PREMANDATORY - 2
Physics PART 1

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Unit - 1 The Universe and Solar System

1. Universe

The Universe is a vast expanse of space. Most astronomers believe that the Universe came into existence after the Big Bang explosion that tookplace about 15 billion years ago. The universe consists of billions of galaxies, stars, planets, comets, asteroids, meteoroids and natural satellites. These are collectively called as celestial bodies, which are located far away from each other. A Light year is the unit used to measure the distance between the celestial bodies.

A light-year is the distance traversed by light in a year at a velocity of 300,000 km per second. Sound travels at a speed of 330 m per second.

Galaxy

It is a huge cluster of stars which are held together by gravitational force. Most of the galaxies are scattered in space, but some remain in groups.The Milky Way Galaxy was formed about 5 billion years after the Big Bang explosion. Our solar system is a part of the Milky Way galaxy. Andromeda galaxy is the nearest to the Earth apart from the 'Magellanic Clouds' galaxy

2. The Solar System

- The word 'solar' is derived from the Roman word 'sol', which means 'Sun God'. The solar system is believed to have formed about 4.5 billion years ago. The solar system is a gravitationally bound system which comprises of the Sun, the eight planets, dwarf planets, satellites, comets, asteroids and meteoroids.

The Sun

- The Sun is at the centre of the solar system. Each member of the solar system revolves around the Sun. The Sun is sohuge that it accounts for 99.8 percent of the entire mass of the solar system. The Sun is made up of extremely hot gases like Hydrogen and Helium. The Sun is a star. It is self-luminous so it gives light on its own. The surface temperature of the Sun is about 6,000° C. It is the source of light and heat energy to the entire solar system. Sunlight takes about 8.3 minutes to reach the Earth.

1.3 million Earths fit inside the Sun. Imagine how big the Sun is.

GEO CONNECT: The ancient Tamils knew that the planets went around the Sun. For example, in Tamil literature Sirupanatruppadai, the line வாள் நிறவிசும்பின் கோள் மீன் சூழ்ந்த இளங்கதிர்ஞாயிறு mentions that the Sun is surrounded by planets.

Planets

- The word planet means wanderer. There are eight planets in the solar system. They are Mercury, Venus, Earth, Mars, Jupiter, Saturn,Uranus and Neptune. All the planets rotate anti-clockwise (from west to east) on their own axes except Venus and Uranus. The elliptical path in which the planets move around the Sun is known as orbit. The eight planets revolve in their respective orbits because of the gravitational pull of the Sun. They do not move out of their paths or away from the solar system.

- The four planets nearer to the Sun are called Inner or Terrestrial Planets (Mercury, Venus, Earth and Mars). The inner planets are comparatively smaller in size and are composed of rocks. The surface of inner planets has mountains, volcanoes and craters. The last four planets are called as Outer Planets or Jovian Planets (Jupiter, Saturn, Uranus, and Neptune). They are also called Gaseous Giants. An asteroid belt is found between Mars and Jupiter.

Mnemonic to remember the order of planets: My Very Educated Mother Just Showed Us Neptune.

Mercury (The Nearest Planet)

- Mercury is the smallest and closest planet to the Sun. It is named after the Roman deity 'Mercury', themessenger to the Gods. It is an airless and waterless planet.It does not have an atmosphere and so experiences extremes of temperature. It has no natural satellites. Mercury can be viewed in the morning and evening with naked eye.

Venus (The Hottest Planet)

- Venus is the second planet from the Sun. It is called Earth's twin, as it is almost the same size as the Earth. It has the longest rotation Venus period(243 days) among the planets in the Solar system. It rotates in the opposite direction to all other planets except Uranus. It has no natural satellites like Mercury. It is named after the Roman goddess of love and beauty. It is often visible in the mornings and the evenings and so it is frequently called as the Morning Star and the Evening Star. After the Moon, it is the brightest natural object in the night sky.

Earth (The Living Planet)

- The Earth is the third planet from the Sun and the fifth largest planet in the solar system. It is called 'blue planet' or 'watery planet' becausethree-fourth of the Earth is covered by water. The Earth is the only planet in the solar system which is not named after any Greek or Roman deity. It is the only planet known to support life. The polar diameter of the Earth is 12, 714 km and the equatorial diameter is 12, 756 km. The Earth revolves around the Sun at a speed of about 30 km per second. Life is possible on Earth because of the presence of land, air and water. The only natural satellite of the Earth is the Moon.

The distance between the Sun and the Earth is about 150 million kilometre. A flight flying at a speed of 800 km per hour from the Earth would take 21 years to reach the Sun.

Mars (The Red Planet)

- Mars is the fourth planet from the Sun and the second smallest planet in the solar system, after Mercury. It is named after the Roman Godof war. It appears red in colour due to the presence of iron oxide on its surface. So, it is often described as The Red Planet. It has a thin atmosphere. It also has polar icecaps like the Earth. Mars has two natural satellites namely Phobos and Deimos. Many orbiters and rovers have been launched to explore this planet.

On 24th September, 2014 Mangalyan (Mars Orbiter Mission - MOM), launched by the Indian Space Research Organization (ISRO), reached the orbit of Mars to analyze its atmosphere and topography. ISRO has now become the fourth space agency to reach Mars after the Soviet Space programme, NASA and the European Space Agency.

Jupiter (the Largest Planet)

- Jupiter is the f fth planet from the Sun and the largest planet in the solar system. It is named after the king of the Roman gods. It is the third brightest objectin the night sky, after moon and Venus. It is the fastest spinning planet in the solar system. It is called a gas giant planet. Its atmosphere is made up of mostly Hydrogen and Helium like the Sun. It has the largest number of natural satellites. Io, Europa, Ganymede and Callisto are a few large satellites of Jupiter.

Saturn (The Ringed planet)

- Saturn is the sixth planet from the Sun and the second largest planet in the solar system, after Jupiter. It is named after the Roman god of agriculture. Saturn has many rings around it. These rings are huge and are mostly made up of ice, rocks and dust particles.

- Saturn has 62 natural satellites around it. Titan, Saturn's largest moon, is theonly satellite in the solar system that has clouds and dense atmosphere composed of nitrogen and methane. The specific gravity of Saturn is less than that of water.

Uranus (The Somersaulting planet)

- Uranus is the seventh planet from the Sun. It was the first to be discovered with a telescope by the astronomer William Herschel in 1781. It appears green due to the presence of ethane. It is named after the Greek god of the sky. It rotates on its axis from east to west like Venus. Its axis is tilted so much that, it appears to orbit the Sun on its sides like a rolling ball. Uranus has 27 natural satellites, of which Titania is the largest.

Neptune (The coldest Planet)

- Neptune is the eighth and the farthest planet from the Sun. There are strongwinds in this planet. It is named after the Roman god of sea. Neptune has 14 natural satellites, the largest being Triton. Because of its distance from the Sun, Neptune is oneof the coldest planets in the solar system. The striking blue and white features of Neptune help to distinguish it from Uranus.

The Dwarf Planets

- Dwarf planets are small celestial bodies found beyond the planet Neptune. They are extremely cold and dark. They are almost spherical in shape, but unlike planets they can share their orbit with other dwarf planets. The five dwarf planets of the solar system are Pluto, Ceres, Eris, Makemake and Haumea.

The Moon - Earth's Satellite

- Satellites are celestial objects, which revolve around the planets. The moon is the Earth's only satellite. It revolves around the Earth once in every 27 days and 8 hours. It takes about the same time for it to complete one rotation around its axis. It has no atmosphere. The surface of the moon is characterized by craters created by the impact of meteors. The distance between the moon and the Earth is about 3, 84,400 km. The size of the moon is one-quarter of the Earth. The Moon is the only celestial body where humans have landed.

Asteroids

- Asteroids are small solid objects that move ISRO launched India's first ever Moon mission, Chandrayaan - 1 in 2008. Around the Sun. They are found as a belt between Mars and Jupiter. They are too small to be called as planets. They are also known as Planetoids or Minor Planets.

Comets

- A comet is a celestial object made up of a head and a tail. The head of a comet consists of solid particles held together by ice andthe tail is made of gases. Halley's Comet is the most famous comet which comes close to the Earth every 76 years. It last appeared in 1986 and will next appear in 2061.

Meteors and Meteorites

- A meteor is a stone like or metallic body. When entering into the Earth's atmosphere, most of them burn. As they often appear as streaks of light in the sky, they are also known as Shooting Stars. Meteors which strike the Earth's surface are called meteorites.

3. Motions of the Earth

- Have you noticed the Sun in the morning, afternoon or evening? Is it in the same place throughout the day? No. It is seen in the east in the morning, overhead in the afternoon and in the west in the evening. Have you ever thought of the reason behind it? This is because of the constant moving of the Earth around the Sun. It seems that the Sun is moving, but it is not so. This is similar to what you experience when you are travelling in a bus or train. When you look out of the window, the trees, lamp posts and other objects seem to be moving, but actually it is you who are moving. To understand the motions of the Earth better, you need to be familiar with the shape and inclination of the Earth.

Shape and Inclination of the Earth

- The Earth is spherical in shape. It rotates on its axis, which is an imaginary line that runs from the North Pole to the South Pole passing through the centre of the Earth. The Earth's axis is always tilted or inclined from the vertical by an angle of 23½°. It makes an angle of 66½° with the plane of the Earth's orbit.

- The velocity of the Earth's rotation varies from 1670 km per hour at the equator to 845 km per hour at 60° N and S latitudes and zero at the poles.

Rotation

- It is the spinning movement of the Earth on its axis. The Earth rotates from west to east (anticlockwise) and takes 23 hours 56 minutes and 4.09 seconds tocomplete one rotation. The time taken by the Earth to complete one rotation is called a day. The rotation of the Earth causes day and night. As the Earth is spherical inshape, only one half of it is illuminated by the Sun at a time. The other half remains dark. The illuminated portion of the Earth experiences day, whereas the darkened part of the Earth experiences night. The line which divides the surface of the Earth into a lighted half and a dark half is called the Terminator Line.

The Midnight Sun is a natural phenomenon that occurs in the summer months in places north of the Arctic Circle or south of the Antarctic Circle, when the Sun remains overhead 24 hours a day.

Revolution

- It is the movement of the Earth around the Sun on its elliptical path. The Earth takes 365 ¼ days for it to complete one revolution. It revolves around the Sun at aspeed of 30 km per second. For the sake of convenience, we take it as 365 days and call it a year. The remaining quarter day is added once in every four years in the month of February. That is why February has 29 days once in four years. It is called a Leap Year. The inclination of the Earth on its axis and its revolution around the Sun cause different seasons.

- The Northern Hemisphere is inclined towards the Sun for six months from 21st March to 23rd September while the Southern Hemisphere is tilted away from the Sun.

- From Sep 23rd to March 21st the southern hemisphere is inclined towards the Sun and the northern hemisphere faces away from the Sun. The changing position of the Earth in its orbit during revolution gives the impression that the Sun is continuouslymoving north and south of the equator. The equator faces the Sun directly on 21 March and 23 September. These two days are called Equinoxes, during which the day and night are equal throughout the Earth.

Perihelionis the Earth's closest position to the Sun. Aphelion is the farthest position of the Earth from the Sun.

- On 21st June, the Tropic of Cancer faces the Sun. This is known as Summer Solstice. It is the longest day in the Northern Hemisphere and longest night (shortest day) in the Southern Hemisphere. On 22nd December, the Tropic of Capricorn faces the Sun. It is called as Winter Solstice. It is the longest day in the Southern Hemisphere and longest night (shortest day) in the Northern Hemisphere.

4. Spheres of the Earth

- The Earth is the most suitable planet to support life. It has three major components that we call as the realms of the Earth-lithosphere, hydrosphere and atmosphere. The three components along with suitable climate make life possible on Earth. All living things exist in a narrow zone called the biosphere. Now let us have a close look at each of the spheres.

Lithosphere

- The word lithosphere is derived from the Greek word Lithos, which means rocky. The Lithosphere is the land on which we live. It is the solid outer layer of the Earth consisting of rocks and soils.

Hydrosphere

- The word Hydro means water in Greek. The hydrosphere consists of water bodies such as oceans, seas, rivers, lakes, ice caps on mountains and water vapour in the atmosphere.

Atmosphere

- The word Atmo means air in Greek. Atmosphere is the envelope of air that surrounds the Earth. Different types of gases make up the atmosphere. The major gases are Nitrogen (78%) and Oxygen (21%). The other gases like Carbon dioxide, Hydrogen, Helium, Argon, and Ozone are present in meageramounts.

Biosphere

- The narrow belt of interaction among the lithosphere, the hydrosphere and the atmosphere, where life exists is known as Biosphere. Bio means life in Greek. It consists of distinct zones. Each zone has its own climate, plant and animal life. These zones are known as ecosystems.

The Gulf of Mannar Biosphere Reserve in the Indian Ocean covers an area of 10,500 sq.km in the ocean.

7th term 3

Unit.2 Universe and Space

GEO Centric Theory

Sky is a wonder. Sun, Moon, stars all appear to rise in the East and move towards the west,giving us an impression that all these objects aregoing around the Earth. Just as in a moving bus the distant mountains and trees appear to move backwards, perhaps really Earth is spinning and that is why Sun, Moon and stars appear to go around the Earth. Does the Earth revolve around the Sun, or the Sun revolves around the Earth? How do you know about it?

When you look at the night sky you can see lot of twinkling objects. But a few of them differ from the others. They don't twinkle and while the other stars hold a fixed pattern from night to night, these drift. They wander across the sky, moving against the backdrop of stars. These are called planets. Our ancestors observed this and they imagined a universe with the Earth at the center, the stars in the distant background, and Sun, Moon and the planets orbiting around us.

Two observations supported the idea that Earth was thecenter of the Universe. First, from anywhere on the Earth, the Sun appears to revolve around the Earth once in a day. While the Moon and the planets have their own motions, they also appear to revolve around the Earth about once per day. Even the celestial sphere studded with stars appears to rise and set in the evening, and make one complete rotation in a year. Second, the Earth seems to be unmoving from the perspective of an earthbound observer; it feels stationary.

As civilization progressed the early astronomers found two types of motion of celestial objects. Let us take the case of Moon. On a daily basis Moon appears to rise in the east and set in the west. Thus, one can say that Moon is going around the Earth with a period of one day. But for a careful observer, it was clear that the Moon was also exhibiting another motion. Suppose, the Moon is appearing in the sky today near the star Asvini, tomorrow we will observe that the Moon is near the star Bharani, a star east of Asvini. And the next day it will be near the star Kartikai, east of Bharani. After 27 days, moving little by little eastwards, the Moon again stations itself near asvini. Thus, everyday Moon appears to move from east to west in one day where as it appears to go in a circle from west to east in the background of stars in about 27 days.

These two motions were puzzling. Very soon astronomers like Aryabhata said thatEarth is spinning in its axis, that is the cause of apparent daily motion from East to West. Whereas the eastward motion of Moon in the celestial sphere with a period of about 27 days, was seen as the 'actual' motion of the celestial objects.

Thus, the geocentric model (also known as geocentrism), that is a description of the Universe with spherical and spinning Earth at the center and the Sun, Moon, stars, andplanets all orbits the Earth emerged in various cultures. In Greece, this model was put forth by the Greek philosopher Plato and his disciple Aristotle in 6th century B.C. It was standardized by a Greeco Roman mathematician Ptolemy in the 2nd Century A.D. A similar model is seen in the Siddhanthic astronomy in India like Aryabhateeyam of Aryabhata.

How moon exhibit phases

Astronomers in ancient times also observed certain facts. The Purananuru (65) of Sangam literature, the poet PoetKalathalaiyar singing in appreciation of CheramanPeruncheralathansays"

On the day when the full moon appears,thesunand moon look at each other with their bright light. In the evening time, one sphere hides behind the mountains."

On the full moon day, when the Sun is setting in the west, precisely at the same time, Moon rises at the East. That is both Sun and Moon are in the opposite side. Likewise when it is waning half moon, the Moon is rises when it is midnight and the waxing half moon rises during noon. From such observations and modelling ancient astronomers could explain why we have waxing and waning of moon.

It is probably easier to understand the waxing and waning of Moon in the order of new moon & full moon and then how the first and third quarter moon (half moon) appear and then the phases in between.

Sun is the source of light. Sun light falls on the spherical earth, but only on the side facing Sun. The opposite side of Earth is without sunlight. As the Earth spins day and night follows as different parts of Earth appear before the Sun. That is at all times one half of Earth is illuminated by Sun and one half is in darkness.

Likewise at all times one half of Moon is illuminated by Sun and the opposite side is shroud in darkness.

As shown in the above diagram, when the moon is positioned between the earth and sun, notice all the illuminated part of Moon is away from Earth. Hence we cannot see any part of the illuminated side of the Moon. Only the dark side of Moon is towards Earth. When the moon is in this position, we have new moon. Now look at the moon when it is behind the Earth. Now the portion of the moon illuminated by sun is totally towardsEarth. The dark side isaway from the Earth. This means the moon willappear to be round in the sky. This is full moon.

When the Sun, Earth and Moon are in 90 degree angle how will the moon appear to a person on the surface of the Earth? Now if you look at the portion of moon facing Earth, we will see half if it illuminated and half is dark side.

Thus, the moon will appear as half moon. The half moon during the waxing period is called as first quarter and the half moon during the waning period is called as third quarter. (figure sun moon and earth are at right angles)

Once we understand those four key moonphases, the phases between them should be fairly easy to visualize.

The word crescent refers to the phases where the moon is less than half illuminated. The word gibbous refers to phases where the moon is more than half illuminated. Waxing essentially means “growing” or expanding in illumination, and waning means “shrinking” or decreasing in illumination. Note all so that these discoveries could be made with naked eye. You do not need telescope or any modern equipment.

Epicycles

Moon going around Earth with 27 day period nicely explained its motion. However astronomers in ancient times faced problem in explaining the motion of the then known five planets- Mercury, Venus, Mars, Jupiter and Saturn

Moon in the background of stars moved everyday eastwards nicely. However for example, if we were observing the motion of Mars from January, it would appear to move eastward in the background stars. That is the position of mars today will be near a star which is east of the star near which it was yesterday. However on June 28, we will see a change. From that datethe Mars would appear to move west rather than its normal eastward motion. This reversal of direction of planets is called as ‘retrograde motion’. If we continue to observe, on August28 once again the Mars would appear to reversethe direction and again on its usual eastward motion in the celestial sphere. Usually Jupiter is brighter than Mars, however, around the period of retrograde motion the Mars was much bright than other times; even brighter than Jupiter.

Other planets also exhibited number of puzzling behaviours. Venus and Mercury always appeared very close to Sun, and hence never appeared in the midnight sky. The brightness of Jupiter also varied again when it exhibited retrograde motion. For example in 2018, Jupiter reversed its direction of motion on March 9,2018 and again resumed its normal eastward motion on July 11, 2018.

The simple geocentric model, where planets go around the Earth could not explain why the brightness of the planets changed, and why they reversed their directions. Change in brightness and retrograde motion would be impossible if we assumed that the planets were at the same distance at all times from Earth.

To explain the puzzling phenomena astronomers in early times proposed a change in the simple geocentric model. This is called as epicycle model.

Ptolemy (2nd cent) in Greece, Aryabhattain India and others used the epicycle model to explain the motion of the celestial objects. Their models were improved by generation of astronomers like Tycho Brahe and NeelakantaSomayaji.

Although, the model explained many phenomena there were number of mismatches. The model was becoming messy.

Arrival of telescope

Telescope was invented by Hans LippersheybutGalilio used it for studying the sky for the first time. The telescope showed more universe was than visible to naked eye. With his simple telescope matching toy telescopes of today, Galilio was able to see mountains on the Moon, small dim stars invisible to naked eye, sunspots on the face of Sun. He was able to demonstrate that the milky way, an hazy bright patch in the sky is nothing but thousands of stars huddled together, Jupiter had moons going around it and Saturn had mysterious appendage which we now know as rings.

One of the most startling observations he made was related to telescopic observation of Venus. This convinced him to accept the theory of the Polish Astronomer Nicolus Copernicus, that it is not Sun, planets and Stars that go around Earth, but it is Earth and other planets that go around the Sun- heliocentric theory.

Heliocentric model

Dissatisfied with the messy epicycle model Nicolus Copernicus, radically proposed that the model will become simple if we assume Sun is at the center and all planets, including Earth, go around it.

Suppose, Earth and Mars are on the two sides of the Sun, then Mars would be far and appear dim, compared to when they are on the same side. Earth orbit around Sun in 365 days, whereas Mars takes 687 days. This implies at times Earth will overtake Mars. When the Earth is approaching and overtaking Mars, the Mars would appear to exhibit retrograde motion. In short all the observed phenomena could be explained in a simple way.

However how do we know that actually Sun is at the center or not?

Galileo found that his observation of Venus gave the observational evidence to support the heliocentric theory. Galileo observed Venus in 1610-1611 with a telescope. To naked eye, Venus is just a gleaming bright spot. However, through a telescope, the shape of the planet can be seen. Galilio was startled to find like Moon Venus too exhibited phases. The shape varied from crescent to gibbous. Also, the size of the planet varied. When the planet was in gibbous phase the size was small, and when it was thin crescent the size was many folds higher.

As the Venus went around the epicycle, as shown in the diagram Venus would exhibit phases. Also at times the planet would be nearer, making the apparent size grow bigger and at times far making the apparent size smaller. Thus, the variation in the brightness can also be explained.

It became clear to Galilio that the geocentric epicycle model will not help in accounting for the observed phases of the Venus.

Look at the above diagram. If the Venus was going around the Sun, and its orbit is inside that of Earth, Venus would appear always near the Sun in the sky. It can never be seen in the midnight sky. Two when it is near the Earth, it would be brighter and bigger compared to when it is on the other side of the Sun. Thirdly only if the Venus is revolving around the Sun, it can exhibit gibbous phase, and the size of the gibbous phase smaller than the crescent phase. If the Venus was revolving around the Earth, we can never see the gibbous phase of the Venus and it would be seen only if it is orbiting the he Sun. This clinching observational evidence proved that at the least Venus orbited around the Sun. Further evidences collected by astronomers using telescope and other advanced modern instruments gave enough evidence that all planets revolve around the Sun.

If Galileo were around today, he would surely be amazed at exploration of our solar system and beyond by ISRO, NASA, Russian space agency and others.

Now we can observe planets orbiting around other stars (called exoplanets), proving that not only planets orbit around the Sun in solar system, but all around the universe suchplanetary systems exist. Who knows, in some ofthere could be life and in rare cases intelligentlife, like humans wondering and exploringuniverse. Imagine a future time when such lifemeet us; how exciting and momentous it wouldbe!

Origin of the Universe

You are a student who belong to a particular class studying in VII std. In your school, there might me many section for VII std. Likewise, there are VI std class, VIII std class and so on. All of them together make the school. Likewise, our Sun is a star with a planetary system. Billions of such stars consitute a system called as galaxy. The name of our galaxy is, Milky Way. Like MilkyWay, there are at least hundreds of billions of galaxies in the Universe.How did all these come about? Where they in existence always or was there a beginning?

When we observed other galaxies we found a strange behavior. All the galaxies were appearing to move away from us. Further, farther they are faster they appear to move. Cosmologists , scientists who study the structure and evolution of universe that is cosmos, reason that this imply at one point of time in the past all matter was confined in a single point and since then it has started to expand.

The event when the matter confined in a single point and began to expand is called 'big bang'. This is considered as the origin of our universe as we know it.

The Big Bang Theory is the prevailing model of the evolution of the Universe. Under this theory, space and time emerged together about 14 billions of years ago. At that time, the entire Universe was inside a bubble that was thousands of times smaller than a pinhead. It was hotter and denser than anything we can imagine. Then it suddenly expanded. The present Universe emerged .Time, space andmatter all began with the Big Bang.

In a fraction of a second, the Universe grew from smaller than a single atom to bigger than a galaxy. And it kept on growing at a fantastic rate. It is still expanding today. Over the next three minutes, the temperature dropped below 1 billion degrees Celsius. After 300 000 years, the Universe had cooled to about 3000 degrees. Atomic nuclei could finally capture electrons to form atoms. At that stage of the evolution of the Universe, it was filled with clouds of hydrogen and helium gas. Giant clouds of hydrogen and helium were gradually drawn to the places where dark matter was most dense, forming the first galaxies, stars, and everything else seen today.

We cannot see anything that happened during the first 300000 years of the Universe. Scientists try to work it out from their knowledge of atomic particles and from computer models. The only direct evidence of the Big Bang itself is a faint glow in space, called cosmic microwave background.

As millions of years passed, the dense areas pulled in material because they had more gravity. Finally, about 100 million years after the Big Bang, the gas became hot and dense enough for the first stars to form. New stars were being born at a rate 10 times higher than in the present-day Universe. Large clusters of stars soon became the first galaxies.

Building Blocks of Universe.

As stated above universe is constituted of galaxies, just as lot of houses in our locality constitute a village or a city. We have lot of things such as rooms, furniture etc. in our homes. Likewise lot of stellar objects such as stars, planets, asteroids and meteors are the building blocks of our universe.

Galaxies.

A galaxy is a large collection of stars or cluster of stars and celestial bodies held together by gravitational attraction. There are about billions of galaxies in the universe. Most galaxies range from thousand to ten thousand parsec in diameter. As we have different types of houses in a locality, the galaxies are also of different types.

Types of galaxies

There are various types of galaxies such as spiral, elliptical, barred spiral and irregular

Spiral Galaxy

Spiral galaxies consist of a flat, rotating disk containing stars, gas and dust, and a centralconcentration of stars known as the bulge. These are often surrounded by a much fainter halo of stars. Spiral galaxies are named by their spiral structures that extend from the centerinto the galactic disc. The spiral arms are sites of ongoing star formation and are brighter than the surrounding disc because of the young, hot stars that inhabit them.

Elliptical Galaxy

An elliptical galaxy is a type of galaxy having an approximately ellipsoidal shape and a smooth image. Unlike flat spiral galaxies with organization and structure, elliptical galaxies are three-dimensional, without much structure, and their stars are in somewhat random orbits around the center. Interestingly Stars found inside of elliptical galaxies are on an average much older than stars found in spiral galaxies. Elliptical galaxies tend to be surrounded by large numbers of globular clusters.

