}{\text{Time taken}}$$

If the distance travelled by one wave is taken as one wavelength (λ) and, the time taken for this propagation is one time period (T), then, the expression for velocity can be written as

$$\therefore V = \frac{\lambda}{T} \quad (5.1)$$

Therefore, velocity can be defined as the distance travelled per second by a sound wave. Since, Frequency (n) =1/T, equation (5.1) can be written as

$$V = n\lambda \quad (5.2)$$

Velocity of a sound wave is maximum in solids because they are more elastic in nature than liquids and gases. Since, gases are least elastic in nature, the velocity of sound is the least in a gaseous medium.

So, $v_S > v_L > v_G$

5.1.5 Factors affecting velocity of sound

In the case of solids, the elastic properties and the density of the solids affect the velocity of sound waves. Elastic property of solids is characterized by their elastic moduli. The speed of sound is directly proportional to the square root of the elastic modulus and inversely proportional to the square root of the density. Thus the velocity of sound in solids decreases as the density increases whereas the velocity of sound increases when the elasticity of the material increases. In the case of gases, the following factors affect the velocity of sound waves.

Effect of density: The velocity of sound in a gas is inversely proportional to the square root of the density of the gas. Hence, the velocity decreases as the density of the gas increases.

$$\mathbf{v} \propto \sqrt{\frac{1}{d}}$$

Effect of temperature: The velocity of sound in a gas is directly proportional to the square root of its temperature. The velocity of sound in a gas increases with the increase in temperature. $v \propto \sqrt{T}$. Velocity at temperature T is given by the following equation:

$$v_T = (v_o + 0.61\,T)\ \text{m s}^{-1}$$

Here, v_o is the velocity of sound in the gas at 0° C. For air, v_o = 331 m s^{-1}. Hence, the velocity of sound changes by 0.61 m s^{-1} when the temperature changes by one degree celsius.

Effect of relative humidity: When humidity increases, the speed of sound increases. That is why you can hear sound from long distances clearly during rainy seasons.

Speed of sound waves in different media are given in table 5.1.

Table 5.1 Speed of sound in different media

S. No.	Nature of the medium	Name of the Medium	Speed of sound (in m s^{-1})
1	Solid	Copper	5010
2		Iron	5950
3		Aluminium	6420
4	Liquid	Kerosene	1324
5		Water	1493
6		Sea water	1533
7	Gas	Air (at 0° C)	331
8		Air (at 20° C)	343

Example Problem 5.1

1. At what temperature will the velocity of sound in air be double the velocity of sound in air at 0° C?

Solution:

Let T° C be the required temperature. Let v_1 and v_2 be the velocity of sound at temperatures T_1K and T_2K respectively. T_1 = 273K (0° C) and T_2 = (T° C + 273)K

$$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} = \sqrt{\frac{273+T}{273}} = 2$$

Here, it is given that, $v_2 / v_1 = 2$.

$$\text{So, } \frac{273+T}{273} = 4$$

$$T = (273 \times 4) - 273 = 819^\circ C$$

5.2 REFLECTION OF SOUND

When you speak in an empty room, you hear a soft repetition of your voice. This is nothing but the reflection of the sound waves that you produce. Let us discuss about the reflection of sound in detail through the following activity.

When sound waves travel in a given medium and strike the surface of another medium, they can be bounced back into the first medium. This phenomenon is known as reflection. In simple the reflection and refraction of sound is actually similar to the reflection of light. Thus, the bouncing of sound waves from the interface between two media is termed as the reflection of sound. The waves that strike the interface are termed as the incident wave and the waves that bounce back are termed as the reflected waves, as shown in Figure 5.3

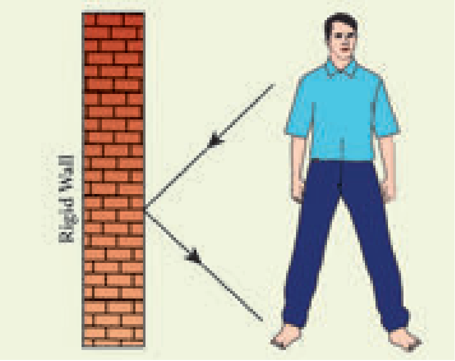

Figure 5.3 Reflection of sound

5.2.1 Laws of reflection

Like light waves, sound waves also obey some fundamental laws of reflection. The following two laws of reflection are applicable to sound waves as well.

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- The incident wave, the normal to the reflecting surface and the reflected wave at the point of incidence lie in the same plane.
- The angle of incidence ∠i is equal to the angle of reflection ∠r.

These laws can be observed from Figure 5.4.

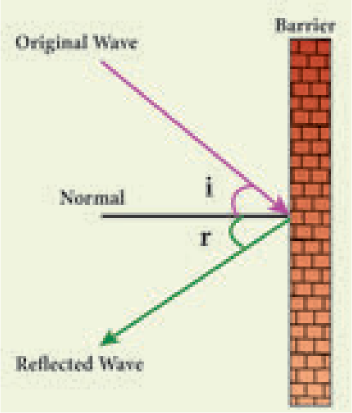

Figure 5.4 Laws of reflection

In the above Figure 5.4, the sound waves that travel towards the reflecting surface are called the incident waves. The sound waves bouncing back from the reflecting surface are called reflected waves. For all practical purposes, the point of incidence and the point of reflection is the same point on the reflecting surface.

A perpendicular line drawn at the point of incidence is called the normal. The angle which the incident sound wave makes with the normal is called the angle of incidence, 'i'. The angle which the reflected wave makes with the normal is called the angle of reflection, 'r'.