Irregular Galaxy

An irregular galaxy is a galaxy that does not have a distinct regular shape, unlike a spiral or an elliptical galaxy, they are often chaotic in appearance, with neither a nuclear bulge nor any trace of spiral arm structure. About one forth of the galaxies found so far are of this type.

Cosmologists say that some irregular galaxies were once spiral or elliptical galaxies but were deformed by an uneven external gravitational force. Irregular galaxies may contain abundant amounts of gas and dust.

Barred Spiral

A barred spiral galaxy is a spiral galaxy with a central bar-shaped structure composed of Stars. Bars are found in approximately in two-thirds to one third of all spiral galaxies. The Milky Way Galaxy, where our own Solar System is located, is classified as a barred spiral galaxy.

Milky Way

The Milky Way is the galaxy in which our solar system is located. Thediameter of Milky Way is over100,000 light years. The MilkyWay includes stars smaller than our Sun as wellas many other stars that are thousands of timesbigger than the Sun. It includes many othercelestial bodies of gases, clouds of dust, deadstars, newly born stars, etc. It is also thoughtto contain at least 100 billion stars. The galaxythat is closest to our Milky Way is Andromeda.The descriptive "milky" is derived from theappearance from Earth of the galaxy – a bandof light seen in the night sky formed from starsthat cannot be individually distinguished by thenaked eye. In Indian mythology, this patch calledas Akasha Ganga. From the Earth, the MilkyWay appears as a band because its disk-shaped structure is viewed from within. Galileo Galilifirst resolved the band of light into individual stars with his telescope in 1610. Until the early 1920s, most astronomers thought that the Milky Way contained all the stars in the Universe. Observations by Edwin Hubble showed that the Milky Way is just one of many galaxies.

The Milky Way does not sit still, but is constantly rotating. Our solar system is located within the disk of the galaxy, about 27,000 light years away from the centre of the galaxy. The solar system travels at an average speed of 828,000 km/h. Even at this rapid speed, the solar system would take about 230 million years to travel all the way around the Milky Way. When the solar system was in the same spot as it is now, there were no humans, no Himalayan mountain on Earth and the dinosaurs were roaming around the Earth.

Tucked inside the very center of the galaxy is a monstrous black hole, billions of times as massive as the sun. Although, black holes cannot be directly viewed, scientists can see their gravitational effects as they change and distort the paths of the material around it, most galaxies, like our milkyway, are thought to have a black hole in their heart.

Constellation

A constellation is a recognizable pattern of stars in the night sky when viewed from the Earth. International Astronomical Union has classified 88 constellations to cover the entire celestial sphere. Many of the old constellations have Greek or Latin names and are often named after mythological characters.

Ursa Major (Saptha Rishi Mandalam) is a large constellation and it covers a large part of the sky. The most striking feature of this constellation is a group of seven bright stars known as big dipper (seven Sages in Indian astronomy).

Ursa Minor in Lattin means 'the little bear' it lies in the northern sky. The Pole star – Polaris (Dhrua) lies within this constellation. The main group, 'little dipper', consists of seven stars and is quite similar to that found in Ursa Major.

Orion was a hunter in Greek mythology. The constellation comprises around 81 stars out of which all but 10 are too faint to be seen with naked eye.

Different constellations become visible in the sky at different times in the year. This happens due to the revolution of the Earth around the Sun.

Unlike galaxy, constellations are mereoptical appearance and not real objects. In galaxy stars are bound by gravity and constitute a system. In a constellation, one star may be near and another very very far, but because they are in the same direction appear to be near to each other in the sky.

Name of Constellations	
Indian Name	**English Name**
Mesham	Aeries
Rishabham	Taurus
Midhunam	Gemini
Kadakam	Cancer
Simmam	Leo
Kanni	Virgo
Thulam	Libra
Vrischikam	Scorpio
Dhanusu	Sagittarius
Makaram	Capricorn
Kumbam	Aquarius
Meenam	Pisces

Stars

A Star is a luminous heavenly body that radiate energy. With naked eyes, we can see nearly 3000 stars in the night sky and many more with the help of a telescope. The stars are remotely located and appear as tiny dots of light. Their light travels long distances to reach us. The atmosphere disturbances do not allow light to reach us in a straight line path. Because of this the stars appear to twinkle. The Sun is the nearest star to the Earth. The next nearest star is Alpha Centauri

Satellites

An object that revolves around a planet in a stable and consistent orbit is called a satellite. Satellites can be classified into two categories – natural and artificial.

Natural satellites

All natural objects revolving around a planet are natural satellites. They are also called moons. Most moons are spherical, the ones that are not usually asteroids or meteors that were captured by the strong gravity of a planet. All planets except mercury and Venus in our solar system have moons. Earth has only one moon-whereas planets like Jupiter and Saturn have more than 60 moons.

Artificial satellites

Artificial satellites are man-made objects placed in an obit to rotate around a planet – usually the Earth. The world's first artificialsatellite launched was Sputnik-1 by Russia,
Aryabhatta was the first satellite launched by India. These satellites are used in television and radio transmission, studying agriculture yield, locating mineral resources, weather forecasting, locate different places on earth.

ISRO

The Indian Space Research Organisation (ISRO) is the space agency of the Government of India headquartered in the city of Bangalore. Its vision is to "harness space technology for national development while pursuing space science research and planetary exploration."

Formed in 1969, ISRO superseded the erstwhile Indian National Committee for Space Research (INCOSPAR) established in 1962 by the Scientist Vikram Sarabhai. The establishment of ISRO thus institutionalized space activities in India. It is managed by the Department of Space, which reports to the Prime Minister of India.

ISRO built India's first satellite, Aryabhatta, which was launched by the Soviet Union on 19 April 1975. It was named after the Indian astronomer Aryabhata. In 1980, Rohini became the first satellite to be placed in orbit by an Indian-made launch vehicle, SLV-3. ISRO subsequently developed two other rockets: the Polar Satellite Launch Vehicle (PSLV) for launching satellites into polar orbits and the Geosynchronous Satellite Launch Vehicle(GSLV) for placing satellites into geostationary orbits. These rockets have launched numerous communication satellites and earth observation satellites. Satellite navigation systems like GAGAN and IRNSS have been deployed. In January 2014, ISRO used an indigenous cryogenic engine in a GSLV-D5 launch of the GSAT-14.

ISRO sent a lunar orbiter, Chandrayan -1, on 22 October 2008 and a Mars orbiter, Mars Orbiter Mission, on 5 November 2013, which entered Mars orbit on 24 September 2014, making India the first nation to succeed on its first attempt to Mars, and ISRO the fourth space agency in the world as well as the first space agency in Asia to reach Mars orbit. On 18 June 2016 ISRO set a record with a launch of 20 satellites in a single payload. On 15 February 2017, ISRO launched 104 satellites in a single rocket (PSLV-C37) and created a world record. ISRO launched its heaviest rocket, Geosynchronous Satellite Launch Vehicle- Mark III (GSLV-Mk III), on 5 June 2017 and placed a communications satellite GSAT-19 in orbit. With this launch, ISRO became capable of launching 4 ton heavy satellites.

ISRO launched Chandran 2 on July 22, 2019, Geosynchronous Satellite Launch Vehicle (GSLV-Mk III). It entered the Moon's orbit on August 20, 2019 and its lander landed on the Moon on September 7.

Do You Know?

In 1989, Galileo Galilei was memorialized with the launch of a Jupiter-bound space probe bearing his name. During its 14-year voyage, the Galileo space probe and its detachable mini-probe, visited Venus, the asteroid Gaspra, observed the impact of Comet Shoemaker-Levy 9 on Jupiter, Europa, Callisto, IO, and Amalthea.

In order to avoid the possible contamination of one of Jupiter's moons, the Galileo space probe was purposely crashed into Jupiter at the end of its mission in September 2003.

8th- term -3

Unit -3 UNIVERSE AND SPACE SCIENCE

Rockets

The universe is a great mystery to all of us. Our minds always try to know about the space around us. Understanding the space will be helpful to us in many ways. Space research provides information to understand the environment of the Earth and the changing climate and weather on Earth. Exploring the space will help us to answer many of the challenges we are facing these days

Discovery of rockets has opened a small portion of the universe to us. Rockets help us to launch space probes to explore the planets in the solar system. They also help us to launch space-based telescopes to explore the universe.

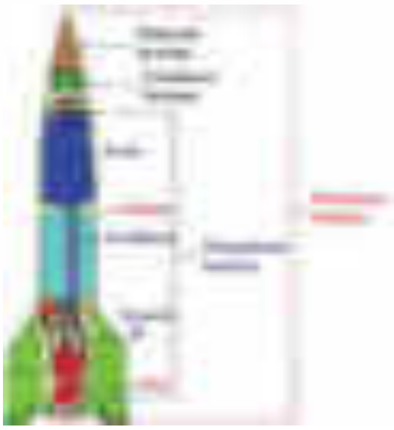
> Rockets were invented in China, more than 800 years ago. The first rockets were a cardboard tube packed with gunpowder. They were called fire arrows. In 1232 AD, the Chinese used these 'fire arrows' to defeat the invading Mongol army. The knowledge of making rockets soon spread to the Middle East and Europe, where they were used as weapons.

More than all rockets enable us to put satellites, which are useful to us in a number of ways. Our country has effective rocket technology and has applied it successfully to provide so many space services globally.

Parts of Rockets

A rocket is a space vehicle with a very powerful engine designed to carry people or equipment beyond Earth and out into space. There are four major parts or systems in a rocket. They are:

- ❖ Structural system
- ❖ Payload system
- ❖ Guidance system
- ❖ Propulsion system



Parts of a Rocket

Structural system (Frame)

The structural system is the frame that covers the rocket. It is made up of very strong but light weight materials like titanium or aluminum. Fins are attached to some rockets at the bottom of the frame to provide stability during the flight.

Payload system

Payload is the object that the satellite is carrying into the orbit. Payload depends on the rocket's mission. The rockets are modified to launch satellites with a wide range of missions like communications, weather monitoring, spying, planetary exploration, and as observatories. Special rockets are also developed to launch people into the Earth's orbit and onto the surface of the Moon.

Guidance system

Guidance system guides the rocket in its path. It may include sensors, on-board computers, radars, and communication equipments.

Propulsion system

It takes up most of the space in a rocket. It consists of fuel (propellant) tanks, pumps and a combustion chamber. There are two main types of propulsion systems. They are: liquid propulsion system and solid propulsion system.

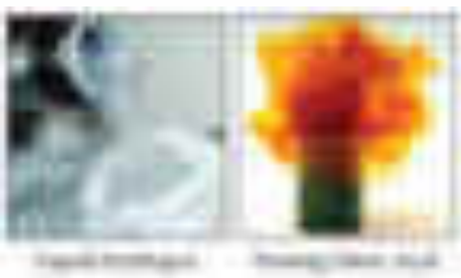
Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Satellite Launch Vehicle (GSLV) rockets are India's popular rockets.

Types of Propellants

A propellant is a chemical substance that can undergo combustion to produce pressurized gases whose energy is utilized to move a rocket against the gravitational force of attraction. It is a mixture, which contains a fuel that burns and an oxidizer, which supplies the oxygen necessary for the burning (combustion) of the fuel. The propellants may be in the form of a solid or liquid.

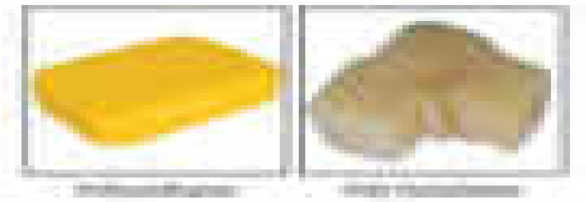
a. Liquid propellants

In liquid propellants fuel and oxidisers are combined in a combustion chamber where they burn and come out from the base of the rocket with a great force. Liquid hydrogen, hydrazine and ethyl alcohol are the liquid fuels. Some of the oxidizers are oxygen, ozone, hydrogen peroxide and fuming nitric acid.



b. Solid propellants

In solid rocket propellants fuel and oxidiser compounds are already combined. When they are ignited they burn and produce heat energy. Combustion of solid propellants cannot be stopped once it is ignited. Solid fuels used in rockets are polyurethanes and poly butadienes. Nitrate and chlorate salts are used as oxidizers



c. Cryogenic propellants

In this type of fuel, the fuel or oxidizer or both are liquefied gases and they are stored at a very low temperature. These fuels do not need any ignition system. They react on mixing and start their own flame.

Cryogenic Fuels

Launching of Satellite

Before being launched into the space, rockets will be held down by the clamps on the launching pad initially. Manned or unmanned satellites will be placed at the top of the rocket. When the fuel in the rocket is burnt, it will produce an upward thrust. There will be a point at which the upward thrust will be greater than the weight of the satellite. At that point the clamp will be removed by remote control and the rocket will move upwards. According to Newton's third law, for every action there is an equal and opposite reaction. As the gas is released downward, the rocket will move upward.

Launching of Rocket

To place a satellite in a particular orbit, a satellite must be raised to the desired height and given the correct speed and direction by the launching rocket. If this high velocity is given to the rocket at the surface of the Earth, the rocket will be burnt due to air friction. Moreover, such high velocities cannot be developed by a single rocket. So, multistage rockets are used. To penetrate the dense lower part of the atmosphere, initially the rocket rises vertically and then it is tilted by a guidance system.

India's Space Programmes

Within few years after the independence, India initiated space research activities. In 1969, Indian Space Research Organisation (ISRO) was formed with the objective of developing space technology and its application for different needs of the nation. India is focusing on satellites for communication and remote sensing, space transportation systems and application programmes. The first ever satellite Aryabhata was launched in 1975. Since then India has achieved a lot in space programmes equal to that of the developed nations.

Rakesh Sharma, an Indian pilot from Punjab was selected as a 'Cosmonaut' in a joint space program between India and Soviet Russia and become the first Indian to enter into the space on 2nd April, 1984.

Chandrayaan – 1

Our country launched a satellite Chandrayaan-1 (meaning Moon vehicle) on 22nd October 2008 to study about the Moon. It was launched from Sathish Dhawan Space Center in Sriharikota, Andhra Pradesh with the help of PSLV (Polar Satellite Launch Vehicle) rocket. It was put into the lunar orbit on 8th November 2008.

The spacecraft was orbiting around the Moon at a height of 100 km from the lunar surface. It collected the chemical, the mineralogical and the geological information about the Moon. This mission was a major boost for the Indian space programs and helped to develop its own technology to explore the Moon. Chandrayaan-1 was operated for 312 days and achieved 95% of its objectives. The scientists lost their communication with the space craft on 28th August 2009. On the successful completion of all the major objectives, the mission was concluded.

Chandrayaan - 1

a. Objectives of Chandrayaan-1

The following were the objectives of Chandrayaan – 1 mission.

- To find the possibility of water on the Moon.
- To find the elements of matter on the Moon.
- To search for the existence of Helium-3.
- To make a 3-dimensional atlas of the Moon.
- To study about the evolution of the solar system.

Kalam Sat is the world's smallest satellite weighing only 64 gram. It was built by a team of high school students, led by RifathSharook, an 18 year old school student from 'Pallapatti' near Karur, Tamil Nadu. It was launched into the space on 22nd June 2017 by NASA.

b. Achievements of Chandrayaan-1

The following are the achievements of Chandrayaan-1 mission.

- The discovery of presence of water molecules in the lunar soil.
- Chandrayaan-1 confirmed that the Moon was completely molten once.
- Chandrayaan-1 has recorded images of the landing site of the US space-craft Apollo-15 and Apollo-11.

Know your Scientist

Dr.MylsamyAnnadurai was born on 2nd July 1958, at Kodhavadi, a small village near Pollachi in Coimbatore district. He pursued his B.E. degree course at Government College of Technology, Coimbatore. In 1982, he pursued his higher education and acquired an M.E. degree at PSG College of Technology, Coimbatore. In the same year he joined the ISRO as a scientist. And later, he got his doctorate degree from Anna University of Technology, Coimbatore. Annadurai is a leading technologist in the field of satellite system. He has served as the Project Director of Chandrayaan-1, Chandrayaan-2 and Mangalyaan. He has also made significant contributions to the cost effective design of Chandrayaan.

- **It has provided high-resolution spectral data on the mineralogy of the Moon.**
- **The existence of aluminium, magnesium and silicon were picked up by the X-ray camera.**
- **More than 40,000 images have been transmitted by the Chandrayaan-1 camera in 75 days.**
- **The acquired images of peaks and craters show that the Moon mostly consists of craters.**
- **Chandrayaan-1 beamed back its first images of the Earth in its entirety.**
- **Chandrayaan-1 has discovered large caves on the lunar surface that can act as human shelter on the Moon.**

Mangalyaan (Mars vehicle)

After the successful launch of Chandrayaan-1, ISRO planned an unmanned mission to Mars (Mars Orbiter Mission) and launched a space probe (space vehicle) on 5th November 2013 to orbit Mars orbit. This probe was launched by the PSLV Rocket from Sriharikota, Andrapradesh. Mars Orbiter Mission is India's first interplanetary mission. By launching Mangalyaan, ISRO became the fourth space agency to reach Mars.

Mangalyaan probe traveled for about a month in Earth's orbit, and then it was moved to the orbit of Mars by a series of projections. It was successfully placed in the Mars-orbit on 24th September 2014.

Mars Orbiter Mission successfully completed a period of 3 years in the Martian orbit and continues to work as expected. ISRO has released the scientific data received from the MOM in the past two years (up to September 2016).

More to know

Mars is the fourth planet from the Sun. It is the second smallest planet in the solar system. Mars is called as the Red Planet because of its reddish colour. Iron Oxide present in its surface and also in its dusty atmosphere gives the reddish colour to that planet. Mars rotates about its own axis once in 24 hours 37 minutes. Mars revolves around the Sun once in 687 days. The rotational period and seasonal cycles of Mars are similar to that of the Earth. Astronomers are more curious in the exploration of Mars. So, they have sent many unmanned spacecrafts to study the planet's surface, climate, and geology.

a. Objectives of Mangalyaan

The following are the objectives of Chandrayaan – 2 mission.

- **To develop the technology required for interplanetary mission.**
- **To explore the surface of Mars.**
- **To study the constituents of the Martian atmosphere.**

- **To provide information about the future possibility of life and past existence of life on the planet**.

India became the first Asian country to reach Mars and the first nation in the world to achieve this in the first attempt. Soviet Space Program, NASA, and European Space Agency are the three other agencies that reached Mars before ISRO.

Chandrayaan - 2

ISRO has currently launched a follow on mission to Chandrayaan-1 named as Chandrayaan-2, on 22nd July 2019. Chandrayaan 2 mission is highly complex mission compared to previous missions of ISRO. It brought together an Orbiter, Lander and Rover. It aims to explore South Pole of the Moon because the surface area of the South Pole remines in shadow much larger than that of North Pole.

Orbiter

It revolves around the moon and it is capable of communicating with Indian Deep Space Network (IDSN) at Bylalu as well as Vikram Lander.

Lander

It is named as Vikram in the memory of Dr.Vikram A. Sarabhai, the father of Indian space program.

Rover

It is a 6 wheeled robotic vehicle named as 'Pragyan' (Sanskrit word) that means wisdom. Chandrayaan-2 was successfully inserted into the lunar orbit on 20th August 2019. In the final stage of the mission, just 2.1 km above the lunar surface, Lander 'Vikram' lost its communication with the ground station on 7th September 2019. But the Orbiter continues its work successfully.

Vikram Lander

Know your Scientist

Dr.Kailasavadivoo Sivan is the chairperson of the Indian Space Research Organization (ISRO). He was born in Sarakkalvilai, in Kanyakumari district of Tamil Nadu. Sivan graduated with a bachelor's degree in Aeronautical Engineering from Madras Institute of Technology in 1980. Then he got his master's degree in Aerospace Engineering from Indian Institute of Science, Bangalore in 1982, and started working in ISRO. He completed his doctoral degree in Aerospace Engineering from Indian Institute of Technology, Bombay in 2006. He was appointed as Chairman of ISRO from 10th January 2018. Sivan is popularly known as the 'Rocket Man' for his significant contribution to the development of cryogenic engines for India's space programs. The ability of 'ISRO' to send 104 satellites in a single mission is a great example of his expertise.

More to know

The Moon is the only natural satellite of the Earth. It is at a mean distance of about 3,84,400 km from the Earth. Its diameter is 3,474 km. It has no atmosphere of its own. It doesn't have its own light, but it reflects the sunlight. The time period of rotation of the Moon about its own axis is equal to the time period of revolution around the Earth. That's why we are always seeing its one side alone.

NASA (National Aeronautics and Space Administration)

NASA is the most popular space agency whose headquarters is located at Washington, USA. It was established on 1st October 1958. It has 10 field centers, which provide a major role in the execution of NASA's work. NASA is supporting International Space Station which is an international collaborative work on space research. It has landed rovers on Mars, analysed the atmosphere of Jupiter, explored Saturn and Mercury.

The Mercury, Gemini and Apollo programs helped NASA learn about flying in space. NASA's robotic space probes have visited every planet in the solar system. Satellites launched by NASA have revealed a wealth of data about Earth, resulting in valuable information such as a better understanding of weather patterns. NASA technology has contributed to make many items used in everyday life, from smoke detectors to medical tests.

Apollo Mission

Apollo Missions are the most popular missions of NASA. These missions made American Astronauts to land on the Moon. It consists of totally 17 missions. Among them Apollo -8 and Apollo-11 are more remarkable. Apollo-8 was the first manned mission to go to the Moon. It orbited around the Moon and came back to the Earth.Apollo-11 was the first 'Man Landing Mission' to the moon. It landed on the

Moon on 20th July 1969. Neil Armstrong was the first man to walk on the surface of the Moon.

The members present in the crew during the Man Landing Mission were Neil Armstrong, Buzz Aldrin and Michael Collins.

NASA's work with ISRO

NASA made an agreement to work with ISRO to launch the NISAR Satellite (NASA-ISRO Synthetic Aperture Radar) and Mars Exploration Missions.

Work of Indians at NASA

People of Indian origin in America are working in NASA and they have made remarkable contribution to NASA.

KalpanaChawla

KalpanaChawla was born on 17th March 1962 in Karnal, Punjab. In 1988, she joined the NASA. She was selected to take part in the Colombia Shuttle Mission in 1997 and she became the first Indian women astronaut to go to space. On her second mission on the Colombia Shuttle, she lost her life, when the shuttle broke down. KalpanaChawla travelled over 10.4 million miles in 252 orbits of the earth, logging more than 372 hours in space.

Sunitha Williams

Sunitha Williams was born on 19th September 1965 in USA. She started her career as an astronaut in August 1998. She made two trips to the International Space Station. She set a record of the longest space walking time by a female astronaut in 2012, with a total space walk of 50 hour and 40 minute (7 space walks). She is one of the crew of NASA's Manned Mars Mission.

9th book
Unit – 9 – Universe

Building block of the Universe

- The basic constituent of the universe is luminous matter i.e., galaxies which are really the collection of billionsof 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 × 1012 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.

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 all the matter were ejected 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, the carbon, calcium, and iron, and silicon are formed in the cores of stars. 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.

Galaxies

- 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 (1011) galaxies in the observable universe. 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.

- 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.

The distance of Andromeda, our nearest galaxy is approximately 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!

- 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. 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 appeartobe 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.

- 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 constellation outlines. There are 88 formally accepted constellations. Aries, Gemini, Leo, Orion, Scorpius and Cassiopeia are some of the constellations.

- The Solar System Sun and the 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.

The Sun

- 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. 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. Sun is believed to be more than 4.6 billion years old.

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 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.

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.

- 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 9.1 tells about the length of a day on each planet.

- The planets are spaced unevenly. The first four planets are relatively close together and close to the Sun. They form the inner solar

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

- 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 the distance 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.

- The four large planets Jupiter, Saturn, Uranus and Neptune spread out in the outer solar system and 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.

- Mercury: Mercury is a rocky planet nearest to the Sun. It is very hot during day but very cold at night. 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. This planet spins in the opposite direction to all other planets. 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

- 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. From space, the Earth appears bluish green due to the reflection of light from water and land mass on its surface.

- 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).

- 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.

- 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. 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.

- Uranus: Uranus is a cold gas giant and 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. 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.

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.

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 ever 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.

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.

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). 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.

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.

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.

- 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= $\frac{\sqrt{GM}}{(R+h)}$ **where,**

G = Gravitational constant (6.673 × 10–11 Nm2kg-2)
M = Mass of the Earth (5.972 × 1024 kg)
R = Radius of the Earth (6371 km)
h = Height of the satellite from the surface of the Earth.

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.

Time period of a Satellite

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

Time period, T = $\frac{Distance\ covered}{Orbital\ Velcity}$

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

Substituting the value of v, we get

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

All stars appear to us as moving from east to west, where as 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.

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

All planets revolve around the Sun in elliptical orbits with Sun at one of their foci.
Second Law – The Law of Equal Areas The line connecting the planet and the Sun covers equal areas in equal intervals of time.

Third Law – The Law of Harmonies

The square of time period of revolution of a planet around the Sun is directly proportional to the cube of the distance between sun and the planets.

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 presentin 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.

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. 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. 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. Its inventors say that the robot could take biopsies with remarkable precision and consistency.

- 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,.

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.

11th geography

Unit II - The Solar System and the Earth

Theories of the Earth's origin

- There are many theories supporting the origin of the earth. One of the earlier and popular arguments of the earth's origin was by a German professor Immanuel Kant. Mathematician Laplace revised it in 1796. It was known as Nebular Hypothesis. It considered that planets were formed out of a cloud of materialassociated with a youthful sun, which was slowly rotating. Lyttleton propounded the accretion theory of the earth's formation. According to this theory, approximately 4.6 billion years ago, the solar system was a cloud of dust and gas known as a solar nebula. As the solar nebula began to spin, the gravity collapsed the materials on itself and it formed the sun in the centre of the solar system. When the sun formed, the remaining materials began to clump up. Small particles drew together, bound by the force of gravity, into larger particles. The solar wind swept away lighter elements, such as hydrogen and helium, from the closer regions. It left only heavy rocky materials to create planets like the Earth. But farther away, the solar winds had less impact on lighter elements, allowing them to coalesce into gas giants. In this way, planets, moons, asteroids, comets, etc., were created.

Voyager 2 travelling at the speed of more than 62,764.416 km/h will still take morethan 296,000 years to pass Sirius, the brightest star in our night sky.

- Earth's rocky core formed first when heavy elements collided and bound together. Dense materials sank to the center, while the lighter material created the crust. The planet's magnetic field probably formed around this time. Gravity captured some of the gases that made up the planet's early atmosphere.

Modern theories of the origin of the Universe

- The most popular argument regarding the origin of the universe is the Big Bang Theory. It is also called expanding universe hypothesis. In 1927, Abbe Georges Lemaitre, a Belgian astronomer was the first to propose, a theory on the origin of the universe. It was Edwin Hubble who provided the evidence that the universe is expanding. It was called, 'the Big Bang Theory'. According to it, the universe was formed during a period of inflation that began about 13.75 billion years ago.

- Like a rapidly expanding balloon, it swelled from a size smaller than an electron to nearly its current size within a fraction of a second. Matter from the universe was thrown out with great force in all directions and started expanding outwards. From this matter, many groups of stars were formed which we call 'galaxies'. A galaxy is a system of billions of stars, stellar remnants, interstellar gas, dust, and dark matter. The word galaxy is derived from the Greek word Galaxias, literally "milky", a reference to the Milky Way (Figure 2.1). The Milky Way is the galaxy that contains our Solar System.

Galaxies are in three major forms:

- Spiral Galaxies: It consists of a fat and rotating disk of stars, gases and dust. It has a central concentration of stars known as the 'bulge'. The Milky Way and the Andromeda are spiral galaxies.

- Elliptical Galaxies: It contains older stars with fewer gases. Messier89 galaxy is an elliptical galaxy.

- Irregular Galaxies: They are youthful galaxies with more dust and gases. This can make them very bright. Large Magellanic Cloud is an example of irregular galaxy.
- Initially, the universe was saturated only by energy. Some of this energy set into particles, which assembled into light atoms like hydrogen and helium. These atoms grouped first into galaxies, then stars and all the other elements. This is generally agreed-upon concept of our universe's origin as estimated by scientists.

- In fact, the stars, planets and galaxies that can be detected make up only 4 percent of the universe, according to astronomers. The other 96 percent of the substances in the universe cannot be seen or easily understandable.

- The new measurement technique called gravitational lensing confirmed the age of the universe and the strength of dark energy. Dark energy is responsible for the accelerating expansion of the universe. Scientists used gravitational lensing to measure the distances light travelled from a bright, active galaxy to the earth and some details of its expansion.

Three scientists, Saul Perlmutter, Brian Schmidt and Adam Riess won the Nobel Prize in Physics (2011) for their discovery that the universe is just expanding and picking up speed.

Star and Constellations

- A star is type of astronomical object which has its own light and heat. The nearest star to earth is the Sun. Sirius is brighter star than the sun. 'Proxima Centaur? is the closest star to the sun. Star is formed when enough dust and gas clump together because of the gravitational forces. Star changes its formsduring its lifetime such as-red giant, white dwarf, neutron star and black hole.

- Constellation (Figure 2.2) is a group of stars that forms a particular shape in the sky. In 1929, the International Astronomical Union (1AU) adopted official constellation boundaries that defined 88 official constellations thatexist today. Earlier Ptolemy, in his book Almagest, listed 48 constellations.

- Ursa Major (Figure 2.3) is a constellation that can be seen in the northern hemisphere and part of the southern hemisphere. Ursa Major means Great Bear in Latin.

The Solar system

- A solar system consists of a star (Figure 2.4) at the centre and the eight planets, moons, asteroids, comets and meteoroids that revolve it. The eight planets, namely the Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune, revolvearound the sun in fixed elliptical paths known as 'orbits'. Most stars host their own planets. So there are billions of other solar systems in the Milky Way galaxy alone.

- Solar systems can also have more than one star. These are called binary star systems if there are two stars or multi-star systems if there are three or more stars. Our solar system is located in an outer spiral arm of the vast Milky Way galaxy. Our solar system orbits the centre of the Milky Way Galaxy at about 828,000 km/h. Our solar system takes about 230 million years to complete one orbit around the galactic centre.

- The solar system is believed to have been formed about 4.6 billion years ago. The solar system also includes the Kuiper Belt that lies past Neptune's orbit. This is a sparsely occupied ring of icy bodies. This is almost all smaller than the dwarf planet Pluto. Beyond the fringes of the Kuiper belt (Figure 2.5) is the Oort cloud. This giant spherical shell surrounds our solar system. It has never been directly observed,by gravitational attraction, producing immense pressure and temperature at its core. There are three main layers in the Sun's interior: the core, the radioactive zone, and the convective zone (Figure 2.6). The core is at the centre. It is the hottest region, where the nuclear fusion reaction to give the sun power. Moving outward next come the radioactive (or radiation) zone. Its name is derived from the way energy is carried outward through this layer, carried by photons as thermal radiation. The third and final region of the solar interior is named the convective (or convection) zone. It is also named after the dominant mode of energy flow in this layer. The boundary between the Sun's interior and the solar atmosphere is called the photosphere. It is what we see as the visible 'surface' of the Sun.

- Did you know that the Sun has an atmosphere? Te lower region of the solar atmosphere is called the chromosphere. Its name is derived from the Greek word chroma (meaning colour), for it appears bright red when viewed during a solar eclipse. A thin transition region, where temperature rises sharply, separates the chromospheres from the vast corona above. The uppermost portion of the Sun's atmosphere is called the corona, and is surprisingly much hotter than the Sun's surface (photosphere) The upper corona gradually turns into the solar wind. Solar wind is a flow of plasma that moves outward through our solar system into interstellar space.

- Therefore, the Sun has six regions: the core, the radioactive zone, and the convective zone in the interior; the photosphere; the chromospheres; and the corona. The temperature of the sun'ssurface is about 5,500 to 6,000 degrees Celsius.

- At the core, the temperature is about 15 million degrees Celsius, which is sufficient to sustain thermonuclear fusion. This is a process in which atoms combine to form larger atoms and in this process, released, staggering amounts of energy. Specifically, in the Sun's core, hydrogen atoms fuse to make helium.

Size and Distance

- The sun has a radius of 695,508 kilometres. It is far more massive than earth and 3,32,946 Earths equal to the mass of the Sun. The Sun's volume would need 1.3 million Earths to fill it.

Venus is hotter than Mercury because Venus has an atmosphere which is thicker and made almost entirely of carbon dioxide

Orbit and Rotation

- The Milky Way has four main spiral arms: the Norma and Cygnus arm, Sagittarius, Scutum-Crux, and Perseus. The Sun is located in a minor arm, the Sagittarius arm. From there, the Sun orbits the centre of the Milky Way Galaxy, bringing the planets, asteroids, comets and other objects along with it. Our solar system is moving with an average velocity of 828,000 kilometres per hour. It takes about 230 million years to make one complete orbit around the Milky Way. The Sun's spin has an axial tilt of 7.25 degrees with respect to the plane of the planets' orbits. Since the Sun is not a solid body, different parts of the Sun rotate at different rates. At the equator, the Sunspins around once about every 25 days, but at its poles the Sun rotates once on its axis every 36 Earth days. Most of the materials are pulled toward the centre to form our Sun. The Sun alone accounts for 99.8% of the mass of the entire solar system.

- Like all stars, the Sun will someday run out of energy. When the Sun starts to die, it will swell so big that it will engulf Mercury y and Venus and maybe even Earth. Scientists predict that the Sun is a little less than halfway through its lifetime and will last another 6.5 billion years before it shrinks down to be a white dwarf.

The Planets

- The word planet in Greek means 'wanderer'. Planet is the celestial body which does not have light or heat of its own. A planet should possess the following qualities:

❖ It should orbit around the sun.
❖ It should not be a satellite of any planet

Due to its own mass and self-gravity, it should get a spherical shape and Any other celestial body should not cross in its orbit.

- The planets are classified in order of their distance from the sun and based on their characteristics. They are:

- The inner planets or terrestrial planets or rocky planets. Mercury, Venus, Earth and Mars are called inner or terrestrial planets.

- The outer planets or gaseous planets or giant planets. Jupiter, Saturn, Uranus and Neptune are called outer or gaseous planets.

Each planet spins on its own axis. Tis movement is called rotation. One rotation makes one 'planet day'. The planets moving around the sun is called revolution or a 'planet-year'.

Planets in the Solar System

Name of the Planet	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
Diameter (KM)	4,879	12,104	12,756	6,794	1,42,984	1,20,536	51,118	49,528
Density (kg/m3)	5,427	5,427	5,514	3,933	1,326	687	1,271	1,638
Rotation Period (hours)	1,407.6	-5,832.5	23.9	24.6	9.9	10.7	17.2	16.1
Length of Day (hours)	4,222.6	2,802	24	24.7	9.9	10.7	17.2	16.1
The Average distance from the sun(10^6 km)	57.9	108.2	149.6	227.9	778.6	1,433.5	2,872.5	4,495.1
Orbital	88	224.7	365.3	687	4331	10,747	30,589	59,800

Period (days)								
Number of Satellites	0	0	1	2	67	53	27	13

The Mercury

- Mercury is the nearest planet to the sun and it is the smallest planet in the solar system. It does not have any satellite. It rotates on its own axis in 58.65 earth days while it takes 88 Earth days to complete one revolution around the sun. Mercury is 0.4 astronomical units away from the Sun. The sunlight takes 3.2 minutes to travel from the Sun to Mercury. Mercury is the second hottest planet though it is nearest to the sun.

The Venus

- 'Venus' is the second nearest planet to the sun. It is also called as 'Earth's Sister' planet due to its similar size and mass as that of our Earth. It is the hottest planet in the solar system and experiences a mean surface temperature of 462°C. It is popularly known as "Morning star and Evening star" It is seen in the east sky before sunrise (dawn) in the morning and in the west sky after the sunset (twilight). It rotates clockwise i.e. east to west direction on its own axis. The rotation and orbit of the Venus are unusual in several ways. Venus is one of just two planets that rotate from east to west. Only Venus and Uranus have this 'backwards' rotation. It completes one rotation in 243 Earth days which is the longest day of any planet in our solar system. The Venus takes 224.7 Earth days to complete one revolution around the sun, and it has no natural satellites. Venus is 0.7 astronomical units away from the sun. The sunlight takes 6 minutes to travel from the sun to Venus.

The Earth

- Earth is the third nearest planet to the sun. It is the fifth largest planet in the solar system. The Earth's orbit lies between the orbits of Venus and Mars. It takes 23 hours 56 minutes and 4 seconds for the earth to complete one rotation on its own axis. The Earth takes 365.25 days (Table 2.1) to complete one revolution around the Sun. Earth's surface temperature varies from - 88° to 58°C and it is the densest planet in the solar system.

- The Earth is a unique planet because of its distance from the sun, its motions, atmosphere with oxygen, presence of water and moderate temperature. The earth is neither too close nor too far from the sun. It is the only known planet to support life. It is also known as the 'Blue Planet' because of the presence of water. Earth has only one natural satellite called the Moon. The sun light takes about 8.3 minutes to reach the earth.

The Mars

- Mars is the fourth nearest planet to the sun and it is the second smallest planet in the Solar system. It is also described as the "Red planet". It is reddish in colour due to the presence of iron oxide on its surface. The landmass of Mars and Earth are very similar. It takes 24 hours and 37 minutesto complete one rotation on its axis and its takes 687 days to complete one revolution around the Sun. The surface temperature of the Mars is ranging from -153° to 20°C. With the exception of the Earth, Mars probably is the most hospitable to life. This planet has seasons, polar ice caps, volcanoes, canyons and weather. Mars has two satellites namely Phobos and Deimos.

The Jupiter

- Jupiter is the largest planet in the solar system. It is made primarily of gases and is therefore known as 'Giant Gas planet'. It takes 9 hours 55 minutes to complete one rotation on its axis and it takes 11.86 years to complete one revolution. Jupiter has the shortest day in the solar system. Jupiter has a faint ring system around it. They are mostly comprised of dust particles. Jupiter has 67 confirmed satellites orbiting the planet. Ganymede, the satellite of Jupiter, is the largest natural satellite in the solar system (even bigger than the planet Mercury).

The Saturn

- Saturn is the sixth planet from the sun and the second largest planet in the solar system. Saturn is called as the Ringed Planet. It is because of large, beautiful and extensive ring systems that encircles the planet. These rings are mostly made from the chunksof ice and carbonaceous dust. Saturn is the only planet in our solar system whose average density is less than water.

- The Saturn has 30 rings and 53confrmed natural satellites. The Saturn takes 10 hours 34 minutes to complete one rotation on its axis and it takes 29.4 years to complete one revolution around the sun.

The Uranus

- Uranus is the seventh planet from the sun and it is not visible to the naked eye. Like Venus, Uranus also rotates on its axis from east to west. Uranus is inclined on its axis at an angle of 98 degrees. The planet is almost lying on its side as it goes around the sun. The sunlight, thus, is received mostly in the polar areas. Hydrogen, helium and methane are the major gases of its atmosphere. It is very cold due to its great distance from the sun. Uranus is named after the ancient Greek god of the sky. It has a dense atmosphere primarily consisting of methane, which lends it a bluish-green appearance. Uranus also has rings and twenty-seven satellites.

The Neptune

- Neptune is the eighth planet from the sun. It takes 16 hours to complete one rotation on its own axis and it takes nearly 165 years to revolve around the sun. It has 13 natural satellites and 5 rings. It is the coldest planet in the Solar System because it is the farthest planet from the Sun. Neptune was the first planet located through mathematical calculations. Neptune is our solar system's windiest planet.

Dwarf Planets

- Dwarf planets are tiny planets in our solar system. Any celestial body orbiting around the sun, weighing for the self-gravity and nearly be round in shape is called 'Dwarf Planet'. It should not be a satellite of any planet. They are five in number Ceres, Pluto, Heumea, Makemake and Eris. As Pluto has not cleared the neighbourhood around its orbit, it is officially demoted in 2006 from its ninth position as a planet.

North Pole of the Uranus experiences 21 years of night time in winter, 21 years of daytime in summer and 42 years of day and night in the spring and fall.

Satellites

- The word 'Satellite' means companion. The moon was the only known satellite in the Solar System until 1610. Today, there are 163 known satellites in the Solar System. The satellites move around a planet from West to East. They do not have own light, but reflect the light of the Sun. They have no atmosphere and water.

Moon: the Earth's Satellite

- The moon is located at a distance of 8, 84,401 km from the earth (Figure 2.7). The moon revolves around the earth. The moon takes 27 days and 7 hours and 43 minutes for both its rotation and revolution around the earth.

- Hence, the observers on the earth could see only one side of the moon.The moon is the fifth largest natural satellite in the solar system. The moon was likely to be formed after a Mars-sized body collided with Earth. There are many craters, high and steep mountains of different sizes which cast shadows on the Moon's surface. The light which is reflected by the Moon will reach the Earth in just one and a quarter seconds.

Apollo 11 was the first manned mission to land on the Moon sent by NASA. Two American Astronauts Neil Armstrong and Edwin Aldrin set foot on the moon's surface on the waterless Sea of Tranquillity on 20th July, 1969. They stayed there for 21 hours 38 minutes and 21 seconds on the moon. Michael Collins piloted Apollo 11.

- Since the moon is smaller than the earth, it has 1/6 of the gravitational pull of the earth. So, man weighs 6 times less on the moon than the earth.

Asteroids

- Asteroids are small rocky celestial bodies that revolve around the Sun, like other planets. They are also called 'Minor Planets'. Tere are lots of asteroids in the solar system. Larger asteroids are called Planetoids. Theseare found in between the planets Mars and Jupiter. Tis belt is known as 'Asteroid belt'. The diameter of the asteroids varies from 100 km to a size of a pebble. The asteroids may be the fragments of a planet exploded in the past or some parts of comets. The new asteroids are being discovered continuously.

Comets

- Comets are the most exciting heavenly bodies and have ever been the objects of man's curiosity as well as fear. The word Comet (Figure 2.8) is derived from the Greek word Aster Kometes meaning 'Long Haired Star'. They are made up of small ice particles and meteoric fragments. They revolve around the Sun. But their orbits are irregular. Sometimes they get very close (Perihelion) to the sun and in other times they go far away (Aphelion) from the sun.

The best known Comet, Halley s Comet, appears once in every 76 years. The Halley s Comet was seen last in 1986 and it will be seen again on 28th July 2061.

Titan – only moon with clouds and atmosphere

Titan is Saturn's largest moon and the second largest (after Ganymede of Jupiter) in the solar system. It is the only moon in the solar system with clouds and a dense, planet-like atmosphere.

Scientists believe that conditions on Titan are similar to Earth's early years (the main difference is that, because of is closer to the sun, Earth has always been warmer). According to NASA, "In many respects, Titan, is one of the most Earth-like worlds we have found to date".
Titan was discovered by Dutch astronomer Christiaan Huygens in 1655. The Huygens lander probe sent to the moon aborad NASA's Cassini spacecraft by the European Space Agency is named in his honour. Huygens was the first human-built object to land on Titan's surface. Diameter:5,150 kilometres, about half the size of Earth and almost as large as Mars. Surface temperature:-179 degrees Celsius, which makes water as hard as rocks and allows methane to be found in its liquid form. Surface pressure. Earth's pressure at sea level is 1 bar while Titan's is 1.6 bars. Orbital period: 15;945 days. Titan's mass is composed mainly of water in the form of ice and rocky material. Titan has no magnetic field.

Meteors

- There is a bright streak of light flashing seen often in the sky during night for a few seconds. They are called as 'shooting stars'. They are the removed pieces of rocks mainly from the Asteroid belt. Tey are called Meteoroids before they enter into our atmosphere. Tey enter into the atmosphere with great speed. But most of them are burnt when they enter into the atmosphere.

- After entering into our atmosphere they are called as Meteors. Some pieces do not burn fully and they fall on the earth and make craters. The large unburned pieces of rocks that fall on the earth are called Meteorites.

- Examples for Meteorite Fall: Meteor crater in Northern Arizona and Lake Lonar in Buldhana District of Maharastra in India were created by meteor impacts.

Shape and size of the Earth

- It once was believed that the Earth was flat and that ships could sail over the edge. This view persisted even in the middle ages and was an issue in recruitment of Columbus.

- Early Greek view was that the world was surrounded by the ocean (Oceanus), origin of all rivers. Anaximander (600 B.C) proposed that cylindrical earth was surrounded by celestial sphere. Pythagoras (582-507 B.C.) believed that the Earth was a sphere, which was considered the most harmonious geometric shape. Aristotle (384-322 B.C.) described observations that supported the theory that the Earth was a sphere. These included the fact that the shadow of the moon is circular in lunar eclipses and constellations were higher in the sky as one travelled south. Eratosthenes

- (275-195 BCE) estimated size of earth from observations that the elevation of the sun varied with position on the Earth's surface in Egypt. Observations of the following suggested that the Earth is a sphere.

Mountain peaks lit by the Sun after sunset.

- Ships disappear below the horizon as they sail across ocean.

The moon looks like a disc.
The Earth casts a circular shadow during lunar eclipses.

- The Earth is an oblate spheroid, bulged at the equator and fattened at the poles. It is called 'Geoid' (Figure 2.9) meaning the earth is earth-shaped. The bulge at the equator is caused by the centrifugal force of the Earth's rotation. The gravitational pull of the earth is the strongest at the fattened poles and it is weaker towards the equator.

- The Sun's gravitational pull differs in force at the poles. The North Pole points in the same direction to the North Star when it revolves about the Sun. If the Earth would not have been tilted on its axis, the days and nights would have been of same duration always.

Motions of the earth

The earth has two basic movements: 1) Rotation and 2) Revolution.

Galactic movement: This is the movement of the earth with the sun and the rest of the solar system in an orbit around the centre of the MilkyWay Galaxy. This, however, has little effect upon the changing environment of the earth.

1. Rotation:

- The spinning of the earth around its axis is called the rotation of the earth. The axis is the imaginary line passing through the centre of the earth. The earth completes one rotation in 23 hours, 56 minutes and 4.09 seconds. It rotates in an eastward directionopposite to the apparent movement of the sun. The earth's axis is inclined at an angle of 66½0 to the orbital plane as it moves around the sun. We can say, the earths axis is tilted at an angle of 23½° (Figure 2.10) from a perpendicular to the elliptic plane. The velocity of earth's rotation varies depending on the distance of a given place from the equator.The rotational velocity at the poles is nearly zero. The greatest velocity of the rotation is found at the equator. The velocity of rotation at the equator is 1,670 km per hour.

Effects of earth's rotation: The rotation of the earth causes the following effects:

- The apparent rising and setting of the sun is actually caused by the earth's rotation which results in the alternate occurrence of day and night everywhere on the earth's surface.

- Rotation of the earth is also responsible for the difference in time between different places on the earth. A 24 hour period divided by 360 degreesgives a difference of 4 minutes for every degree of longitude that passes the sun. The hour (60 minutes) is thus 1/24 of a day.

- When you observe through a moving train, trees, houses and fields on the other side of the track appear to move in the direction opposite to that of the speeding train. The apparent movement of the sun and the other heavenly bodies in relation to the rotating earth is similar. As the earth rotates from west to east, the sun, moon, planets and stars appear to rise in the east and set in the west.

- Rotation causes the working of the Coriolis force which results in the deflection of the winds and the ocean currents from their normal path.

- Tide is caused by the rotation of the earth apart from the gravitational pull of the sun and the moon.

- Rotation causes a flattening of Earth at the two poles and bulging at the Equator. Hence, there is a difference in diameter at the poles and equator.

- Circle of Illumination: The line around the earth separating the light and dark is known as the circle of illumination (Figure 2.11).

- It passes through the poles and allows the entire earth to have an equal amount of time during the daylight and night time hours. This line can be seen from space, and the exact location of the line is dependent on the various seasons.

Revolution of the Earth

- The movement of the earth in its orbit around the sun in an anti-clockwise direction, that is, from west to east is called revolution of the earth. The earth revolvesin an orbit at an average distance of 150 million km. The distance of the earth from sun varies time to time due to the elliptical shape of the orbit. About January 3rd the earth is closest to the sun and it is said to be at Perihelion ('peri' means close to and Helios means sun). At Perihelion, the distance is 147 million km.

- Around July 4th the earth is farthest from the sun and it is said to be at Aphelion (Ap means away and Helios means sun). At Aphelion the distance of the earth is 152 million km away from the sun.

- The period taken by the earth to complete one revolution around the sun is 365 days and 6 hours (5 hours, 48 minutes and 45 seconds) or 365¼ days. The speedof the revolution is 1,07,000 km per hour. The speed is 30 km per second. The bullet from a gun travels with a speed of 9 km per second.

Period of Revolution and Leap year

- The period of time the earth takes to make one revolution around the sun determines the length of one year. The earth takes 365 days and 6 hours to complete one revolution. Earth takes 365.25 days to complete one trip around the Sun .That extra quarter of a day presents a challenge to our calendar system, which has one year as 365 days. To keep our yearly calendars consistent with our orbit around the Sun once in, every four years we add one day.

- The extra day added to is called a leap day, and the year the extra day is added to is called a leap year. The extra day is added to the month of February which has 29 days in a leap year.

Effects of revolution of the earth

- The revolution of the earth around the sun results in the following

Cycle of seasons,bVariation in length of days and nights,

- Variation in distribution of solar energy over the earth and the temperature zones.

Seasons

- The seasons are caused due to the combined effect of the earth's revolution and the tilt of its axis in the same direction throughout the year. In general, spring, summer, autumn and winter are the four seasons (Figure 2.12). The latitude atwhich the sun appears directly overhead changes as the earth orbits the sun. The sun appears to follow a yearly pattern of northward and southward motion in the sky, known as the 'apparent movement of the sun'. It gives an impression that the sun is continuously swinging north and south of the equator. Actually it is the earth that is moving around the sun on its tilted axis. It varies when observed on a daily and monthly basis, at different times of the year. On 21 March and 23 September the sun rises precisely in the east and sets exactly in the west.

Equinoxes and solstices

- You already knew that the sunrays are vertical at noon. The vertical rays fall on a small area, giving more heat.

Equinoxes

- Equinoxes occur when the earth reaches the points in its orbits where the equatorial and the orbital planes intersect, causing the sun to appear directly overhead at the equator. During the equinoxes the periods of day light and darkness are equal all over the world. On 21 March the sun is directly overhead at the equator. Throughout the world, on this day all the places experience almost equal hours of day and night. This position of the sun is called spring equinox. Again on 23 September the sun is directly overhead on the equator and it is called autumn equinox.

Position of the earth on 21 March

- Neither pole is inclined towards the sun. The rays of the sun fall vertically on the equator. All the places have equal days and nights as both the poles receive therays of the sun. It is spring in the northern hemisphere and autumn in the southern hemisphere. This day (21 March) is known as spring equinox.

Position of the earth on 23 September.

- Neither pole of the earth is inclined towards the sun. The rays of the sun fall vertically on the equator. All the places have equal days and nights. It is autumn in the northern hemisphere and spring in the southern hemisphere. Tis day (23 September) when sun's rays for fall vertically on the equator, is known as autumnal equinox (Figure 2.13).

Position of the earth on 21 June

- The North Pole is inclined or tilted towards the sun. It, therefore, experiences complete light for 24 hours. The South Pole is tilted away from the sun so it is in complete darkness for 24 hours. The rays of the sun fall vertically at the tropic of cancer (23½^{o} N). In the Northern hemisphere, the days are longer than the nights (Table 2.2). It is summer in the northern hemisphere and winter in the southern hemisphere. The day 21 June is known as summer solstice.

Position of the earth on 22 December

- The South Pole is inclined towards the sun and the North Pole is away from it. The rays of the sun fall vertically at the tropic of Capricorn (23½^{o} S). The greater part of the southern hemisphere gets the direct rays of the sun so the days are long and the nights are short here. In the northern hemisphere the nights are longer than the days at this time. The southern hemisphere has summer. The northern hemisphere has winter. This day (22 December), when the sun's rays fall vertically on the Tropic of Capricorn, is known as winter solstice.

Eclipses

- Let us understand the effect of the revolution of the earth on the length of the days and the nights. The duration of the daylight varies with latitude and seasons.

- An eclipse is a complete or partial obscuration of light from a celestial body and it passes through the shadow of another celestial body. The eclipses are of two types. They are:

Solar Eclipse

- It occurs on New Moon days, when the moon is between the Sun and the Earth. Thus it obscures a part of the Sun viewed from the Earth, but only from a small area of the world. It lasts only for a few minutes. A partial solar eclipse (Figure 2.14) happens when the moon partially covers the disc of the sun. An annular solar eclipse occurs when themoon passes centrally across the solar disc. During a total solar eclipse, the moon's shadow is short enough to cover the whole sun. The outer regions still glow and look bright as a ring. Such a phenomenon is called Diamond Ring

Geo connects History

Secret to Great Pyramid's Near Perfect Alignment Possibly Found!

The Great Pyramid of Giza, 4,500 years ago, is an ancient feat of engineering. Now an archaeologist has figured out how the Egyptians may have aligned the pyramid almost perfectly along the cardinal points, north-south-east-west. Egyptians may have used the autumn equinox. Methods used by the ancient Egyptians to align the pyramids along the cardinal points are accurate.

On the day of the fall equinox, a surveyor placed a rod into the ground and tracked its shadow throughout the day. The result was a line running almost perfectly east-west. Te Egyptians could have determined the day of the fall equinox by counting forward 91 days after the summer solstice.

Rotation	Revolution
Spinning of the earth from west to east on its axis	Movement of the earth around the sun in its elliptical orbit.
It takes 24 hours to complete a rotation (or a day)	It takes 365 ¼ days to complete on revolution (Or a year)
It is known as the daily or diurnal movement.	It is known as the annual movement of the earth.
Rotation causes days and nights to alternate, tides, deflection of winds and ocean currents and also gives the earth its shape.	Revolution results in the varying lengths of day and night,, changes in the altitude of the midday sun and change of seasons.

Lunar Eclipse

- It occurs on a Full Moon position when the earth is between the sun and the moon. The earth's shadow obscures themoon as viewed from the earth. A partial lunar eclipse can be observed when only a part of the moon's surface is obscured by earth's umbra (Figure 2.15). A penumbral lunar eclipse happens when the moon travels through the faint penumbral portion of the earth's shadow. A total lunar eclipse occurs when the earth umbra obscures the entire the moon's surface. Lunar eclipse can be seen from anywhere on the night side of the Earth. It lasts for a few hours due to the smaller size of the moon.

- The changing angles between the earth, the sun and the moon determine the phases of the moon. Phases of the moon (Figure 2.16) start from the 'New Moon' every month. Then, only a part of the Moon is seen bright called 'Crescent', which develops into the 'first quarter'. With the increasing brightness it turns into three quarters known as 'Gibbous' and then it becomes a 'Full Moon'. These stages are the waxing moon. After the full moon, the moon starts waning or receding through the stages of Gibbous, last quarter, crescent, andfinally becomes invisible as dark New Moon.

The varying lengths of daylight in different latitudes

- It is evident from the table that the duration of daylight is 12 hours throughout the year at the equator only. As one moves away from the equator, the seasonal variations in the duration of daylight increase. The seasonal variations in the duration of daylight are maximum at the polar region.

Effects of the spherical shape of the earth

Variation in the amount of solar radiation received:

- If the earth were a flat surface, oriented at right angle to the sun, all the places on the earth would have received the same amount of radiation. But the earth is spherical/ geoid. Hence the sunrays do not heat the higher latitudes of the earth as much as the tropics. On any given day only the places located atparticular latitude receive vertical rays from the sun. As we move north or south of this location, the sun's rays strike at decreasing angles. The yearly fluctuations in the angle of the sun's rays and the length of the days change with the continual change of the earth's position in its orbit around the sun at an inclination of 66½ to the orbital plane.

Difference in the angle of the sun's rays striking diferent parts of the earth.

- Away from the equator, the sun's rays strike the earth's surface at particular angle. The slanting rays are spread over a large area and do not heat with the same intensity as the direct rays. As we go pole wards, the rays spread over the regions beyond the Arctic and the Antarctic circles in an extremely slanting manner. This is how we get the various temperature zones.

- Lower the degree of latitude; higher the temperature. Not only that, the rays striking at a low angle must travel through a greaterthickness of the atmosphere than the rays striking at a higher angle. The rays striking at a lower angle are subject to greater depletion by refection and absorption by the atmosphere.

Temperature zones

- The spherical shape of the earth along with its movement around the sun causes differences in the angles at which the sun's rays fall on the earth's surface. This causes a difference in the distribution of heat on the earth's surface.

- As a result, the world has been divided into three distinct heat zones or temperature zones. They are the Torrid zone, Temperate zone and Frigid zone. You will learn more about it under the unit atmosphere.

Time Zones of the World

- People during the medieval period were using sundials and water clocks to observe the Sun's meridian passing at noon. In 17th century, the people started using pendulum clock which did not show accurate time while travelling in the sea. Later chronometer was invented in 1764. Chronometer measures time accurately and the mariners widely used this during the 19th century. But in many towns and cities clocks were set based on sunset and sunrise. The use of local solar time hindered the development of railways and telecommunications. A time zone is a region on the earth where uniform standard time should be maintained for transport, commercial and social purposes. For example, if different time zones were followed, the trains coming from different regions, sharing single track may meet with accidents.

- The world time zone (Figure 2.17) was formed, relating longitude and the rotation of the earth. The Prime Meridian is the centre of time zone extending from 7½ºW and 7½ º E longitudes. The 24 hours time zone system had been developed so that all the time zones should be referred with respect to Greenwich Mean Time. Earth was divided into 24 time zones, each one zone for one hour of the day. It is because earth rotates 15º of longitude in one hour (360º divided by 24 hours). The time when solar noon occurs at the Prime Meridian is fixed as noon for all places between 7½º E and 7½º W.

Daylight Saving Time

In the mid latitude countries of Europe, North America, Australia and South America, the day time are longer in summer than the night. In spite of employing daylight duration, the clocks are adjusted 1 hour forward in spring and 1 hour backward in autumn. This time is generally known as 'the Daylight Saving Time' (DST).

Time Zones

- On its axis, the earth rotates 360 degrees every 24 hours. You can look at it as it takes one day to complete a full circle. Divided up into an hourly rate, the earth rotates 15 degrees every hour (360/24). This number plays an important role in determining time zones. You have already learned about the latitudes and longitudes and their importance in the lower classes.

- An important factor in determining time zones is the lines of latitude and longitude, imaginary lines known as latitudes and longitudes dividing theearth. Latitude lines are drawn east - west and they measure the location in northern and southern hemisphere. The line starts at the equator and measure distance from 0 degrees to 90 degrees north and also 0 degrees to 90 degrees south. They also become shorter farther away from the equator. On the other hand, longitude lines are drawn north - south and they measure eastern and western hemisphere. They start at the Prime Meridian (or 0 degree) and measure from 0 degrees to 180 degrees east and 180 degrees west. Unlike lines of latitude, these lines are fairly equal in length. The origin of this spherical coordinate system is at 0 degree latitude and 0 degree longitude. This spot can be found in the Atlantic Ocean just south west of Africa. Also, the two lines connect at 180 degrees or at the International Date Line (Figure 2.18). This too helps to determining different time zones of the world.

- Together all of the above information can be used to calculate the difference of time between two locations.First, we need to know what longitudes the two places are located.

- Next, you would need to find the differences in longitude (in degrees) between the two places. If both places are located on the same side of the Prime Meridian, then the numbers are just simply subtracted to find the difference. If they are on the opposite side of the Prime Meridian then the two numbers should be added together to find the difference.

- Third, we need to divide the difference (measured in degrees) by 15 since there are 15 degrees in every hour. This will give us the difference in time between the two locations. So if you know what time it is in one location, and the longitude of another location, then just simple addition or subtraction problem will give us the time in a different time zone. Let's look at another way we may have to calculate the difference between times of two locations.

- Another calculation you may have to make is over the International Date Line. This line is strategically placed in the Pacific Ocean so that no two neighbouring cities are one day apart in time. It can be difficult to calculate though the International Date Line when trying to determine the amount of time difference between locations on either side. This calculation is very similar to the situation with the Prime Meridian. We must start by finding the difference in longitude (or degrees) of the two places. We do this by adding the two numbers. Then, divide by the 15 degrees that occurs in one hour and this will give you the time difference between two locations throughthe International Date Line. And again, just add or subtract that difference from the time that we already know to come up with the new time in the new time zone.

Example of Time Calculations

- To review, to find the difference between the two longitudes and divide by 15, this gives you the difference in hours between the two locations. Second, add or subtract the number of hours from the time of day that was already known, we will need to add the numbers if we are going east, and subtract if we are going west. Here are some examples of how we may need to calculate the difference of time zones.

- If you are in London at 12:00, and want to know what time it is in Japan, you would need to first figure out that London is 0 degrees (right on the prime meridian), and Japan is 135 degrees East. So the difference is 135 degrees (135-0), divided by 15 which equals 9. It means there is a 9-hour difference between London and Japan. Since Japan is further east than London is, you would add 9 hours to 12:00. The answer is at 12:00 noon London time, it is 9:00pm in Japan.

- Now we suppose imagine that we are going through the International Date Line. Pretend you are in Japan, which is 135 degrees east and you wanted to know what time it is in Hawaii, which is 150 West. Well, there is 45 (180-135) degrees difference between Japan and the IDL. Also there is 30 (180-150) degrees difference between the IDL and Hawaii. Therefore the difference in time is (45 + 30/15 = 5) 5 hours. Now the tricky part is that Japan and Hawaii are on different days. It is one day ahead on the left side of the IDL compared to the right side. If it is3:00pm in Japan on Thursday that means it is 3:00 + 5 hours = 8:00pm in Hawaii. However notice that when crossing the IDL we subtract a day going east. So, in Hawaii it is 8:00pm on Wednesday.

- Now note that Latitudinal lines are imaginary horizontal lines over the Earth's globe. 0° longitudinal line is Equator. Earth completes one rotation on its axis in 24 hours and in the process turns a complete circle of 360°. This means Earth rotates 360°/24 = 15° in one hour. Every gain or loss of 1° longitude stands for 4 minutes.

360° = 24 hours = 1440 min
Difference of time for 15° longitude = one hour.
Difference of time for 1° longitude = 4 minutes.

Longitude Calculations Procedures

First locate the two places involved
find the longitude difference
Convert the longitude difference to time and,
Adjust the time according to the direction of movement, (west or east).

Example 1

Ponni starts her journey at longitude 0° at 12 noon and she's moving towards eastward of longitude 10°. Calculate the time that Ponni will arrive at her destination.

Solution

Initial time = 12 noon
Destination = 10°E

Conversion of degree to time 1 hour =15°
and 4 minutes =1°
Hence 10° = (4 x 10) minutes
= 40 minutes
Destination time = Initial time + calculated time
= 12 noon + 40minutes
= 12:40pm

Example 2

If the time at village A (long 75° W) is 5:00 pm on Friday. Calculate the time and day at village B (long 120°E)

Solution

360° = 24hrs
15° = 1 hour
1° = 4 minutes
Village A = 75°W
Village B = 120°E
We will add (west and east)
(75 + 120)° = 195°
195 divided by 15°= 13hrs
Destination time = initial + calculatedtime
= 5:00 + 13hrs
= 18:00
18:00 = 6:00
Answer = 6:00am on Saturday

Example 3

Calculate the local time in New York (USA) longitude 75°W, when it is 10am in Nigeria of longitude 15°E

Solution

Initial time = 10:00am
New York = 75°W
Nigeria = 15° E We will add (west and east)
(75 + 15)° = 90°
90° divided by 15° = 6 hrs
Destination time = initial + calculated time
= 10:00am + 6hrs
= 14:00pm
14:00pm = 4:00pm
Answer = 4:00pm

Force, Motion and Energy
6th term 1
Unit 2Forces and Motion

Motion and Rest
What is rest? What is motion?

Suppose there is a book on your table right in the middle. Is the book moving? You will say "it is not moving; it is at rest". If you push the book to one side of the table to clear space for keeping your notebook, then you will say the book is moving.

When the book was at the same place with respect to the table, you say the book was at rest; but when it was pushed from one place on the table to another place, you say it was moving.

When there is a change of position of an object with respect to time, then it is called motion, if it remains stationary it is called rest.

Contact, Non-Contact Forces

In all the above cases, the force is executed by touching the body. so, these type of force is called Contact Force. Mysteriously ripen coconut falls to the ground. What pulls it to the ground? We would have heard of the 'force of gravity' of Earth. Gravity pulls the ripen coconut from the tree to the ground.

Bring a magnet near the small iron nail. Suddenly the nail jumps into the air and sticks with the magnet. Observe that the magnet and the nail did not touch each other. Still, there was a pulling force that made the nail to jump towards the magnet. In these two examples, the force is applied without touching the object. Such forces are known as "non-contact forces"

Forces can be classified into two major types; contact and non-contact forces. Wind is making a fag flutter, a cart pulled by a bullock are contact forces. Magnetism, gravity are some examples of non-contact forces.

Periodic and non- periodic motions

A fly buzzing around the room is a combination of all these and flight path is zigzag.

You can classify the motion according to the path taken by the object. Linear- moving in a straight line, like a person walking on a straight path, free fall. Curvilinear - moving ahead but changing direction, like a throwing ball. Circular -moving in a circle, swirling stone tied to the rope. Rotatory -The movement of a body about its own axis, like a rotating top.

Oscillatory -coming back to the same position after a fixed time interval, like a pendulum.
Zigzag (irregular)- like the motion of a bee or people walking in a crowded street.

Oscillations at Greater Speed

Ask your friend to hold the two ends of a stretched rubber band. Strike it in the middle. Do you see it oscillates very fast? When the oscillation is very swift, it is called as vibration

Fast oscillations are referred to as vibrations.

Uniform and non-uniform motion

Suppose a train leaves Thiruchirapalli and arrives at Madurai. Is the train travelled in an uniform speed? First, the train was stationary. When the train left the station, the motion was slow and only after it left some distance that it gathered speed. After that it slowed down while crossing bridges and stop at intermediate stations for passengers. Finally, as the train approached Madurai, again, it slowed and finally came to a halt. That is the speed was not same all through the journey time. That is the speed was non-uniform. This motion is said to be non-uniform motion.

In a nutshell, we can classify the motion in terms a) path b) if it is periodic or not c) if the speed is uniform or not. However, in real life, the motions are combinations many types.

Robots are automatic machines. Some robots can perform mechanical and repetitive jobs faster, more accurately than people. Robots can also handle dangerous materials and explore distant planets. The term comes from a Czech word, 'robota' meaning 'forced labour'. Robotics is the science and study of robots.

What Can Robots Do?

Robots can sense and respond to their surroundings. They can handle delicate objects or apply great force-for example, to perform eye operations guided by a human surgeon, or to assemble a car. With artificial intelligence, robots will also be able to make decisions for themselves.

How Do Robots Sense?

The quadruped al military robot

Electronic sensors are a robot's eyes and ears. Twin video cameras give the robot a 3-D view of the world. Microphones detect sounds. Pressure sensors give the robot a sense of touch, to judge how hard to grip an egg. Heavy luggage built-in computers send and receive information with radio waves.

Artificial Intelligence

Artificial intelligence attempts to create computer programs that think like human brains. Current research has not achieved this, but some computers can be programmed to recognize faces in a crowd.

Can Robots Think?

Articulated welding robots (Industrial) Robots can think. They can play complex games, such as chess, better than human beings. But will a robot ever know that it is thinking? Humans are conscious-we know we are thinking-but we don't know how consciousness works. We don't know if Robots can ever be conscious.

Nano robotics

Future of Nano robotics
Nano-robots or Nano bots are robots scaled down to microscopic size in order to put them into very small spaces to perform a function. Future Nano bots could be placed in the blood stream to perform surgical procedures that are too delicate or too difficult for standard surgery. Imagine if a Nano bot could target cancer cells and destroy them without touching healthy cells nearby.

7^{TH} TERM 1
UNIT 2. Force and Motion

Speed - Velocity
Speed
Recapitulation

Speed is the rate of change of distance .
Speed = distance /time
Unit is metre/second (m/s)
We can classify speed into two types.

Uniform speed

If a body in motion covers equal distances in equal intervals of time, then the body is said to be in uniform speed.

Non- uniform speed

If a body covers unequal distances in equal intervals of time, the body is said to be in non-uniform speed.
Average speed = total distance travelled / time taken to travel the distance.

Velocity

Velocity is the rate of change in displacement.
Velocity (v) = displacement / time
SI unit of velocity is meter / second (m/s).

1 km/h = 5/18 m/s

How we got this ?
1 km = 1000 m
1 h = 3600 s
1 km / h = 1000 m / 3600 s = 5/ 18 m /s

If an athlete in the diagram takes 25 s to complete a 200 m sprint event. Find her speed and velocity.

Speed = distance / time

= 200 / 25
= 8 m/s

velocity = displacement /time

= 50 / 25
= 2 m/s

Uniform velocity

A body has uniform velocity, if it covers equal displacement in the same direction in equal intervals of time. E.g. light travels through vacuum.

Non uniform velocity

If either speed or direction changes, the velocity is non uniform. E.g. a train starting and moving out of the station.

Average velocity

Average velocity = total displacement / total time taken
E.g. Figure shows a car that travels 5 km due east and makes a U – turn to travel another 7 km. If the time taken for the whole journey is 0.2 h. Calculate the average velocity of the car.
Average velocity = total displacement/time taken. (taking the direction due east of point O as positive)

= (5 – 7) / 0.2
= –2 / 0.2
= –10 km/h (or) –10 × 5/18 = 25/9
= –0.28 m / s

The triangle method can help you to recall the relationship between velocity (v), displacement (d), and time(t).
v = d / t , t = d / v, d = v × t

Acceleration

Acceleration (a)

Acceleration is the rate of change in velocity. In other words if a body changes its speed or dirction then it is said to be accelerated.

Acceleration = change in velocity/ time
= [final velocity (v) – intial velocity (u)] / time (t)

a = (v–u) / t

SI unit of acceleration is m/s_2
In other words, the object undergoes acceleration when its speed and/or direction change(s).

Positive acceleration

If the velocity of an object increases with respect to time, then the object is said to be in positive acceleration or just acceleration.

Negative acceleration or deceleration or retardation

If the velocity of an object decreases with respect to time, then the object is said to be in negative acceleration or deceleration or retardation.

The velocity of a golf ball rolling in a straight line changes from 8 m/s to 2 m/s in 10 s. What is its deceleration, assuming that it is decelerating uniformly?

Initial velocity (u) = 8 m/s
Final velocity (v) = 2 m/s
Time taken(t) = 10 s
Acceleration (a) = (v – u)/t
= (2 – 8)/10
= –0.6 m/s²
The deceleration is –0.6 m/s²

Uniform acceleration

An object undergoes uniform acceleration when the change (increase or decrease) in its velocity for every unit of time is the same. Table shows a moving bus with uniform acceleration.

When the velocity of the object is increasing by 20 m/s the acceleration is 20 m/s^2. When the velocity of the object is decreasing by 20 m/s the deceleration is 20 m/s^2.

Non – uniform acceleration

An object undergoes non uniform acceleration if the change in its velocity for every unit of time is not the same.

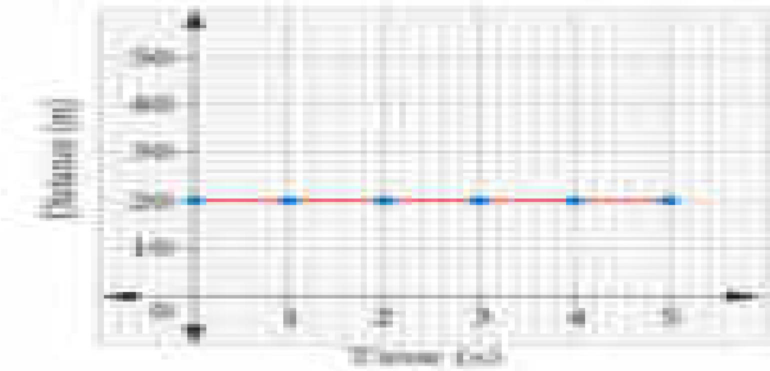
Time(s)	0	1	2	3	4	5
Change in Velocity(m/s)	0	10	30	20	10	20

Note that the change in velocity is not the same for every second. The moving object is undergoing non uniform acceleration.

Distance – Time Graphs

Figure shows a car travelling along a straight line away from the starting point O. The distance of the car is measured for every second. The distance and time are recorded and a graph is plotted using the data. The results for four possible journeys are shown below.

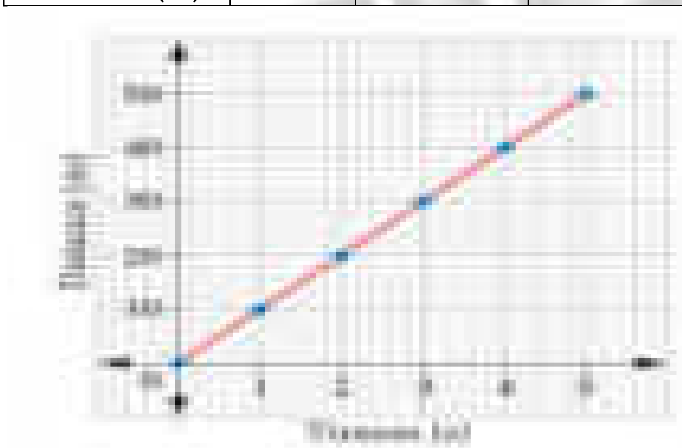
Time (s)	0	1	2	3	4	5
Distance(m)	20	20	20	20	20	20



The graph has zero gradient. The distance is a constant for every second.

(b) Car travelling at uniform speed of 10 m s^{-1}

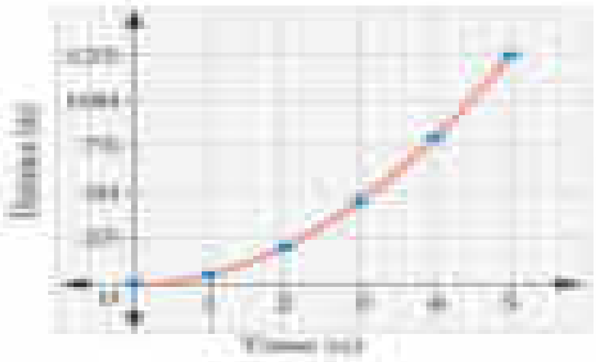
Time (s)	0	1	2	3	4	5
Distance (m)	0	10	20	30	40	50



The graph has a zero constant gradient. The distance increases 10 m every second.

(C) Car travelling at increasing speed

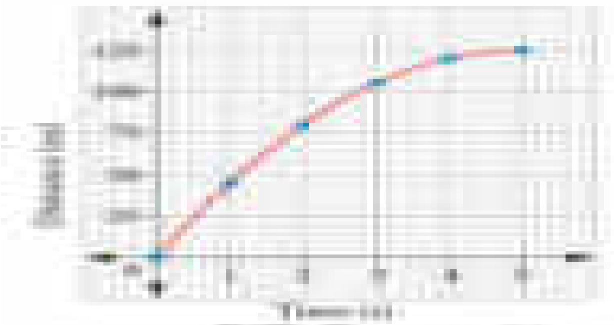
Time (s)	0	1	2	3	4	5
Distance(m)	0	5	20	45	80	125



The graph has an increasing gradient. The speed increases The instantaneous speed of the car at t = 3 s is given by the gradient of the tangent at the point.

(D) Car travelling at decreasing speed

Time (s)	0	1	2	3	4	5
Distance	0	45	80	105	120	125

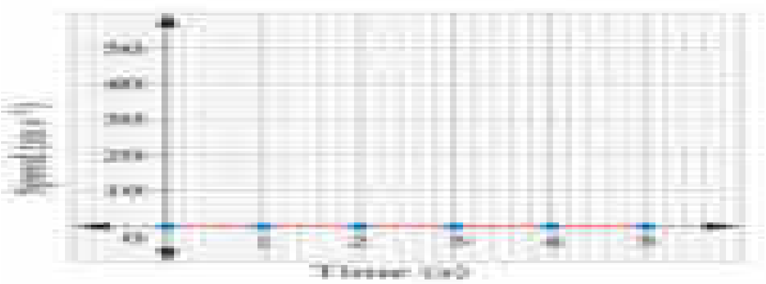


Speed – time graphs

Let us consider a bus travelling from Thanjavur to Trichy. The speed of the bus is measured for every second. The speed and time are recorded and a graph is plotted using the data. The results for four possible journeys are shown.

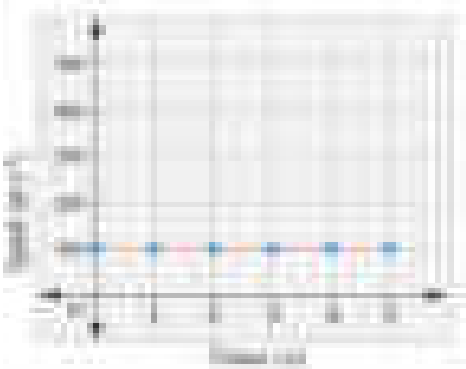
1. Bus at rest

Time (s)	0	1	2	3	4	5
Speed(ms^{-1})	0	0	0	0	0	0



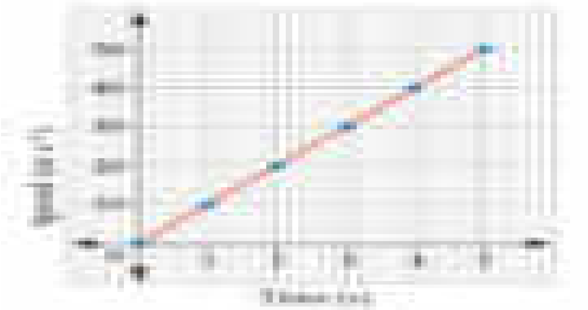
2. Bus travelling at uniform speed of m/s

Time(s)	0	1	2	3	4	5
Speed($m\ s^{-1}$)	10	10	10	10	10	10



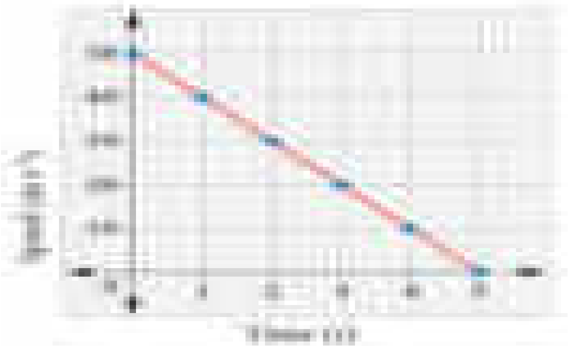
3. Bus travelling with uniform acceleration

Time	0	1	2	3	4	5
Speed (m s^{-1})	10	10	20	30	40	50



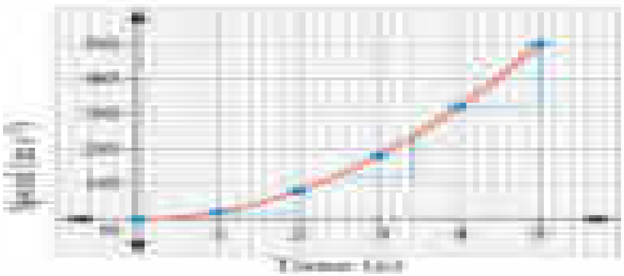
4. Bus travelling with uniform deceleration

Time (s)	0	1	2	3	4	5
Speed ms-1)	50	40	30	20	10	0



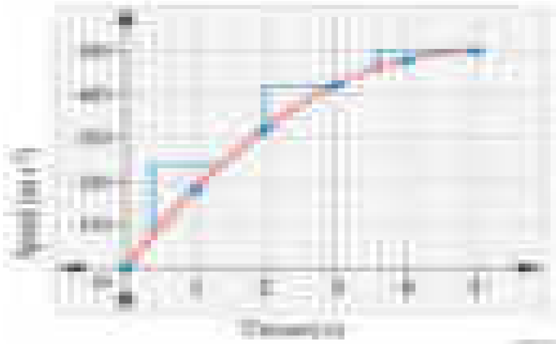
5. Bus travelling with increasing acceleration (non – uniform acceleration)

Time(s)	0	1	2	3	4	5
Speed (ms^{-1})	0	2	8	18	32	50



6. Bus travelling with decreasing acceleration (non – uniform acceleration)

Time (s)	0	1	2	3	4	5
Speed (ms^{-1})	0	18	32	42	48	50



Comparisons between distance – time and speed – time graphs

Speed – time graphs and Distance – time graphs look very similar, but they give different information. We can differentiate them by looking at the labels.

From A to B	From B to C	From C to D
Car accelerates uniformly from rest.	Car moves at constant speed.	Car decelerates uniformly to a stop.

Centre of Gravity and Stabilty
Centre of gravity

Try to balance a cardboard on your figure tip. What do we observe. We observe there is only one point which the cardboard is balanced. The point which the cardboard is balanced is called the cenre of gravity of the cardboard.

Centre of gravity: The centre of gravity of an object is the point through which the entire weight of the object appears to act.
How to we find the centre of gravity of a object?

Centre of gravity for Regular – shaped objects

Generally the centre of gravity of the geometrical shaped object lie on the geometric centre of the object.
Examples of centre of gravity for Regular-shaped objects. 1. Weight of Card,

2. Weight of Triangle, 3. Weight of Disc, 4. Weight of Ring.

What about irregular shaped objects?

Apparatus: Irregularly shaped card, string, pendulum bob, stand
1. Make three holes in the lamina.
2. Suspend the lamina from the optical pin through one of the holes as shown.
3. Suspend the plumbline from the pin and mark the position of the plumbline on the lamina.
4. Draw lines on the lamina representing the positions of the plumbline.
5. Repeat the above steps for the holes.
6. Label the intersection of the three lines as X, the position of the centre of gravity of the lamina.

Meter Rule

The ruler is in equilibrium when supported at its centre of gravity.
For a regular object such as a uniform meter rule, the centre of gravity is at the centre of the object. When the object is supported at that point, it will be balanced. If it is supported at any other point, it will topple.

Stability

Stability is a measure of the body's ability to maintain its original position.
The three types of stability are
(a) Stable equilibrium
(b) Unstable equilibrium
(c) Neutral equilibrium

Stable Equilibrium

The frustum can be tilted through quite a big angle without toppling.
Its centre of gravity is raised when it is displaced.
The vertical line through its centre of gravity still falls within its base.
So it can return to its orginalpositionl.

Unstable Equilibrium

The frustum will topple with the slightest tilting. Its centre of gravity is lowered when it is displaced.

Neutral Equilibrium

(d) It causes frustum to topple.
(e) The frustum will rolls about but does not topple.
(f) Its centre of gravity remains at the same height when it is displaced.
(g) The body will stay in any position to which it has been displaced.

Condition for Stability

To make a body more stable.
Lower its centre of gravity.
Increase the area of its base.
This box is at the point of tipping over.
A heavy base lowers at the centre of gravity So the box does not tip over.
A brode base makes the box more difficult to tip over

The Thanjavur Doll

It is s type of traditional Indian toy made of terracotta material. The centre of gravity and the total weight of the doll is concentrated at its bottom most point, generating a dance-like continuous movement with slow oscillations.

Real Life Applications of Centre of Gravity

It is for the reasons of stability that the luggage compartment of a tour bus is located at the bottom and not on the roof. Extra passengers are not allowed on the upper deck of a crowded double decker bus. Racing cars are built low and broad for stability. Table lamps and fans are designed with large heavy bases to make them stable.

Science Today Typical Speeds

Tortoise 0.1 m/s
Person walking 1.4 m / s
Falling raindrop 9-10 m / s
Cat running 14 m/s
Cycling 20-25 km/h
Cheetah running 31 m/s
Bowling speed of fast bowlers 90-100 miles /h
Badminton smash 80-90 m/s Passenger jet 180 m/s

8^{TH} TERM 1
Unit-2 Forces and Pressure

Definition of force

Force is that which changes or tends to change: i) the state of rest or ii) the state of uniform motion of a body or iii) the direction of a moving body or iv) the shape of a body.

Pushes and pulls are forms of forces. The direction of a force is in the direction in which a push or a pull is applied. Thus, force is a vector quantity, which has magnitude and direction. It is measured with a unit called "newton (N)".

Thrust

It is a force acting perpendicularly on any given surface area of a body. It is measured by the unit newton.

Pressure

The effect of force can be measured using a physical quantity called pressure. It can be defined as the amount of force or thrust acting perpendicularly on a surface of area one square meter of a body. Unit of pressure is pascal (Pa) or N m^{-2}.

Pressure = $\frac{Thrust(or)Force}{Area}$, P = F A. The SI unit of pressure is pascal (named after the French scientist Blaise Pascal). 1 pascal = 1 N m^{-2}

Pressure exerted by a force depends on the magnitude of the force and the area of

SOLVED PROBLEM:

Calculate the pressure exerted by the foot of an elephant using the following data. Average weight of an elephant is 4000 N. Surface area of the sole of its foot is 0.1m2 .

Solution:

Average weight of the elephant = 4000 N
Weight of one leg = force exerted by one leg = 4000/4 = 1000 N
Area of the sole of one foot = 0.1 m^2.

Pressure= $\frac{Force}{Area} = \frac{1000}{0.1}$

= 10000 $\frac{N}{m2}$ = 10^4 N m^{-2}

Pressure exerted by one leg of the elephant is 10,000 newton on one square metre.

Increasing pressure:

The effect of pressure can be increased by increasing the thrust or by decreasing the area of the surface of the body experiencing the thrust.

Examples:

The axe, nail, knife, injection needle, bullet etc., all these are having sharp fine edges so as to exert a larger pressure on a smaller area of the body; in order to get the maximum effect from them.

It is very difficult to walk on sand. But, camels can walk easily on it because they have large padded feet, which increase the area of contact with the sandy ground. This reduces the pressure and enables them to walk easily on the sand.

Examples:

More number of wheels are provided for a heavy goods-carrier for decreasing the pressure; thereby increasing the area of contact on the road.
Broader straps are provided on a back-pack for giving a lower pressure on the shoulders by providing a larger area of contact with the shoulder.
It is difficult to drive an automobile, which has flattened tyres.

PRESSURE EXERTED BY AIR - ATMOSPHERIC PRESSURE

You all know very well that air fills the space all around us. This envelope of air is called as atmosphere. It extends up to many kilometres above the surface of the Earth. All objects on the surface of the Earth experience the thrust or force due to this atmosphere.

The amount of force or weight of the atmospheric air that acts downward on unit surface area of the surface of the Earth is known as atmospheric pressure. It can be measured using the device called barometer. The barometer was invented by "Torricelli".

Atmospheric pressure decreases with altitude from the surface of the Earth.

Atmospheric pressure can be measured by the height of the mercury column in a barometer. The height of the mercury column denotes the atmospheric pressure at that place at a given time in 'millimetre of mercury'.

Even if you tilt the tube at various angles, you will see that the level of mercury will not vary. At sea level, the height of the mercury column is around 76 cm or 760 mm. The pressure exerted by this mercury column is considered as the pressure of magnitude 'one atmosphere' (1atm).

1atmospheric peressure =1at = pressure exerted by the mercury column of height 76 cm in the barometer = 1.01×10^5 N $m^{-2.}$
In the SI system 1 atm = 1,00,000 pascal (approximately).
SI unit of atmospheric pressure is Nm^{-2} or pascal.
To realise the effect of atmospheric pressure:

FORCES IN LIQUIDS

Buoyant force of a liquid

An upward force is exerted by water on a floating or a partly submerged body. This upward force is called buoyant force. The phenomenon is known as "buoyancy". This force is not only exerted by liquids, but also by gases. Liquids and gases together are called fluids.

This upward force decides whether an object will sink or float. If the weight of the object is less than the upward force, then the object will float. If not, it will sink.

A body floats if the buoyant force > its weight; A body sinks if its weight > buoyant force.

Pressure exerted by liquids

Liquids do not have a definite shape. The force acting on unit area of the surface, on which the liquid is placed, is called the static pressure of the liquid. Liquids exert a pressure not only on the base of their container/vessel, but also on its side walls. The pressure exerted by a liquid depends upon the depth of the point of observation considered in it.

An instrument used to measure the difference in the liquid pressure is called a "manometer". You can measure the pressure of fluids enclosed in a definite container using the manometer.

a) Pressure exerted by a liquid on the base of a container depends upon the height of the liquid column:

You have already studied that the atmospheric pressure is measured in terms of the height of the mercury column in a barometer.

b) Liquids exert the same pressure in all directions at a given depth:
c) Liquid pressure varies with the depth:

Home Assignments

1. Ask your family doctor how blood pressure is to be measured?
2. Read the life history of Blasie Pascal.

Pascal's law:

The pressure applied at any point of a liquid at rest, in a closed system, will be distributed equally through all regions of the liquid.

Application of Pascal's law:

Some of the following examples highlight their working according to Pascal's law.

In an automobile service station, the vehicles are lifted upward using the hydraulic lift, which works as per Pascal's law.
The automobile brake system works according to Pascal's law.
The hydraulic press is used to make the compressed bundles of cotton or cloth so as to occupy less space.

All the above questions have an answer, i.e., "due to surface tension".

Surface tension is the property of a liquid. The molecules of a liquid experience a force, which contracts the extent of their surface area as much as possible, so as to have the minimum value. Thus, the amount of force acting per unit length, on the surface of a liquid is called surface tension. It has the unit N m^1.

Application of surface tension:

Water molecules rise up due to surface tension. Xylem tissues are very narrow vessels present in plants. Water molecules are absorbed by the roots and these vessels help the water to rise upward due to "capillarity action" (you will study this topic in the forth-coming classes), which is caused by the surface tension of water.

For a given volume, the surface area of a sphere is the minimum. This is the reason for the liquid drops to acquire a spherical shape. Water strider insect slides on the water surface easily due to the surface tension of water.

During a heavy storm, sailors pour soap powder or oil into the sea near their ship to decrease the surface tension of sea water. This process reduces the impact of the violent water current against the all of ship.

VISCOUS FORCE OR VISCOSITY
Definition:

When a liquid is flowing, there is a frictional force between the successive layers of the liquid. This force which acts in order to oppose the relative motion of the layer is known as viscous force. Such a property of a liquid is called viscosity.

Viscosity force is measured by the unit called poise in CGS and kg m^{-1} s^{-1} or N s m^{-2} in SI.

Friction

Reason: Ram's brother falls down due to the lack of friction between his feet and the banana peels.

You have studied that forces are classified into two types: contact force and non-contact force. Now, you are going to study one of the contact forces, i.e., friction.

It is easy to hold a tumbler due to the friction between the surfaces of your palm and the tumbler. But, when oil is applied to your palm, the contact force between your fingers and the tumbler is reduced. So, the friction is reduced. Hence, it is difficult to hold it with an oily hand.

Origin of friction

Frictional force or friction arises when two or more bodies in contact move or tend to move, relative to each other. It acts always in the opposite direction of the moving body. This force is produced due to the geometrical dissimilarities of the surface of the bodies, which are in relative motion.

Effects of friction:

Friction can produce the following effects:
a) Friction opposes motion.
b) Friction causes wear and tear of the surfaces in contact.
c) Friction produces heat.

Types of friction:

Friction can be classified into two basic types: static friction and kinetic friction.

Static friction: The friction experienced by the bodies, which are at rest is called static friction. (E.g.: all the objects rigidly placed to be at rest on the Earth, a knot in a thread.)

Kinetic friction: Friction existing during the motion of bodies is called kinetic friction.
Further, kinetic friction can be classified into two: sliding friction and rolling friction.

Sliding friction: When a body slides over the surface of another body, the friction acting between the surfaces in contact is called sliding friction.

Rolling friction: When a body rolls over another surface, the friction acting between the surfaces in contact is called rolling friction.

Rolling friction is less than sliding friction. That is why wheels are provided in vehicles, trolleys, suitcases etc.

Reason: When you push the book, the pencils roll in the direction of the applied force. They prevent the contact of the book with the rough surface. Rolling pencils offer the least amount of friction. So, it is easy to displace the book in comparison with sliding it on the table.

This method is often used in moving heavy wood from one place to another.

Factors affecting friction
a) Nature of a surface:
b) Weight of the body:

It is easy to pedal your cycle without any load on its carrier. With a load placed on its carrier, it is difficult to move it because the weight on the carrier increases the friction between the surface of the tyre and the road.

c) Area of contact:

For a given weight, the friction is directly related to the area of contact between the two surfaces. If the area of contact is greater, then, the friction will be greater too.

A road roller has a broad base, so it offers more friction on the road. But, a cycle has the least friction, since the area of contact of the tyre with the surface of the road is less.

Advantages of friction

Friction is a necessity in most of our day to day activities. It is desirable in most situations of our daily life.

We can hold any object in our hand due to friction. We can walk on the road because of friction. The footwear and the ground help us to walk without slipping.

Writing easily with a pen on paper is due to friction. Automobiles can move safely due to friction between the tyres and the road. Brakes can be applied due to frictional resistance on brake shoes. We are able to light a matchstick, sew clothes, tie a knot or fix a nail in the wall because of friction.

Though it is giving a negative effect, in most of our day to day life friction helps us to make our life easy. So, it is called as “necessary evil”.

Disadvantages of friction

Friction wears out the surfaces rubbing with each other, like screws and gears in machines or soles of shoes. To overcome the friction an excess amount of effort has to be given to operate a machine. This leads to wastage of energy.
Friction produces heat, which causes physical damage to the machines.

Increasing and decreasing friction

a) Area of contact:

Friction can be increased by increasing the area of the surfaces in contact. Have you seen the sole of a shoe, which has grooves? It is done to provide the shoes a better grip with the floor, so that you can walk safely. Treaded tyres (tyres with slots and projections) are used to increase the friction.

Brake shoes in a cycle have to be adjusted so that they are as close as possible to the rim of the wheel, in order to increase the friction.

E.g.: Sumo players, Kabbadi players rub their hand with mud, to get a better grip. Football shoes are having soles with many projections, for providing a stronger grip with the ground.

b) Using lubricants:

A substance, which reduces the frictional force, is called a lubricant. E.g.: grease, coconut oil, graphite, castor oil, etc.
The lubricants fill up the gaps in the irregular surfaces between the bodies in contact. This provides a smooth layer thus preventing a direct contact between their rough surfaces.

c) Using ball bearing:

Since, the rolling friction is smaller than sliding friction, sliding is replaced by rolling with the usage of ball bearings. You can see lead shots in the bearing of a cycle hub.

Heat

6th Standard - Term-II
Unit 1: Heat

Sources Of Heat

♦ **Sun**

- We all know that the sun gives us light. Does it give us heat? After standing under the sun light for some time, touch your head. Does it feel hot? Yes, it feels hot because the sun gives out heat besides light. Now, You can understand why it is diff cult to walk bare-footed on sunny days in the afternoon.

♦**Combustion (Burning)**

- Heat energy can be generated by the burning of fuels like wood, kerosene, coal, charcoal, gasoline/petrol, oil, etc., In your home, how do you get heat energy to cook food?♦ **Friction**
- Rub your palms for some time and then hold them todo you feel? We can generate heat by rubbing two surfaces of some substances. In the past people used to rub two stones together to light f re.

♦ **Electricity**

- Whenelectric current fows through a conductor, heat energy is produced. The waterheater, iron box, electric kettle etc., work on this principle.

Heat

Molecules in objects are constantly vibrating or moving inside objects. We cannot see that movement with our naked eye. When we heat the object this vibration and movement of molecules increases and temperature of the object also increases.

Thus, Heat is an energy that raises the temperature of a thing by causing the molecules in that thing to move faster.

Heat is not a matter. It doesn't occupy space. It has no weight. Like light, sound and electricity, heat is a form of energy.

In short, Heat is the total kinetic energy of constituent particles of objects. **SI Unit of Heat is joule**. The unit calorie is also used.

Hot and cold objects

- In our day-to-day life, we come across a number of objects. Some of them are hot and some of them are cold. How do we decide which object is hotter than the other?

- use the tip of our finger to find out whether the tea in a cup has enough heat to drink or whether milk has been cooled enough to set for making curds. We often determine heat by touching the objects. But is our sense of touch reliable?

Temperature

Definition of Temperature

- The measurement of warmness or coldness of a substance is known as its Temperature.

- SI unit of temperature is kelvin. Celsius and Fahrenheit are the other units used. Celsius is called as Centigrade as well.

- It determines the direction of flow of heat when two bodies are placed in contact

Is Neela correct?

- Beaker A and B has water at 80o C.

- Then pour the water of A and B to an empty beaker C. Now, What is the temperature of the water in the beaker C? Neelasays it will be 160°C.

- What is your opinion? Does Neela say correctly? Make a guess and verify it experimentally

- One day in 1922, the air temperature was measured at 59°C in the shade in Libya, Africa. The coldest temperature in the world was measured in the Antarctic continent. It was approximately – 89oC. The minus sign (–) is used when the temperature falls below the freezing point of water, which is 0°C. If water becomes ice at 0°C, you can imagine how cold – 89°C would be. Our normal body temperature is 37°C. Our body feels cool if the air temperature is around 15 to 20 degree Celsius. Can you estimate the night temperature in your village or city during winter

Heat and Temperature

- Heat and temperature are not the same thing, they in fact mean two different things;

- Temperature is related to how fast the atoms or molecules move or vibrate within the substance.

- 2. Heat not only depends on the temperature of the substance but also depends on how many molecules are there in the object.

- 3. Temperature measures the average kinetic energy of molecules. Heat measures the total Kinetic Energy of the molecules in the substance.

- Total heat is measured by calorie, the amount of heat needed to raise one gram of water by one degree centigrade.

Flow of Heat

An analogy between temperature and water level:

- Water**'flows'** when there is a difference in the 'levels' of water in different places. It does not matter if there is more water in one place or another. Water from a puddle can flow into a reservoir or the other way around. The **'temperature'** of an object is like the water level – itdetermines the direction in which 'heat' will flow. Heat energy flows from higher temperature to lower temperature.

Thermal contact and Thermal equilibrium

- Consider two bodies A and B. Let the temperature of A be higher than that of B. On bringing bodies A and B in contact , heat will flow from hot body A to the cold body B. Heat will continue to flow till both the bodies attain the same temperature.

Expansion in solids

- Sam is trying to open a tight jar, but he cannot open it. He asks his uncle to help. His uncle says that pour some hot water on the lid of the jar. Sam does so and tries to open it now. Wow! The jar is opened easily! Do you have such experience? How do you open a tightly closed cap of thepen which could not be opened by you normally?

- Most substances expand when heated andcontract when cooled. The change in length / area or volume (due to contraction / expansion) is directly related to temperature change.

- The expansion of a substance on heating is called, the thermal expansion of that substance.

Linear and Cubical Expansion

❖ A solid has a definite shape, so when a solid is heated, it expands in all directions i.e., in length, area and volume, all increase on heating.

- The expansion in length is called linear expansion and the expansion in volume is called cubical expansion.
- Why is the iron rim of a bullock cart wheel heated before it is fitted onto the wheel? Why is a small gap left between two lengths of railway lines?
- We can perform an interesting experiment to find out an answer to these questions. All we need to do is to heat a cycle spoke.

Uses of Thermal Expansion

Fitting the iron rim on the wooden wheel

- The diameter of the iron ring is slightly less than that of the wooden wheel. Therefore, it cannot be easily slipped on from the rim of wooden wheel. The iron ring is, therefore, fi rst heated to a higher temperature so that it expands in size and the hot ring is then easily slipped over to the rim of the wooden wheel. Cold water is now poured on the iron ring so that it contracts in size and holds the wooden wheel tightly.

Rivetting

- Rivets are used to join two steel plates together. Hot rivet is driven through the hole in the plates. One end of the rivet is hammered to form a new rivet head. When cooled, the rivet will contract and hold the two plates tightly together.

Thermal Expansion Examples

Give Reasons for the following

- Gaps are left in between rails while laying a railway track.
- Gaps are left in between two joints of a concrete bridge.

Cracking of a thick glass tumbler

- Glass is a poor conductor of heat. When hot liquid is poured into the tumbler, the inner surface of the tumbler becomes hot and expands while the outer surface remains at the room temperature and does not expand. Due to this unequal expansion, the tumbler cracks. Electric wires Electric wires between electric posts contract on cold days and sag in summers. To solve this problem, we leave wires slackso that they are free to change length.

- Glassware used in kitchen and laboratory are generally made up of Borosilicate glass (pyrex glass). The reason is that the Borosilicate glass do not expand much on being heated and therefore they do not crack.

7th Standard - Term(II)
Unit 1. Heat and Temperature

Temperature Units:

- There are three units which are used tomeasure the temperature: DegreeCelsius,Fahrenheit and Kelvin.

  - **Degree Celsius:** Celsius is written as°C andreadas degree. For example 20°C; it is read as twentydegree Celsius. Celsiusis called as Centigrade aswell.

  - **Fahrenheit:** Fahrenheit is written as °F forexample 25°F; it is read as twentyfive degreeFahrenheit.

  - **Kelvin:** Kelvin is written as K. For example100K; it is read as hundred Kelvin.

  - The SI unit of temperature is kelvin (K).

Measuring Temperature

- The temperature of theobject is well approximatedwith the kinetic energy ofthe substances. The hightemperature means that themolecules within the objectare moving at a faster rate.But the question arises, how to measureit? Molecules inany substance are very smallto analyze and calculate its movement (Kineticenergy)in order to measure its temperature.You must use an indirect method to measure thekinetic energy of the molecules of a substance.We studied that solids expandswhen heat issupplied to it. Like solid substances, liquids arealso affected by heat.

- In a thermometer, when liquid gets heat,it expands and when it is cooleddown, itcontracts. It is used to measure temperature.Like solid and liquid objects,the effect ofheat is also observed on gaseous objects.

Thermometer:

- Thermometer is the most common instrumentto measure temperature.Thereare various kinds of thermometers.Some of them are like glass tubes which lookthin and are filled with some kind of liquid.Why Mercury or Alcohol is used inThermometer?Mostly Alcohol and Mercury are used inthermometers as theyremain in liquid formeven with a change of temperature in them.A small change inthe temperature causeschange in volume of a liquid. We measure thistemperatureby measuring expansion of a liquidin thermometer.

Properties of Mercury:-

- Its expansion is uniform. (For equal amountsof heat it expands by equal lengths.)
- It is opaque and shining.
- It does not stick to the sides of the glass tube.
- It is a good conductor of heat.
- It has a high boiling point (357°C) and a lowfreezing point (−39°C). Hence a wide rangeof temperatures can be measured using amercury thermometer

Properties of Alcohol

- The freezing point of alcohol is less than−100°C. So it can be used to measure verylow temperatures.
- Its expansion per degree Celsius rise intemperature is very large.
- It can be coloured brightly and hence iseasily visible.

Types of Thermometers

- There are differenttypes of thermometers formeasuring the temperaturesofdifferent things like air,our bodies, food and manyother things. Among these,thecommonly used thermometers are clinicalthermometers and laboratorythermometers.

Clinical Thermometer

- These thermometers are used to measurethe temperature of a human body, athome,clinics and hospitals. All clinical thermometershave a kink that prevents themercury fromflowing back into the bulb when thethermometer is taken out of thepatient'smouth, so that the temperature can benoted conveniently. There aretemperaturescales on either side of the mercurythread, one in Celsius scale and theotherin Fahrenheit scale. Since the Fahrenheitscale is more sensitive than theCelsiusscale, body temperature is measured inF only. A clinical thermometerindicatestemperatures from a minimum of 35°C or94°F to a maximum of 42°C or108°F.

Precautions to be Followed While Using aClinical Thermometer

- ❖ The thermometer should be washed beforeand after use, preferably with anantisepticsolution.

- ❖ Jerk the thermometer a few times to bringthe level of the mercury down.

- ❖ Before use, the mercury level should bebelow 35°C or 94°F.

- ❖ Do not hold the thermometer by its bulb.

- ❖ Keep the mercury level along your line ofsight and then take the reading.
- ❖ Handle the thermometer with care. If it hitsagainst some hard object, it may break.
- ❖ Do not place the thermometer in a hot flameor in the hot sun.

Laboratory Thermometers

- Laboratory thermometers are used tomeasure the temperature in school andotherlaboratories for scientific research. They arealso used in the industry as theycan measuretemperatures higher than what clinicalthermometers can record. Thestem and thebulb of a lab thermometer are longer whencompared to that of aclinical thermometer andthere is no kink in the lab thermometer.A laboratorythermometer has only theCelsius scale ranging from −10°C to110°C.

Precautions to be Followed While Using a Laboratory Thermometer

- ❖ Do not tilt the thermometer whilemeasuring the temperature. Place itupright.
- ❖ Note the reading only when thebulb has been surrounded by thesubstance from all sides.

Do you know?

- In humans, the averageinternal temperature is37°C (98.6°F), though itvariesamong individuals.However, no person always has exactlythe same temperature atevery moment ofthe day. Temperatures cycle regularly upand down through theday according toactivities and external factors.

Clinical Thermometer	**Laboratory Thermometer**
Clinical Thermometer is scaled from 35°C to 42°C or from 94°C to 108°F.	Laboratory thermometer is generally from -10°C-110°C.
Mercury level does not fall on its own, as there is a link near the bulb to prevent the fall of mercury level.	Mercury level falls on its own as no kink is present
Temperature can be read after removing the thermometer from armpit or mouth.	Temperature is read while keeping the thermometer in the source of temperature, e.g. a liquid or any other thing.
To lower the mercury level jerks are given.	No need to give jerk to lower the mercury level

It is used for taking the body temperature	It is used to take temperature in laboratory

Digital Thermometer

- Here is a lot of concernover the use of mercury inthermometers. Mercuryis atoxic substance andis very difficultto dispose of if athermometer breaks. These days, digitalthermometers are available which donot use mercury. Instead, it has asensorwhich can measure the heat coming outfrom the body directly and from thatcan measure the temperature of thebody.Digital thermometers are mainlyused totake the body temperature.

Caution

- Alex wanted to measure the temperatureof hot milk using a clinicalthermometer. Histeacher stopped him from doing so.We are advised not to use aclinicalthermometer for measuring the temperature ofany object other than humanbody. Also we areadvised to avoid keeping it in the sun or near aflame. Why?A clinical thermometer has smalltemperature range. The glass will crack/ burstdue toexcessive pressure created by expansionof mercury.

Do you know?

Maximum - Minimum thermometer

- The maximum andminimum temperatures ofthe previous day reported inweatherreports are measured by a thermometercalled the maximum – minimumthermometer.

Scales of thermometers

Celsius scale

- Celsius is the common unit of measuringtemperature, termed after Swedishastronomer,Anders Celsius in 1742, before that it wasknown as Centigrade asthermometers usingthis scale are calibrated from (Freezing pointof water) 0°C to 100°C (boiling point of water).

- In Greek, 'Centium' means 100 and 'Gradus'means steps, both words make itcentigrade andlater Celsius.

Fahrenheit Scale

- Fahrenheit is a Common unit to measurehuman body temperature. It istermed after thename of a German Physicist Daniel GabrielFahrenheit. Freezingpoint of water is taken as32°F and boiling point 212°F. Thermometers withFahrenheit scale are calibrated from 32°F to 212°F.

Kelvin scale

- Kelvin scale is termed after Lord Kelvin.It is the SI unit of measuringtemperature andwritten as K also known as absolute scale as itstarts from absolutezero temperature.

- Temperature in Celsius scale can be easily converted to Fahrenheit and Kelvin scale as discussed

  - Relation between Fahrenheit scale and Celsius scales is as under.

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

- The equivalence between principal temperatures scales are given in Table for some temperatures.

Temperature	**Celsius scale (°C)**	**Fahrenheit scale (°F)**	**Kelvin scale (K)**
Boiling temperature	100	212	373.15
Freezing point of water	0	32	273.15
Mean temperature of human body	37	98.6	310.15
Room temperature	72	23	296.15

8th Standard
Term II
Unit 1. Heat

Effect of heat

- When heat energy is supplied to any substance, it brings about many changes. There are three important changes that we can see in our daily life. They are:
    - Expansion
    - Increase in temperature
    - Change in state

Expansion in solids

- Why didn't the ball go through the ring initially but went through it after some time? When the ball is heated the atoms in the ball gain heat energy. They start vibrating and force each other apart. As a result an expansion takes place. That's why the ball did not go through the ring. After some time, as the ball lost the heat energy to the surrounding it came back to its original size and it went through the ring. This shows that heat energy causes expansion in solids. This expansion takes place in liquids and gases also. It is maximum in gases.

- You would have noticed some space being left in railway tracks. Why? It is because railway tracks which are made up of iron metal expand during summer. When there is a gap, there will not be any damage in the track due to expansion of the metal rod

Rise in Temperature

- When the water is heated, water molecules receive heat energy. This heat energy supplied increases the kinetic energy of the molecules. temperature of the water increases. This shows that heat energy causes increase in temperature.

- Heat energy change in temperature

Change of State

- In ice cubes the force of attraction between the water molecules is more. So they are close together. When we heat them the force of attraction between the molecules decreases and the ice cubes become water. When we heat the water, the force of attraction decreases further. Hence they move away from one another and become vapour. Since water vapour escape to the surrounding, water level decreases further. From this we understand that heat energy causes change in the state of the substances. When heat energy is removed, changes take place in reverse direction.

- If heat energy is supplied to or taken out from a substance, it will undergo a change from one state of matter to another. One of the following transformations may take place due to heat energy.

  - **Solid to Liquid (Melting)**
  - **Liquid to Gas (Vapourisation)**
  - **Solid to Gas (Sublimation)**
  - **Gas to Liquid (Condensation)**
  - **Liquid to Solid (Freezing)**
  - **Gas to Solid (Deposition)**

- Water is the only matter on the Earth that can be found naturally in all three states - Solid, Liquid and Gas.

Transfer of heat

- If heat energy is supplied to any substance, it will be transferred from one part of the substance to another part. It takes place in different ways depending on the state of the substance. Three ways of heat transfer are:

  - **Conduction**
  - **Convection**
  - **Radiation**

Conduction

- How did the other end of the spoon become hot? It is because heat in the hot water is transferred from one end to other end of the spoon. In solid substances such as silver spoon, atoms are arranged very closely. Hot water molecules which are vibrating transfer the heat energy to the atoms in the spoon and make them vibrate. Those atoms make other atoms to vibrate and thus heat is transferred to the other end of the spoon.

- In conduction heat transfer takes place between two ends of the same solid or through two solid substances that are at different temperatures but in contact with one another. Thus, we can define conduction as the process of heat transfer in solids from the region of higher temperature to the region of lower temperature without the actual movement ofatoms or molecules.

- All metals are good conductors of heat. The substances which does not conduct heat easily are called bad conductors or insulators. Wood, cork, cotton, wool, glass, rubber,etc are insulators.

Conduction in daily life

❖ We cook food in vessels made up of metals. When the vessel is heated, heat is transferred from the metal to the food.

- ❖ When we iron dresses heat is transferred from the iron to the cloth.
- ❖ Handles of cooking utensils are made up of plastic or wood because they are poor conductors of heat.
- ❖ The temperature inside igloo (snow house) is warm because snow is a poor conductor of heat.

Convection

- When water in the vessel is heated, water molecules at the bottom receive heat energy and move upward. Then the molecules at the top comes down and get heated. This kind of heat transfer is known as convection. This is how air in the atmosphere is also heated. Thusthe form of heat transfer from places of high temperature to places of low temperature by the actual movement of molecules is called convection. Convection takes place in liquids and gases.

Convection in daily life

- **Formation of land breeze and sea breeze is due to convection of air.**
- **Wind flows from one region to another region by convection.**
- **In hot air balloons heat is transferred by convection and so the balloon raises.**
- **In refrigirators, cool air moves downward and replaces the hot air because of convection**.

Radiation

- Radiation is the third form of heat transfer. By conduction, heat is transferred through solids, by convection heat is transferred through liquids and gases, but by radiation heat can be transferred throughempty space even through vacuum. Heat energy from the Sun reaches the Earth by this
- Heat transfer by radiation is visible to our eyes. When a substance is heated to 500°C the radiation begins to become visible to the eye as a dull red glow, and it is sensed as warmth by the skin. Further heating
- rapidly increases the amount of radiation, and its perceived colour becomes orange, yellow and finally white
- form of heat transfer. Radiation is defined as the way of heat transfer from one place to another in the form of electromagnetic waves.

Radiation in daily life

- ❖ · Heat energy from the Sun reaches the Earth by radiation.

- While standing near fire we feel the heat which is transferred as radiation.
- Black surfaces absorb heat radiation. So that the bottom of the cooking vessels are painted black.
- White colour reflects heat radiation. That's why we are advised to wear white cloth during summer.

Calorimetry

- We studied about the effects of heat energy. When heat energy is supplied to substances, physical changes take place in them. Solid form of water (ice) is changed to liquid form, and liquid form of water is changed to gaseous form. These are all the physical changes due to heat energy. Similarly, heat energy produces chemical changes also. To know more about the physical and chemical changes that take place in substances, we need to measure the amount of heat involved. The technique used to measure the amount of heat involved in a physical or a chemical process is known as calorimetry.

Temperature

- Temperature is a physical quantity which expresses whether an object is hot or cold. It is measured with the help of thermometer. There are three scales to measure the temperature.

  They are:
  - **Celcius scale**
  - **Fahrenheit scale**
  - **Kelvin scale**

- Among these three scales, Kelvin scale is the most commonly used one. You will study about this in detail in Standard IX.

Unit of Heat

- We know that heat is a form of energy. The unit of energy in SI system is joule. So, heat is also measured in joule. It is expressed by the symbol J. The most commonly used unit of heat is calorie. One calorie is the amount of heat energy required to raise the temperature of 1 gram of water through 1°C. The relation between calorie and joule is given as, 1 calorie = 4.186 J.

- The amount of energy in food items is measured by the unit kilo calorie. 1 kilo calorie = 4200 J (Approximately).

Heat capacity

- In general, the amount of heat energy gained or lost by a substance is determined by three factors. They are:
  - **Mass of the substance**
  - **Change in temperature of the substance**
  - **Nature of the material of the substance**

- Different substances require different amount of heat energy to reach a particular temperature. This nature is known as heat capacity of a substance. Heat capacity is defined as the amount of heat energy required by a substance to raise its temperature by 1°C or 1 K. It is denoted by the symbol C'. Heat capacity

$$\frac{Amount\ of\ heat\ energy\ reqiured(Q)}{Raise\ in\ temperature\,(\Delta T)}$$

Therefore, C' = Q / ΔT

- The unit of heat capacity is cal / °C. In SI system, it is measured in JK-1.

Specific heat capacity

- When the heat capacity of a substance is expressed for unit mass, it is called specific heat capacity. Specific heat capacity of a substance is defined as the amount of heat energy required to raise the temperature of 1 kilogram of a substance by 1°C or 1 K. It is denoted by the symbol C.

Specific heat of capacity

$$= \frac{Amount\ of\ heat\ energy\ reqiured(Q)}{Mass \times Raise\ in\ temperature\,(\Delta T)}$$

Therefore, C = Q /m . ΔT

The SI unit of specific heat capacity is J Kg-1 K -1.

Calorimeter

- A calorimeter is a device used to measure the amount of heat gained or lost by a substance. It consists of a vessel made up of metals like copper or aluminium which are good conductors of heat and electricity.

- The metallic vessel is kept in an insulating jacket to prevent heat loss to the environment. There are two holes in it. Through one hole a thermometer is inserted to measure thetemperature of the contents. A stirrer is inserted through another hole for stirring the content in the vessel. The vessel is filled with liquid whichis heated by passing current through the heating element. Using this device we can measure the heat capacity of the liquid in the container.

- The world's first ice-calorimeter was used in the year 1782 by Antoine Lavoisier and Pierre- Simon Laplace, to determine the heat generated by various chemical changes.

Thermostat

- A thermostat is a device which maintains the temperature of a place or an object constant. The word thermostat is derived from two Greek words, 'thermo' meaning heat and 'static' meaning staying the same. Thermostats are used in any device or system that gets heated or cools down to a pre-set temperature. It turns an appliance or a circuit on or off when a particular temperature is reached. Devices which use thermostat include building heater, central heater in a room, air conditioner, water heater, as well as kitchen equipments including oven and refrigerators. Sometimes, a thermostat functions both as the sensor and the controller of a thermal system.

Thermos Flask

(Vacuum flask)

- The thermos flask (Vacuum flask) is an insulating storage vessel that keeps its content hotter or cooler than the surroundings for a longer time. It is primarily meant to enhance the storage period of a liquid by maintaining a uniform temperature and avoiding possibilities of getting a bad taste.

- The vacuum flask was invented by Scottish scientist Sir James Dewar in 1892. In his honour it is called Dewar flask. It's also known as Dewar bottle.

Working of Thermos flask

- A thermos flask has double walls, which are evacuated. It is silvered on the inside. The vacuum between the two walls prevents heat being transferred from the inside to the outside by conduction and convection.

- With very little air between the walls, there is almost no transfer of heat from the inner wall to the outer wall or vice versa. Conduction can only occur at the points where the two walls meet, at the top of the bottle and through an insulated support at the bottom. The silvered walls reflect radiated heat back to the liquid in the bottle.

9th Standard
Unit – 7 – Heat

Heat transfer takes place in three ways:

i. **Conduction,**
ii. Convection,
iii. Radiation

Conduction

- In solids, molecules are closely arranged so that they cannot move freely. When one end of the solid is heated, molecules at that end absorb heat energy and vibrate fast at their own positions. These molecules in turn collide with the neighboring molecules and make them vibrate faster and so energy is transferred. This process continues till all the molecules receive the heat energy.

- The process of transfer of heat in solids from a region of higher temperature to a region of lower temperature without the actual movement of molecules is called conduction.

Conduction in daily life

i. Metals are good conductors of heat. So, aluminium is used for making utensils to cook food quickly.

ii. Mercury is used in thermometers because, it is a good conductor of heat.

iii. We wear woolen clothes is winter to keep ourselves warm. Air, which is a bad conductor, does not allow our body heat to escape.

Convection

- In this activity, water molecules at the bottom of the beaker receive heat energy and move upward and replace the molecules at the top. Same thing happens in air also. When air is heated, the air molecules gain heat energy allowing them to move further apart. Warm air being less dense than cold air will rise. Cooler air moves down to replace the air that has risen. It heats up, rises and is again replaced by cooler air, creating a circular flow.

- Convection is the flow of heat through a fluid from places of higher temperature to places of lower temperature by movement of the fluid itself.

Convection in daily life

Hot air balloons:

- Air molecules at the bottom of the balloon get heated by a heat source and rise. As the warm air rises, cold air is pushed downward and it is also heated. When the hot air is trapped inside the balloon, it rises.

Breezes:

- During day time, the air in contact with the land becomes hot and rises. Now the cool air over the surface of the sea replaces it. It is called sea breeze. During night time, air above the sea is warmer. As the warmer air over the surface of the sea rises, cooler air above the land moves towards the sea. It is called land breeze.

Winds:

- Air flows from area of high pressure to area of low pressure. The warm air molecules over hot surface rise and create low pressure. So, cooler air with high pressure flows towards low pressure area. This causes wind flow.

Chimneys:

- Tall chimneys are kept in kitchen and industrial furnaces. As the hot gases and smoke are lighter, they rise up in the atmosphere.

Radiation

- Radiation is a method of heat transfer that does not require particles to carry the heat energy. In this method, heat is transferred in the form of waves from hot objects in all direction. Radiation can occur even in vacuum whereas conduction and convection need matter to be present. Radiation consists of electromagnetic waves travelling at the speed of light. Thus, radiation is the flow of heat from one place to another by means of electromagnetic waves.

- Transfer of heat energy from the sun reaches us in the form of radiation. Radiation is emitted by all bodies above 0 K. Some objects absorb radiation and some other objects reflect them.

- While firing wood, we can observe all the three ways of heat transfer. Heat in one end of the wood will be transfered to other end due to conduction. The air near the wood will become warm and replace the air above. This is convection. Our hands will be warm because heat reaches us in the form of radiation.

Radiation in daily life

i. White or light colored cloths are good reflectors of heat. They keep us cool during summer.

ii. Base of cooking utensils is blackened because black surface absorbs more heat from the surrounding.

iii. Surface of airplane is highly polished because it helps to reflect most of the heat radiation from the sun.

Concept of temperature

- Temperature is the degree of hotness or coolness of a body. Hotter the body, higher is its temperature.

Unit of Temperature

- The SI unit of temperature is kelvin (K). For day to day applications, Celsius (°C) is used. Temperature is measured with a thermometer.

Temperature scales

There are three scales of temperature.

i. Fahrenheit scale

ii. Celsius or Centigrade scale

iii. Kelvin or Absolute scale

Fahrenheit scale

- In Fahrenheit scale, 32 °F and 212 °F are the freezing point and boiling point respectively. Interval has been divided into 180 parts.

- Celsius temperature scale

- In Celsius scale, also called centigrade scale, 0°C and 100 °C are the freezing point and boiling point respectively. Interval has been divided into 100 parts. The formula to convert a Celsius scale to Fahrenheit scale is:

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

The formula for converting a Fahrenheit scale to Celsius scale is:

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

Kelvin scale (Absolute scale)

- Kelvin scale is known as the absolute scale. On the Kelvin scale 0 K represents absolute zero, the temperature at which the molecules of a substance have their lowest possible energy. The solid, liquid, gaseous

- The temperature at which the pressure and volume of a gas theoretically reaches zero is called absolute zero. This is shown in Figure 7.7.

- For all gases, the pressure extrapolates to zero at the temperature –273.15 °C. It is known as absolute zero or 0 K. Some base linetemperatures in the three temperature scales are shown in Table.

Temperature	Kelvins (K)	DegreCelcius (°C)	Degrees Fahrenheit (°F)
Boiling point of water	373.15	100	212
Melting point of ice	273.15	0	32
Absolute zero	0	-273	-460

Change of state

- The process of changing of a substance from one physical state to another at a definite temperature is known as change of state. For example, water molecules are in liquid state at normal temperature. When water is heated to 100°C, it becomes steam which is a gaseous state of matter. On reducing the temperature of the steam it becomes water again. If we reduce the temperature further to 0 °C, it becomes ice which is a solid state of water. Ice on heating, becomes water again. Thus, water changes its state when there is a change in temperature. There are different such processes in the change of state in matter. Figure 7.8 shows various processes of change of state.

Melting – Freezing

- The process in which a solid is converted to liquid by absorbing heat is called melting or fusion. The temperature at which a solid changes its state to liquid is called melting point. The reverse of melting is freezing. The process in which a liquid is converted to solid by releasing heat is called freezing. The temperature at which a liquid changes its state to solid is called freezing point. In the case of water, melting and boiling occur at 0°C.

Boiling-Condensation

- The process in which a liquid is converted to vapor by absorbing heat is called boiling or vaporization. The temperature at which a liquid changes its state to gas is called boiling point. The process in which a vapor is converted to liquid by releasing heat is called condensation. The temperature at which vapour changes its state to liquid is called condensation point. Boiling point as well as condensation point of water is 100°C.

Sublimation

- Some solids like dry ice, iodine, frozen carbon dioxide and naphthalene balls change directly from solid state to gaseous state without becoming liquid. The process in which a solid is converted to gaseous state is called sublimation. Various stages of conversion of state of matter by heat with the corresponding change in temperature.

Latent heat

- The word, 'latent' means hidden. So, latent heat means hidden heat or hidden energy. In order to understand latent heat, let us do the activity given belowIn the above activity, temperature is constant at 0°C until entire ice is converted into liquid and again constant at 100°C until all the ice is converted into vapor. Why? It is because, when a substance changes from one state to another, a considerable amount of heat energy is absorbed or liberated. This energy is called latent heat. Thus, latent heat is the amount of heat energy absorbed or released by a substance during a change in its physical states without any change in its temperature.

- Heat energy is absorbed by the solid during melting and an equal amount of heat energy is liberated by the liquid during freezing, without any temperature change. It is called latent heat of fusion. In the same manner, heat energy is absorbed by a liquid during vaporization and an equal amount of heat energy is liberated by the vapor during condensation, without anytemperature changes. This is called latent heat of vaporization.

Specific latent heat

- Latent heat, when expressed per unit mass of a substance, is called specific latent heat. It is denoted by the symbol L. If Q is the amount of heat energy absorbed or liberated by 'm' mass of a substance during its change of phase at a constant temperature, then specific latent heat is given as $L = Q/m$.

- Thus, specific latent heat is the amount of heat energy absorbed or liberated by unit mass of a substance during change of state without causing any change in temperature. The SI unit of specific latent heat is J/kg.

10^th Standard

Unit 3. Thermal Physics

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.

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.

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:

  - **Linear expansion**
  - **Superficial expansion**
  - **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.

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

$$\Delta L / L_o = \alpha_L \Delta T$$

Δ L - Change in length (Final length- Original length)

Lo - Original length

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

αL - 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.

$$\Delta A / A_o = \alpha_A \Delta T$$

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

Ao- Original area

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

αA - 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.

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

$$\Delta V / V_o = \alpha_V \Delta T$$

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

Vo - Original volume

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

αV - Coefficient of cubical expansion.

- Different materials possess different coefficient of cubical expansion.The following table gives the coefficient of cubical expansion for some common materials.

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.

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 L1. Now, heat the container and the liquid using a burner.

- 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 L2.

- 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 L3. Now, the difference between the levels L1 and L3 is called as **apparent expansion,** and the difference between the levels L2 and L3 is called **real expansion**. The real expansion is always more than that of apparent expansion.

Real expansion = L3 – L2
Apparent expansion = L3 – L1

FUNDAMENTAL LAWS OF GASES

- The three fundamental laws which connect the relation between pressure, volume and temperature are as follows:
    - Boyle's Law
    - Charles's law
    - Avogadro's law

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.

$$P \propto 1/V$$

- 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 = constant

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 α T
or
V /T= constant

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.

i.e. V α n
(or) V/N= constant

- Avogadro's number (NA) is the total number of atoms per mole of the substance. It is equal to 6.023 × 1023 /mol.

GASES

- Gases are classified as real gases and ideal gases.

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.

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.

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,**

$$PV = constant \ (3.1)$$

According to Charles's law,

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

According to Avogadro's law,

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

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

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

- 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, NA.

i.e. $n = \mu NA$. (3.5)

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

$PV/ \mu NAT = constant$

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

$PV/ \mu NAT = kB$

$PV = \mu NAkB\ T$

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

8.31 J mol−1 K−1.

$PV = RT$ (3.6)

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

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 L1 = 50 ml
Level of the liquid L2 = 48.5 ml
Level of the liquid L3 = 51.2 ml

Apparent expansion = L3 − L1
= 51.2 ml – 50 ml = 1.2ml
Real expansion = L3 − L1
= 51.2 ml – 48.5ml = 2.7ml

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 (V1 cc) to V2 cc. Find the final volume V2.

Data:

Initial pressure (P1)= P
Final Pressure (P2) = 4P
Initial volume (V1) = 20cc = 20cm3
Final volume (V2) = ?

Using Boyle's Law, PV = constant

$$P1V1 = P2V2$$

$$P1 / P2 \times V2 = V1$$

$$= P/4P \times 20cm^3$$

$$\mathbf{V2 = 5\ cm^3}$$

UNIT 8: HEAT AND THERMODYNAMICS

Anomalous expansion of water:

- The volume of given amount of water decreases as it is cooled but up to 4°C. Below 4°C volume increases so density decreases. Water has maximum density at 4°C. this behaviour is called anomalous expansion of water.

- Since ice have lower density than water at 4°C the ice will float at top of water. As water freezes only at top, species in bottom of the lake will be safe.

Change of state:

- Latent heat capacity of substance is defined as the amount of heat energy required to change the state of unit mass of the material.
- When heat is added or removed during a change of state, the temperature remains constant.

- The triple point of substance is the temperature and pressure at which the three phases (gas, liquid and solid) of that substance coexist in thermodynamic equilibrium. The triple point of water is at 273.1 K at a partial vapour pressure of 611.657 Pascal.

Calorimetry:

- A sample is heated at high temperature (T_1) and immersed into water at room temperature (T_2) in the calorimeter. After some time both reach a final equilibrium temperature T_f.

$$\mathbf{T_f = \frac{m_1 s_1 T_1 + m_2 s_2 T_2}{m_1 s_1 + m_2 s_2}}$$

Here $s1$ and $s2$ specific heat capacity of hot sample and water respectively.

Newton's law of cooling:

- Newton's law of cooling states that the rate of loss of heat of a body is directly proportional to the difference in the temperature between that body and its surroundings.

$$\mathbf{\frac{dQ}{dt} \propto -(T - T_s)}$$

- The negative sign indicates that quantity of heat lost by liquid goes on decreasing with time. Where T= temperature of object T_s= temperature of surrounding

Laws of Heat transfer:

Prevost theory of heat exchange:

- Only at absolute zero temperature a body will stop emitting. Therefore Prevost theory states that all bodies emit thermal radiation at all temperatures above absolute zero irrespective of the nature of the surroundings. A body at high temperature radiates more heat to the surroundings than it receives from it.

Stefan Boltzmann Law:

- Stefan Boltzmann law states that, the total amount of heat radiated per second per unit area of a black body is directly proportional to the fourth power of its absolute temperature.

$$\boldsymbol{E = \sigma T^4}$$

Stefan constant, $\boldsymbol{\sigma = 5.67 \times 10^{-8}\ Wm^{-2}k^{-4}}$

If a body is not a perfect black body, then

$$\boldsymbol{E = e\sigma T^4}$$

- 'e' is emissivity of surface. Emissivity is defined as ratio of energy radiated from a material's surface to that radiated from a perfect black body at same temperature and wavelength.

Wien's displacement law:

- Wien's law states that, the wavelength of maximum intensity of emission of a black body radiation is inversely proportional to the absolute temperature of the black body.

$$\boldsymbol{\lambda_m = \frac{b}{T}}$$

Where Wien's constant, $b = 2.898 \times 10^{-3}\ m\ K$

- It implies that if temperature of the body increases, maximal intensity wavelength (λ_m) shift s towards lower wavelength (higher frequency) of electromagnetic spectrum.

- The Sun is approximately taken as a black body. Since any object above 0 K will emit radiation, Sun also emits radiation. Its surface temperature is about 5700K.

$$\lambda_m = \frac{b}{T} = \frac{2.898 \times 10^{-3}}{5700} \approx 508 \text{ nm}$$

- The humans evolved under the Sun by receiving its radiations. The human eye is sensitive only in the visible spectrum. Suppose if humans had evolved in a planet near the star Sirius (9940K), then they would have had the ability to see the Ultraviolet rays!

THERMODYNAMICS:

- A branch of physics which describes the laws governing the process of conversion of work into heat and conversion of heat into work is thermodynamics.

- A thermodynamic system is a finite part of the universe. It is a collection of large number of particles (atoms and molecules) specified by certain parameters called pressure (P), Volume (V) and Temperature (T). The remaining part of the universe is called surrounding.

Thermal equilibrium:

- Two systems are said to be in thermal equilibrium with each other if they are at the same temperature, which will not change with time.

- A system is said to be in mechanical equilibrium if no unbalanced force acts on the thermodynamic system or on the surrounding by thermodynamic system.

- There is no net chemical reaction between two thermodynamic systems in contact with each other then it is said to be in chemical equilibrium.

If two systems are set to be in thermodynamic equilibrium, then the systems are at thermal, mechanical and chemical equilibrium with each other. In a state of thermodynamic equilibrium the macroscopic variables such as pressure, volume and temperature will have fixed values and do not change with time.

Thermodynamic state variables:

- Heat and work are not state variables rather they are process variables.

- There are two types of thermodynamic variables: Extensive and Intensive

Extensive variable depends on the size or mass of the system.

Example: Volume, total mass, entropy, internal energy, heat capacity etc. Intensive variables do not depend on the size or mass of the system.

Example: Temperature, pressure, specific heat capacity, density etc.

- The equation which connects the state variables in a specific manner is called equation of state. A thermodynamic equilibrium is completely specified by these state variables by the equation of state.

ZEROTH LAW OF THERMODYNAMICS:

- The zeroth law of thermodynamics states that if two systems, A and B, are in thermal equilibrium with a third system, C, then A and B are in thermal equilibrium with each other.

Example: Temperature of the thermometer will be same as the human body. This principle is used in finding the body temperature.

INTERNAL ENERGY (U):

- The internal energy of a thermodynamic system is the sum of kinetic and potential energies of all the molecules of the system with respect to the centre of mass of the system. The energy due to molecular motion including translational, rotational and vibrational motion is called internal kinetic energy (E_K) The energy due to molecular interaction is called internal potential energy (E_P). Example: Bond energy.

$$U = E_K + E_P$$

- Since ideal gas molecules are assumed to have no interaction with each other the internal energy consists of only kinetic energy part (E_K) which depends on the temperature, number of particles and is independent of volume. However this is not true for real gases like Van der Waals gases.

- Internal energy is a state variable. It depends only on the initial and final states of the thermodynamic system and not the way it is arrived at.

- Internal energy of a thermodynamic system is associated with only the kinetic energy of the individual molecule due to its random motion and the potential energy of molecules which depends on their chemical nature.The bulk kinetic energy of the entire system or gravitational potential energy of the system should not be mistaken as a part of internal energy.

Heat does not always increase the internal energy.

Joule's Mechanical Equivalent of Heat:

- In the eighteenth century, Joule showed that mechanical energy can be on converted into internal energy and vice versa. In fact, Joule was able to show that the mechanical work has the same effect as giving heat. He found that to raise 1 g of an object by 1°C, 4.186 J of energy is required.

$$1\ cal = 4.186\ J$$

First Law of Thermodynamics:

- This law states that 'Change in internal energy (ΔU) of the system is equal to heat supplied to the system (Q) minus the work done by the system (W) on the surroundings'.

$$\Delta U = Q - W$$

System gains heat	Q is positive	Internal energy increase
System loses heat	Q is negative	Internal energy decreases
Work done on the system	W is negative	Internal energy increase
Work done by the system	W is positive	Internal energy decreases

- This law is applicable to solid, liquid and gases.

Quasi static process:

- A quasi-static process is an infinitely slow process in which the system changes its variables (P,V,T) so slowly such that it remains in thermal, mechanical and chemical equilibrium with its surroundings throughout.

Work Done in Volume changes:

$$W = \int_{V_i}^{V_f} PdV$$

- If work is done on the system $V_i > V_f$ and W is negative. The area under the PV diagram will give the work done during expansion or compression.

SPECIFIC HEAT CAPACITY OF A GAS:
Specific heat capacity at constant pressure (s_p):

- ❖ The amount of heat energy required to raise the temperature of one kg of a substance by 1 K or 1°C by keeping the pressure constant is called specific heat capacity of at constant pressure.

❖ In this process a part of the heat energy is used for doing work (expansion) and the remaining part is used to increase the internal energy of the gas.

Specific heat capacity at constant volume (s_v):

- The amount of heat energy required to raise the temperature of one kg of a substance by 1 K or 1°C by keeping the volume constant. If the volume is kept constant, then the supplied heat is used to increase only the internal energy. No work is done by the gas.

$\boldsymbol{s_p}$is always greater than $\boldsymbol{s_v}$.

- The amount of heat required to raise the temperature of one mole of a substance by 1K or 1°C at constant volume is called molar specific heat capacity at constant volume (Cv). If pressure is kept constant, it is called molar specific heat capacity at constant pressure (Cp).

$$C_v = \frac{1}{\mu}\frac{dU}{dT}$$

Meyer's Relation:

$$C_p - C_v = R$$

THERMODYNAMIC PROCESS

Isothermal process (constant temperature):

$$\Delta U = 0$$
$$Q = W$$

So, the heat supplied to a gas is used to do only external work.

Examples:

(i) When water is heated, at the boiling point, the temperature will not increase unless the water completely evaporates. Similarly, at the freezing point, when the ice melts to water, the temperature of ice will not increase even when heat is supplied to ice.

(ii) All biological processes occur at constant body temperature (37°C).

Adiabatic process:

- This is a process in which no heat flows into or out of the system (Q=0). But the gas can expand by spending its internal energy or gas can be compressed through some external work.

$$\Delta U = W$$

The adiabatic process can be achieved by the following methods

- ❖ Thermally insulating the system from surroundings.
- ❖ If the process occurs so quickly that there is no time to exchange heat with surroundings even though there is no thermal insulation.

Example: When the warm air rises from the surface of the Earth, it adiabatically expands. As a result the water vapour cools and condenses into water droplets forming a cloud.

$$PV^{\gamma} = constant$$

Hereγ is adiabatic exponent and $\gamma = {C_p}/{C_v}$ which depends on nature of gas.

- The PV diagram for an adiabatic process is also called *adiabat.* The PV diagram for isothermal and adiabatic processes look similar. But the adiabatic curve is steeper than isothermal curve.

$$TV^{\gamma-1} = constant$$
$$T^{\gamma}P^{1-\gamma} = constant$$

Work done in adiabatic process,

$$W_{adia} = \frac{\mu R}{\gamma - 1}[T_i - T_f]$$

- ❖ In adiabatic expansion, work done is positive and $T_i > T_f$ and gas cools.
- ❖ In adiabatic compression, work done is negative and $T_i < T_f$ and temperature of gas increases.

Isobaric Process (constant pressure):

Examples for Isobaric process:

- ❖ When the gas is heated and pushes the piston so that it exerts a force equivalent to atmospheric pressure plus the force due to gravity.

- ❖ When the food is cooked in an open vessel, the pressure above the food is always at atmospheric pressure.

Work done in an isobaric process,

$$W = P\Delta V = \mu R T_f \left(1 - \frac{T_i}{T_f}\right)$$

$$\Delta U = Q - P\Delta V$$

Isochoric Process (constant volume):

$$\Delta V = 0 \text{ and } W = 0. \text{ So,} \qquad \Delta U = Q$$

Examples:

- When food is being cooked in closed position, after a certain time you can observe the lid is being pushed upwards by the water steam. This is because when the lid is closed, the volume is kept constant. As the heat continuously supplied, the pressure increases and water steam tries to push the lid upwards

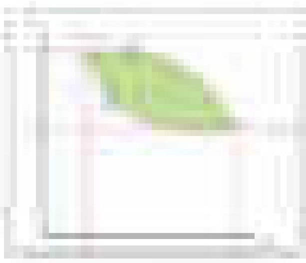
- In automobiles the petrol engine undergoes four processes. First the piston is adiabatically compressed to some volume as shown in the Figure (a). In the second process (Figure (b)), the volume of the air-fuel mixture is kept constant and heat is being added. As a result the temperature and pressure are increased. This is an isochoric process. For a third stroke (Figure (c)) there will be an adiabatic expansion, and fourth stroke again isochoric process by keeping the piston immoveable (Figure (d)).

Cyclic process:

- The thermodynamic system returns to its initial state after undergoing a series of changes. The change in the internal energy is zero. From the first law of thermodynamics, the net heat transferred to the system is equal to work done by the gas.

$$Q_{net} = Q_{in} - Q_{out} = W$$

PV diagram for cyclic process:



- The total work done is green shaded area in the figure. If the net work done is positive, then work done by the system is greater than the work done on the system. If the net work done is negative then the work done by the system is less than the work done on the system.

- Further, in a cyclic process the net work done is positive if the process goes clockwise and network done is negative if the process goes anti-clockwise.

Limitations of First Law of Thermodynamics:

- The first law of thermodynamics explains well the inter convertibility of heat and work. But it does not indicate the direction of change.

For example,

  - ❖ According to first law, it is possible for the energy to flow from hot object to cold object or from cold object to hot object. But in nature the direction of heat flow is always from higher temperature to lower temperature
  - ❖ Heat produced against friction is not reconverted to the kinetic energy of the car.

Reversible Process:

- A thermodynamic process can be considered reversible only if it possible to retrace the path in the opposite direction in such a way that the system and surroundings pass through the same states as in the initial, direct process.

Example: A quasi–static isothermal expansion of gas, slow compression and expansion of a spring. Conditions for reversible process:

1. The process should proceed at an extremely slow rate.

2. The system should remain in mechanical, thermal and chemical equilibrium state at all the times with the surroundings, during the process.

3. No dissipative forces such as friction, viscosity, electrical resistance should be present.

Irreversible process:

- All natural processes are irreversible. Irreversible process cannot be plotted in PV diagram.

- According to second law of thermodynamics "Heat always flows from hotter object to colder object spontaneously". This is known as the Clausius form of second law of thermodynamics.

Process		Heat Q	Temperature & internal	Pressure	Volume	Equation of state	Work done (ideal gas)
Isothermal	Expansion	$Q > 0$	Constant	Decrea	Increas	$PV = constant$	$W = \mu RT\ ln\left(\frac{V_f}{V_i}\right) > 0$
	Compressi	• $Q < 0$	Constant	Increas	Decrea		$W = \mu RT\ ln\left(\frac{V_f}{V_i}\right) < 0$
Isobaric	Expansion	$Q > 0$	Increases	Consta	Increas	$\frac{V}{T} = constant$	$W = P[V_f - V_i] = P\Delta V$
	Compressi	$Q < 0$	Decrease	Consta	Decrea		$W = P[V_f - V_i] = P\Delta V$
Isochoric	Expansion	$Q > 0$	Increase	Increas	Consta	$\frac{P}{T} = constant$	Zero
	Compressi	$Q < 0$	Decrease	Decrea	Consta		
Adiabatic	Expansion	$Q = 0$	Decrease	Decrea	Increas	$PV^{\gamma} = constant$	$W_{adia} = \frac{\mu R}{\gamma - 1}[T_i - T_f] > 0$
	Compressi	$Q = 0$	Increase	Increas	Decrea		$W_{adia} = \frac{\mu R}{\gamma - 1}[T_i - T_f] < 0$

HEAT ENGINE:

❖ Heat engine is a device which takes heat as input and converts this heat in to work by undergoing a cyclic process.

- A heat engine has three parts:

(a) Hot reservoir (or) Source: It is maintained at a high temperature T_H

(b) Working substance

- It is a substance like gas or water, which converts the heat supplied into work.
- The working substance in steam engine is water which absorbs heat from the burning of coal. The heat converts the water into steam.
- This steam is does work by rotating the wheels.(c) Cold reservoir (or) Sink: It is maintained at lower temperature T_L

Reservoir:

- It is defined as a thermodynamic system which has very large heat capacity. By taking in heat from reservoir or giving heat to reservoir, the reservoir's temperature does not change.

- The heat engine works in a cyclic process. After a cyclic process it returns to the same state. Since the heat engine returns to the same state after it ejects heat, the change in the internal energy of the heat engine is zero.

$$efficiency, \eta = \frac{output}{input} = \frac{W}{Q_H} = \frac{Q_H - Q_L}{Q_H} = 1 - \frac{Q_L}{Q_H}$$

- Since $QL < QH$, the efficiency (η) always less than 1. This implies that heat absorbed is not completely converted into work.

Kelvin-Planck statement:

It is impossible to construct a heat engine that operates in a cycle, whose sole effect is to convert the heat completely into work. This implies that no heat engine in the universe can have 100% efficiency.

Carnot's ideal Heat Engine:

- A reversible heat engine operating in a cycle between two temperatures in a particular way is called a Carnot Engine.

- The carnot engine has four parts.

i Source: It is at T_H. Any amount of heat can be extracted, without changing temperature.

ii Sink: It is maintained at T_L. It can absorb any amount of heat.

iii Insulating stand: It is made of perfectly non-conducting material.

iv Working substance: It is an ideal gas enclosed in a cylinder with perfectly non-conducting walls and perfectly conducting bottom. A non-conducting and frictionless piston is fitted in it.

The working substance is subjected to four successive reversible processes forming what is called Carnot's cycle.

a) Quasi-static Isothermal Expansion
b) Quasi- static Adiabatic Expansion
c) Quasi-static Isothermal compression
d) Quasi-static Adiabatic Compression

- After one cycle the working substance returns to the initial temperature TH. This implies that the change in internal energy of the working substance after one cycle is zero.

Efficiency of Carnot Engine:

$$\text{efficiency}, \eta = 1 - \frac{T_L}{T_H}$$

a) It can be 100% only when $T_L = 0\ K$ which is impossible.

b) Efficiency is independent of working substance.

c) When $T_L = T_H, \eta = 0.$ No carnot engine can have source and sink at same temperature.

d) Carnot theorem is stated as 'Between two constant temperatures reservoirs, only Carnot engine can have maximum efficiency. All real heat engines will have efficiency less than the Carnot engine'

e) The efficiency depends on the ratio of the two temperature and not on the difference in the temperature. The engine which operates in lower temperature has highest efficiency.

Entropy and second law of thermodynamics:

$$\textbf{entropy} = \frac{\mathbf{Q}}{\mathbf{T}}$$

- Change in entropy of Carnot Engine in one cycle is zero. "For all the processes that occur in nature (irreversible process), the entropy always increases. For reversible process entropy will not change".
- Entropy determines the direction in which natural process should occur.
- Entropy is also called 'measure of disorder'. All natural process occur such that the disorder should always increases.
- **Example:**a drop of ink diffusing in water.

Refrigerator:

- A refrigerator is a Carnot's engine working in the reverse order.

- The working substance (gas) absorbs quantity of heat $Q_L$from cold body (sink) at lower temperature T_L. A certain amount of work W is done on the working substance by the compressor and a quantity of heat $Q_H$is ejected to the hot body (source) i.e., atmosphere at T_H.

$$Q_L + W = Q_H$$

As a result, cold reservoir gets further cooled down and surroundings are heated more.

$$\text{coefficient of performance, COP} = \beta = \frac{Q_L}{W} = \frac{Q_L}{Q_H - Q_L} = \frac{T_L}{T_H - T_L}$$

1. The greater the COP, the better is the condition. A refrigerator has COP around 5 to 6.

2. Lesser the difference in the temperatures of the cooling chamber and the atmosphere, higher is the COP of a refrigerator.

3. In the refrigerator the heat is taken from cold object to hot object by doing external work. It is not a violation of second law of thermodynamics, because the heat is ejected to surrounding air and total entropy of (refrigerator + surrounding) is always increased.

Greenhouse effect:

- Top of the atmosphere is at -19°C and bottom of the atmosphere is at +14°C. The increase in 33°C from top to bottom is due to Greenhouse gases and this effect is called Greenhouse effect.

- The greenhouse gases are mainly CO_2, water vapour, Ne, He, NO_2,

- CH4, Xe, Kr, ozone and NH3. Except CO2 and water vapour, all others are present only in very small amount in the atmosphere. The radiation from the Sun is mainly in the visible region of the spectrum. The earth absorbs these radiations and reradiate in the infrared region. Carbon dioxide and water Vapour are good absorbers of infrared radiation since they have more vibrational degree of freedom compared to nitrogen and oxygen which keeps earth warmer.

- The amount of CO2 present in the atmosphere is increased from 20% to 40% due to human activities since 1900s. The major emission of CO2 comes from burning of fossil fuels in automobiles. Due to this increase in the CO2 content in the atmosphere, the average temperature of the earth increases by 1°C. This effect is called global warming. It has serious influence and alarming effect on ice glaciers. In addition, the CO_2 content is also increasing in ocean which is very dangerous to species in the oceans.

- Another very important greenhouse gas is Chloroflouro carbon(CFC) which is used as coolant in refrigerators. In the human made greenhouse gases CO2 is 55%, CFCs are 24%. Nitrogen oxide is 6% and methane is 15%. CFCs also has made huge damage to ozone layer.

Light

Unit - 1. Light

Do You Know?

Light is the only source of energy for plants. So, they entirely depend on light. People and animals derive energy from carbohydrates, protein and fat through their food. Plants produce food using the energy from Sun light, carbon-di-oxide and water by the process called as Photosynthesis. Sun light acts a vital role in the process of photosynthesis.

Sources of Light.

Objects which are able to emit light are known as light sources. Light rays can come from different sources. There are two types of sources of light.

1. Natural sources of light
2. Artificial sources of light

Natural Sources of light

Sources which emit light naturally are known as natural sources of light. The Sun is theprimary and the major source of natural light. Stars also produce light, in the same way as the Sun do. However, as they are much farther away than the Sun, the light from them are too weak. The moon provides light, particularly in the night. Some living organisms have the ability to produce light named by bioluminescence. It is the effect of certain chemical reactions occurring in the organism. Fireflies, jellyfish, glow worm, certain deep sea plants and some microorganisms can emit light naturally.

Artificial Sources of light

Apart from the natural sources, light can also be produced artificially. The different light sources that are able to produce light artificially can be put under three broad categories.

Do You Know?

Is the moon a luminous object?

The moon provides light as well, but it cannot produce light by its own. The light emitted by the Moon is the light of the Sun reflected towards the Earth. When we see the Moon, we see only the Moon's lighted part. Thus, half of the moon is always facing the Sun and receiving light from it. Hence, we receive light from the moon.

Artificial sources are man – made light sources such as flame of candle, incandescent lamp, neon lamp, Sodium lamp etc.

1. Incandescent Sources: When certain objects are heated to a high temperature, they begin to emit light. The glowing of hot iron rod is a kind of Incandescent light.

Example: Candle, incandescent lamp.

2. Gas Discharge Sources: Passing electricity through certain gases at a very low pressure (discharging) can produce light .

Example: Neon lamp, Sodium lamp

Do You Know?
We often use a kind of gas discharge lamp that uses fluorescence to produce visible light. The electric current in the gas excites mercury vapour, which produces short-wave ultraviolet light that then causes a phosphor coating on the inside of the lamp to glow in visible light.

Properties of light

In this section, we shall examine some properties of light. Light has some fundamental properties as mentioned below

- **Rectilinear propagation of light**
- **Reflection**
- **Speed**
- **Interaction of light with matter**
  - **Types of material according to permeability**
  - **Formation of shadows**
  - **Plane mirror and images**
- **Spectrum**

The path of light
How does light travel?

• Have you ever seen the scene of light penetrating through the branches of trees in denser forest?
• Have you ever seen the path of sun light entering through the hole of a cement grilbuilding?
• Have you ever seen the path of a laser light?

Pinhole Camera

Pin hole camera is a simple device which helps us to understand about the rectilinear propagation of light

The above picture shows a model of a pin– hole camera. O is small hole by a pin. XY is the object and Y'X' is the image of XY. As light travels in straight line, one light ray from X travels along the XO strikes the screen X'.

In similar way, another light ray staringfrom Y and travels along YO strikes the screen Y'. Similarly, all the rays in between X and Y fall on the screen between Y' and X'. Thus Y'X' becomes the image of XY. The image produced is temporary, if a simple paper is used. The image can be made permanent if the paper is replaced by a photographic plate.

Reflection

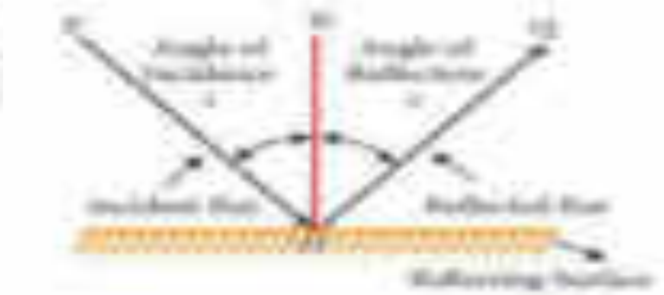
A mirror reflects our face. A still water body like a pond reflects the scenery around it. When we see our face in the mirror, we see the light rays from our face bouncing off the surface of the mirror. How therays of the light are reflected?

Take a plane mirror. Cover it with black paper. Cut a small slit as shown in the figure. Ifyou shine light on the mirror from a torch lightor sunlight, you will get a small ray of light. We can use this to study the properties of light.

Place a blank white sheet on a level ground out in the open. Choose a place where partly the sheet gets sunlight and partly it is in shadow. Hold the mirror with the slit facing the sun. You can see a straight ray of light reflected from the slit on the paper. Hold another mirror to reflect this ray. Observe well.

The light falling on the mirror is called as incident ray and the light reflected is called reflected ray.

Terms used in reflection of light.



Incident ray: The ray of light that falls on thesurface of the reflection materials. In figure, PO is the incident ray.

Reflected ray: The ray of light that comes from the point when the incident ray falls on the reflection material. In the figure, OQ is the reflected ray.

Point of incidence: The point of which are incident ray strikes the reflecting surface is the point of incidence. In the figure ‘O’ point of incidence.

Normal: The perpendicular line drawn from the point of incidence to the plane of reflecting surface is called normal. In figure, ON is the normal.

Angle of incidence: The angle formed between the incident ray PO and the normal 'ON' is angle of incidence. It is denoted by I Angle of reflection: The angle formed between the reflected ray OQ and the normal ON is angle of reflection. It is denoted by i

Laws of reflection:

1. The angle of incidence is always equal to the angle of reflection. i = r
2. The incident ray, the reflected ray and the normal at the point of incidence lie on the same plane.

Speed of light:

When lighting a bulb in a dark room, light spreads the whole room quickly. This is because the light travels very fast. Light travels three lakh kilometersper second in air or vacuum. In theory, nothing can travel faster than light

Interaction of light with matter

Take a piece of clear glass, a paper and a metal sheet. Shine a light from one side of each object and see if the light penetrate on the other side. Readily, we can see light enters and comesout of the other end of clear glass, whereas thelight is bit dim through a paper. Light does not pass through metal sheet. Depending upon permeability, materials can be classified into three categories.

Transparent Material:

Materials that allow light to pass through completely are known as transparent material.

Example: Eye glasses, clear drinking glass, clear water, face glasses used in buses.

Translucent Material:

Objects that allow light to pass through partially are called translucent material. For example, we cannot see the image of someone who stands behind a rough window glass, because it allows only a part of light from the person.

Shadows
How are shadows formed?

As we saw earlier, light is obstructed by certain materials. Light travels in a straight line. Hence it cannot go around such objects. That is why we see shadow. Shadow is always against, opposite side of light source. It is caused by opaque objects that stop light from propagating.

Parts of shadow

When an opaque object is placed in the path of light from a point source, a uniform dark shadow will appear on the screen. This is shadow

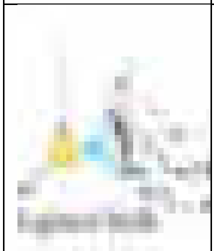
Opaque Material:

Materials that are not able to allow light to pass through, are called opaque material.

Example: Wall, thick card board, stone, etc. is called as umbra. When an opaque object isplaced in the path of light coming from a broad source of light, a small umbra will appear on the screen and an illuminated shadow area appears around umbra. This illuminated shadow area is called as penumbra. The penumbra always surrounds the umbra. The umbra is the darkest part of a shadow. In this part, light rays are completely prevented by the opaque object. The lighter shade of shadow is the penumbra.

Properties of shadow

1. All objects do not form shadows. Only opaque objects form shadows
2. Shadows will be formed in the opposite side of light source
3. It cannot be determined the characteristics of an object by its shadow.
4. The shadow will be always darker, whatever may be the color of light rays
5. Light source, opaque object are shadow all are in a straight line.
6. The size of shadow depends upon the distance between light source and object and the distance between object and the screen.

Arrangement	Activity	Observation	You Learn
	Place a lighter bulb in front of are rectangular card board with a hole at the center	A shadow with a spot light appears in the screen.	Light rays are passing only through the hole and are not allowed by the remaining part of card board
	Place a pencil in the path of light ray coming from a bulb	A shadow of pencil appears in the screen	The size of the shadow is proportional to the size of the opaque objects.

Eclipses

An eclipse is an incident, when any astronomical object is partially or fully obscured due to the placement of another astronomical object in the presence of light. Thus, solar and lunar eclipses are occurring that are due to the property of light known as the rectilinear propagation of light.

Solar eclipse

Solar eclipse occurs, when the moon arrives between the sun (S) and the earth(E). The shadow of the moon appears on the earth at A as shown in picture. Hence, those who are at the region A are unable to see the Sun instantly. This is solar eclipse. But, those who are at the region B and C are able to see the sun partially

Lunar eclipse

Lunar eclipse: Lunar eclipse occurs, when the earth (E) comes between the sun (S) and the moon (M). The earth prevents light coming from the sun and makes shadow on the moon. This is lunar eclipse

Plane Mirror and Reflection

A polished (or) smooth surface (like glass) which forms image by reflection is known as mirror. A plane mirror is a mirror with a flat reflective surface. A plane mirror makes an Image of objects in front of it.

Real and virtual images

We have seen images being formed in a pinhole camera and a mirror. Can we see what is different in both of these images? Firstly, the image of the pinhole camera was formed on a screen.While the image made by the mirror is not obtained on a screen. The images that are obtained on a screen are called 'real image' and that which cannot be obtained on a screen 'virtual image'. Also notice that the image on pinhole camera was upside down. While the mirror image was upright.

Properties of Image formed in a plane mirror
Image formed in a plane mirror is upright
Image formed in a plane mirror is virtual
The image is of the same size as the object
The distance of the image from the planemirror is equal to the distance of the object from the mirror
Image is laterally inverted.

Colour

Colour of sunlight : Light is a form ofenergy in the form of a wave that simulates that retina of our eyes. Visible light is a spectrum of a number of waves with different wavelength range from 400nm to 700nm (1nm = 10-9 metre) each wave has a definite wavelength represents a particular color. The band of visible light is VIBGYOR.

V - Violet
I - Indigo
B - Blue
G - Green
Y - Yellow
O - Orange
R – Red

Violet colour has shorter wavelength and red color has longer wavelength.

When light ray of particular wavelength(Colour) strikes the retina of our eye, our brainperceives that specific colour. When all colors of visible light strikes the retina of our eye at the same time, our brain perceives white. Th is shows, white is not a colour at all. But, it is the combination of all the colors of the visible light spectrum. If all the wavelength (colours) of visible light spectrum give appearance of white similarly, the observe of all there wavelength of visible light, will lead appearance of black

What is prism?

A prism is an object made up of a transparent material, like glass or plastic that has at least two flat surfaces that from an acute angle (less than 90O degrees).

Difference between the images formed in Pinhole camera and Plane mirror	
Images formed by hole camera	**Images formed in Plane mirror**
The image is real	The image is virtual
The image may not be equal to the size of the object	The image is equal to the size of the object
The image is inverted	The image is erect

Do you Know?

Why danger lights in vehicles are red in colour?

1. Red color is scattered the least by air molecules.
2. Red color has the highest wavelength of all the other colors. So red color is able to travel the longest distance through air, fog.

When white light is passed through a prismas shown in the figure, the colors of the rainbow emerge from the prism.

Newton Disc:

Newton suggested a process of mixing different colors to make white color by setting an arrangement as shown figure below. Newton Disc is a card board disc with seven equal sectorscolored red, yellow,orange, green, blue, indigo and violet. When the disc turned quickly, the retina receives the sensation of the spectrum simultaneously and disc appears white. Using this disc, one can explain that white is a combination of VIBGYOR

We know that white shirt will reflect white light and we have seen that white light consists of different colours. When we look at the white shirt through the yellow gelatin paper, we seeit as yellow in color. From this, we can say thatthe yellow gelatin paper did not allow any other color except yellow to pass through. Similarly, we conclude that red gelatin paper allows only red light and blue gelatin paper allows only the blue light.

Synthesis of colour

Synthesis of colour is the method of creating colour by mixing various proportion of two (or) three distinct colours of light. These distinct colours are Red, Green and Blue called as primary colours.

• Equal proportions of two primary colourcreate a secondary color.
• Magenta, Cyan and yellow are called secondary colour.
•Equal proportions of all three primary colour create white.

8^{th} term 1 Unit - 3. Light

Types of Mirrors

We use mirrors in our daily life for various purposes. We use them for decoration. In vehicles, they are used as rear view mirrors. They are also used in scientific apparatus, like telescope. The mirror is an optical device with a polished surface that reflects the light falling on it. A typical mirror is a glass sheet coated with aluminium or silver on one of its sides to produce an image. Mirrors have a plane or curved surface. Curved mirrors have surfaces that are spherical, cylindrical, parabolic and ellipsoid. The shape of a mirror determines the type of image it forms. Plane mirrors form the perfect image of an object. Whereas, curved mirrors produce images that are either enlarged or diminished. You would have studied about plane mirrors in your lower classes. In this section, you will study about spherical and parabolic mirrors.

Do You Know?

Method of coating a glass plate **with a thin layer of reflecting metals was in practice during the 16th century in Venice, Italy. They used an amalgam of tin and mercury for this purpose. Nowadays, a thin layer of molten aluminium or silver is used for coating glass plates that will then become mirrors.**

Spherical mirrors

Spherical mirrors are one form of curved mirrors. If the curved mirror is a part of a sphere, then it is called a 'spherical mirror'. It resembles the shape of a piece cut out from a spherical surface. One side of this mirror is silvered and the reflection of light occurs at the other side.

Figure 3.1 Spherical mirror

Concave mirrors

A spherical mirror, in which the reflection of light occurs at its concave surface, is called a concave mirror. These mirrors magnify theobject placed close to them. The most common example of a concave mirror is the make-up mirror.

Convex mirror

A spherical mirror, in which the reflection of light occurs at its convex surface, is called a convex mirror. The image formed by these mirrors is smaller than the object. Most common convex mirrors are rear viewing mirrors used in vehicles.

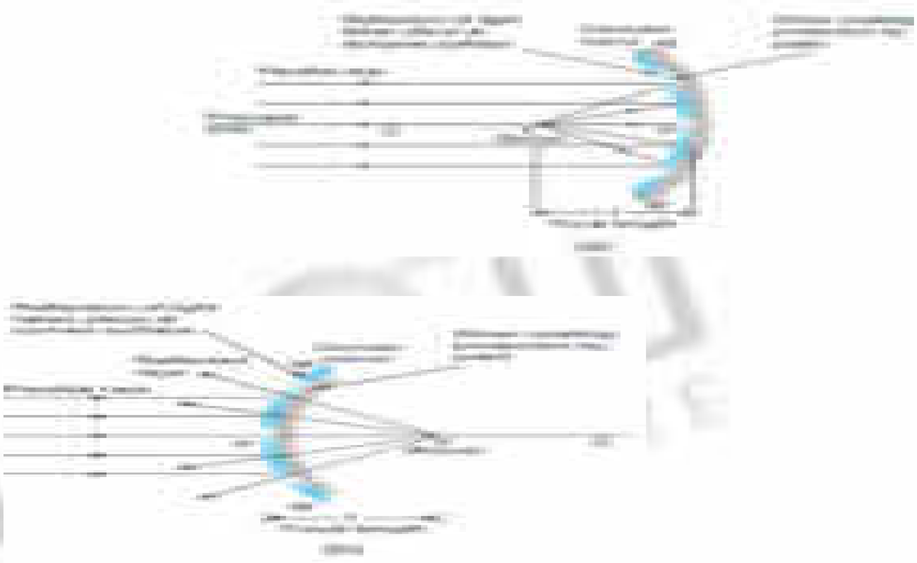


Figure 3.2 Concave and Convex mirrors

Do You Know?
Convex mirrors used in vehicles as rear-view mirrors are labeled with the safety warning: 'Objects in the mirror are closer than they appear' to warn the drivers. This is because inside the mirrors, vehicles will appear to be coming at a long distance.

Parabolic mirrors

A parabolic mirror is one type of curved mirror, which is in the shape of a parabola. It has a concave reflecting surface and this surface directs the entire incident beam of light to converge at its focal point.

In the same way, light rays generated by the source placed at this focal point will fall on this surface and they will be diverged in a direction, which is parallel to the principal axis of the parabolic mirror. Hence, the light rays will be reflected to travel a long distance, without getting diminished.

Parabolic mirrors, also known as parabolic reflectors, are used to collect or project energy such as light, heat, sound and radio waves. They are used in reflecting telescopes, radio telescopes and parabolic microphones. They are also used in solar cookers and solar water heaters.

Do You Know?

The principle behind the working of a parabolic mirror has been known since the Greco-Roman times. The first mention of these structures was found in the book, 'On Burning Mirrors', written by the mathematician Diocles. They were also studied in the 10th century, by a physicist called IbnSahl. The first parabolic mirrors were constructed by Heinrich Hertz, a German physicist, in the form of reflector antennae in the year 1888.

TERMS RELATED TO SPHERICAL MIRRORS

In order to understand the image formation in spherical mirrors, you need to know about some of the terms related to them.

Center of Curvature: It is the center of the sphere from which the mirror is made. It is denoted by the letter C in the ray diagrams. (A ray diagram represents the formation of an image by the spherical mirror. You will study about them in your next class).

Pole: It is the geometric centre of the spherical mirror. It is denoted by the letter P. Radius of Curvature: It is the distance between the center of the sphere and the vertex. It is shown by the letter R in ray diagrams. (The vertex is the point on the mirror's surface where the principal axis meets the mirror. It is also called as 'pole'.)

Principal Axis: The line joining the pole of the mirror and its center of curvature is called principal axis.

Focus: When a beam of light is incident on a spherical mirror, the reflected rays converge (concave mirror) at or appear to diverge from (convex mirror) a point on the principal axis. This point is called the 'focus' or 'principal focus'. It is also known as the focal point. It is denoted by the letter F in ray diagrams.

Focal length: The distance between the pole and the principal focus is called focal length (f) of a spherical mirror. There is a relation between the focal length of a spherical mirror and its radius of curvature. The focal length is half of the radius of curvature.

That is, focal length= $\frac{Radiusofcurvature}{2}$

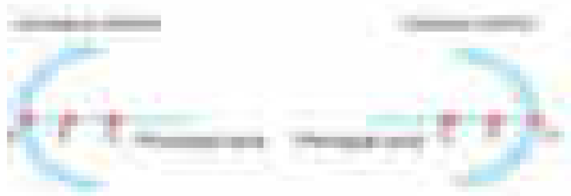


Figure 3.4 Terms related to spherical mirror

PROBLEM 1
The radius of curvature of a spherical mirror is 20cm. Find its focal length
Solution:
Radius of curvature =20cm
Focal length (f0 = $\frac{Radiusofcurvature}{2}$
= $\frac{R}{2}$ = $\frac{20}{2}$ =10cm

PROBLEM 2
Focal length of a spherical mirror is 7 cm. What is its radius of curvature?
Solution:
Focal length = 7 cm
Radius of curvature (R) = 2 × focal length = 2 × 7 = 14 cm

IMAGES FORMED BY SPHERICAL MIRRORS

Images formed by spherical mirrors are of two types: i) real image and ii) virtual image. Real images can be formed on a screen, while virtual images cannot be formed on a screen. Image formed by a convex mirror is always erect, virtual and diminished in size. As a result, images formed by these mirrors cannot be projected on a screen.

The characteristics of an image are determined by the location of the object. As the object gets closer to a concave mirror, the image gets larger, until attaining approximately the size of the object, when it reaches the centre of curvature of the mirror. As the object moves away, the image diminishes in size and gets gradually closer to the focus, until it is reduced to a point at the focus when the object is at an infinite distance from the mirror.

The size and nature of the image formed by a convex mirror is given

Image formed by a convex mirror

Position Of The Object	Position Of The Image	Image Size	Nature Of The Image
At infinity	At F	Highly diminished, point sized	Virtual and erect
Between infinity the pole (P)	Between P and F	Diminished	Virtual erect

Concave mirrors form a real image and it can be caught on a screen. Unlike convex mirrors, concave mirrors show different image types. Depending on the position of the object in front of the mirror, the position, size and nature of the image will vary. Table 3.2 provides a summary of images formed by a concave mirror.

Table 3.2 Image formed by a concave mirror

POSITION OF THE OBJECT	POSITIOIN OF THE IMAGE	IMAGE SIZE	NATURE OF THE IMAGE
At infinity	At F	Highly diminished	Real and inverted
Beyond C	Between C and F	Diminished	Real and inverted
At C	At C	Same size as the object	Real and inverted
Between C and F	Beyond C	Magnified	Real and inverted
At F	At infinity	Highly magnified	Real and inverted
Between F and P	Behind the mirror	Magnified	Virtual and erect

You can observe from the table that a concave mirror always forms a real and inverted image except when the object is placed between the focus and the pole of the mirror. In this position, it forms a virtual and erect image.

Application of curved Mirrors
Concave mirrors

1. **Concave mirrors are used while applying make-up or shaving, as they provide a magnified image.**
2. **They are used in torches, search lights and head lights as they direct the light to a long distance.**
3. **They can collect the light from a larger area and focus it into a small spot. Hence, they are used in solar cookers.**
4. **They are used as head mirrors by doctors to examine the eye, ear and throat as they provide a shadow-free illumination of the organ.**
5. **They are also used in reflecting telescopes. Figure 3.3 Concave mirrors**

Convex mirrors

- **Convex mirrors are used in vehicles as rear view mirrors because they give an upright image and provide a wider field of view as they are curved outwards.**
- **They are found in the hallways of various buildings including hospitals, hotels, schools and stores. They are usually mounted on a wall or ceiling where hallways make sharp turns.**
- **They are also used on roads where there are sharp curves and turns.**

Not all the objects can produce the same effect as produced by the plane mirror. A ray oflight, falling on a body having a shiny, polished and smooth surface alone is bounced back. This bouncing back of the light rays as they fall on the smooth, shiny and polished surface is called reflection.

Reflection involves two rays: i) incident ray and ii) reflected ray. The incident ray is the light ray in a medium falling on the shiny surface of a reflecting body. After falling on the surface, this ray returns into the same medium. This ray is called the reflected ray. An imaginary line perpendicular to the reflecting surface, at the point of incidence of the light ray, is called the normal.

The relation between the incident ray, the reflected ray and the normal is given as the law of reflection. The laws of reflection are as follows:

- The incident ray, the reflected ray and the normal at the point of incidence, all lie in the same plane.
- The angle of incidence and the angle of reflection are always equal.

Figure 3.7Reflection of light

Do You Know?
Silver metal is the best reflector of light. That's why a thin layer of silver is deposited on the side of materials like plane glass sheets, to make mirrors.

TYPES OF REFLECTION

You have learnt that not all bodies can reflect light rays. Th e amount of reflection depends on the nature of the reflecting surface of a body. Based on the nature of the surface, reflection can be classified into two types namely, i) regular reflection and ii) irregular reflection.

Regular reflection

When a beam of light (collection of parallel rays) falls on a smooth surface, it gets reflected. After reflection, the reflected rays will be parallel to each other. Here, the angle of incidence and the angle of reflection of each ray will be equal. Hence, the law of reflection is obeyed in this case and thus a clear image is formed. This reflection is called 'regular reflection' or 'specular reflection'. Example: Reflection of light by a plane mirror and reflection of light from the surface of still water.

Irregular reflection

In the case of a body having a rough or irregular surface, each region of the surface is inclined at different angles. When light falls on such a surface, the light rays are reflected at different angles. In this case, the angle of incidence and the angle of reflection of each ray are not equal. Hence, the law of reflection is not obeyed in this case and thus the image is not clear. Such a reflection is called 'irregular reflection' or 'diff used reflection'. Example: Reflection of light from a wall.

MULTIPLE REFLECTIONS

You can see three images. How is it possible to have three images with two mirrors? In the activity given above, you observed that for a body kept in between two plane mirrors, which were inclined to each other, you could see many images. This is because, the ‘image’ formed by one mirror acts as an ‘object’ for the other mirror. The image formed by the first mirror acts as an object for the second mirror and the image formed by the second mirror acts as an object for the first mirror. Th us, we have three images of a single body. This is known as multiple reflection. This type of reflections can be seen in show rooms and saloons.

The number of images formed, depends on the angle of inclination of the mirrors. If the angle between the two mirrors is a factor of 360°, then the total number of reflections is finite. If θ (Theta) is the angle of inclination of the plane mirrors, the number of images formed $=\frac{360}{0}$-1. As you decrease this angle, the number of images formed increases. When they are parallel to each other, the number of images formed becomes infinite.

Problem.3
If two plane mirrors are inclined to each other at an angle of 90°, find the number of images formed.
Solution:
Angle of inclination = 90°
Number of images formed =
$\frac{360^0}{\theta} - \frac{360^o}{90^o}$ **– 1 = – 1 = 4 -1 = 3**

Kaleidoscope

It is a device, which functions on the principle of multiple reflection of light, to produce numerous patterns of images. It has two or more mirrors inclined with each other. It can be designed from inexpensive materials and the colourful image patterns formed by this will be pleasing to you. This instrument is used as a toy for children.

Periscope

It is an instrument used for viewing bodies or ships, which are over and around another body or a submarine. It is based on the principle of the law of reflection of light. It consists of a long outer case and inside this case mirrors or prisms are kept at each end, inclined at an angle of 45°. Light coming from the distant body, falls on the mirror at the top end of the periscope and gets reflected vertically downward. This light is reflected again by the second mirror kept at the bottom, so as to travel horizontally and reach the eye of the observer. In some complex periscopes, opticfibre is used instead of mirrors for obtaining a higher resolution. Th e distance between the mirrors also varies depending on the purpose of using the periscope.

Uses

• It is used in warfare and navigation of the submarine.
• In military it is used for pointing and firing guns from a 'bunker'. • Photographs of important places can be taken through periscopes without trespassing restricted military regions.
• Fibre optic periscopes are used by doctors as endoscopes to view internal organs of the body.

REFRACTION OF LIGHT

We know that when a light ray falls on a polished surface placed in air, it is reflected into the air itself. When it falls on a transparent material, it is not reflected completely, but a part of it is reflected and a part of it is absorbed and most of the light passes through it. Th rough air, light travels with a speed of 3 x10^8 m s-1, but it cannot travel with the same speed in water or glass, because, optically denser medium such as water and glass offer some resistance to the light rays.

So, light rays travelling from a rarer medium like air into a denser medium like glass or water are deviated from their straight line path. Th is bending of light about the normal, at the point of incidence; as it passes from one transparent medium to another is called refraction of light.

When a light ray travels from the rarer medium into the denser medium, it bends towards the normal and when it travels from the denser medium into the rarer medium, it bends away from the normal. You can observe this phenomenon with the help of the activity given below.

In this activity, the light rays actually travel from the water (a denser medium) into the air (a rarer medium). As you saw earlier, when a light ray travels from a denser medium to a rarer medium, it is deviated from its straight line path. So, the pencil appears to be bent when you see it through the glass of water.

Refractive Index

Refraction of light in a medium depends on the speed of light in that medium. When the speed of light in a medium is more, the bending is less andwhen the speed of light is less, the bending is more.

The amount of refraction of light in a medium is denoted by a term known as refractive index of the medium, which is the ratio of the speed of light in the air to the speed of light in that particular medium. It is also known as the absolute refractive index and it is denoted by the Greek letter 'μ' (pronounced as 'mew').

$$\mu = \frac{Speedoflighinair(c)}{Speedoflight \text{ int } hemedium(v)}$$

Refractive index is a ratio of two similar quantities (speed) and so, it has no unit. Since, the speed of light in any medium is less than its speed in air, refractive index of any transparent medium is always greater than 1.
Refractive indices of some common substances are given in Table 3.3.

Substances	Refractive Index
Air	1.0
Water	1.33
Ether	1.36
Kerosene	1.41
Ordinary Glass	1.5
Quartz	1.56
Diamond	2.41

In general, the refractive index of one medium with respect to another medium is given by the ratio of their absolute refractive indices.

$$\mu_2 \frac{Absoluterefactiveindexofthe\sec ondmedium}{Absoluterefactiveindexofthefivemedum}$$

[illegible]

Thus, the refractive index of one medium with respect to another medium is also given by the ratio of the speed of light in first medium to its speed in the second medium.

PROBLEM 4
Speed of light in air is 3 × 108 m s-1 and the speed of light in a medium is 2 ×108 ms-1. Find the refractive index of the medium with respect to air.
Solution:

Refractive index (μ)= $\frac{Speedoflightinair(c)}{Speedoflight\text{ int }hemedum(v)}$

$$\mu = \frac{3X10^8}{2X10^8} = 1.5$$

PROBLEM 5
Refractive index of water is 4/3 and the refractive index of glass is 3/2. Find the refractive index of glass with respect to the refractive index of water.
Solution:

[illegible]

Snell's Law of Refraction

Refraction of light rays, as they travel from one medium to another medium, obeys two laws, which are known as Snell's laws of refraction. They are:

I) The incident ray, the refracted ray and the normal at the point of intersection, all lie in the same plane.

II) The ratio of the sine of the angle of incidence (i) to the sine of the angle of refraction (r) is equal to the refractive index of the medium, which is a constant.

Snell's Law

In the above activity, you can see that the first prism splits the white light into seven coloured light rays and the second prism recombines them into white light, again. Thus, it is clear that white light consists of seven colours. You can also recall the Newton's disc experiment, which you studied in VII standard. Splitting of white light into its seven constituent colours (wavelength), on passing through a transparent medium is known as dispersion of light.

Why does dispersion occur? It is because, light of different colours present in white light have different wavelength and they travel at different speeds in a medium. You know that refraction of a light ray in a medium depends on its speed. As each coloured light has a different speed, the constituent coloured lights are refracted at different extents, inside the prism. Moreover, refraction of a light ray is inversely proportional to its wavelength.

Thus, the red coloured light, which has a large wavelength, is deviated less while the violet coloured light, which has a short wavelength, is deviated more.

The most common usage of mirror writing can be found on the front of ambulances, where the word "AMBULANCE" is often written in very large mirrored text.

Lateral inversion

You might have heard about inversion. But what is lateral inversion? The word lateral comes from the Latin word latus which means side. Lateral inversion means sidewise inversion. It is the apparent inversion of left and right that occurs in a plane mirror. Why do plane mirrors reverse left and right, but they do not reverse up and down? Well, the answer is surprising. Mirrors do not actually reverse left and right and they do not reverse up and down also. What actually mirrors do is reverse inside out. Look at the image below (Figure 6.2) and observe the arrows, which indicate the light ray from the object falling on the mirror. The arrow from the object's head is directed towards the top of the mirror and the arrow from the feet is directed towards the bottom. The arrow from left hand goes to the left side of the mirror and the arrow from the right hand goes to the right side of the mirror. Here, you can see that there is no switching. It is an optical illusion. Thus, the apparent lateral inversion we observe is not caused by the mirror but the result of our perception.

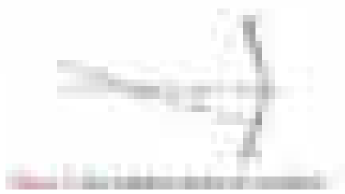
Real and Virtual Image

If the light rays coming from an object actually meet, after reflection, the image formed will be a real image and it is always inverted. A real image can be produced on a screen. When the light rays coming from an object do not actually meet, but appear to meet when produced backwards, that image will be virtual image. The virtual image is always erect and cannot be caught on a screen (Figure
binoculars, cameras and projectors are used in educational, scientifi c and entertainment fields.

Rules for the construction of image formed by spherical mirrors

From each point of an object, number of rays travel in all directions. To find the position and nature of the image formed by a concave mirror, we need to know the following rules.

Rule 1: A ray passing through the centre of curvature is reflected back along its own path (Figure 5).



Rule 2: A ray parallel to the principal axis passes through the principal focus after reflection (Figure 6).

Rule 3: A ray passing through the focus gets reflected and travels parallel to the principal axis (Figure 7).

Rule 4: A ray incident at the pole of the mirror gets reflected along a path such that the angle of incidence (APC) is equal to the angle of reflection (BPC) (Figure 8).

Concave Mirror

Ray diagrams for the formation of images

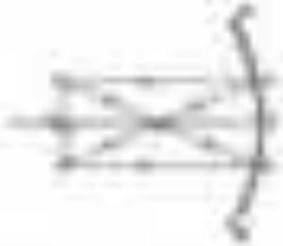
We shall now find the position, size and nature of image by drawing the ray diagram for a small linear object placed on the principal axis of a concave mirror at different positions.

Case-I: When the object is far away (at infinity), the rays of light reaching the concave mirror are parallel to each other (Figure 10).

Position of the Image: The image is at the principal focus F.
Nature of the Image: It is (i) real, (ii) inverted and (iii) highly diminished in size.

Case-II: When the object is beyond the centre of curvature (Figure 11).
Position of the image: Between the principal focus F and centre of curvature C.

Nature of the image: Real, inverted and smaller than object.
Case – III: When the object is at the centre of curvature (Figure 12).
Position of the image: The image is at the centre of curvature itself.
Nature of the image: It is i) Real, ii) inverted and iii) same size as the object.

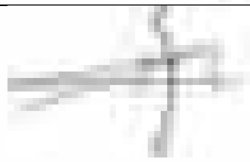


Case – IV: When the object is in between the centre of curvature C and principal focus F (Figure 13).
Position of the image: The image is beyond C

Nature of the image: It is i)Real ii) inverted and iii) magnified.

Case – V: When the object is at the principal focus F (Figure 14).
Position of the image: Theoretically, the image is at infinity.
Nature of the image: No image can be captured on a screen nor any virtual image can be seen.

Case – VI: When the object is in between the focus F and the pole P (Figure 15). Position of the image: The image is behind the mirror.
Nature of the image: It is virtual,erect and magnified.

S. No	Position of Object	Ray Diagram	Position of Image	Size of Image	Nature of Image
1.	At infinity		At the principal focus	Point size	Real and Inverted
2.	Beyond the Centre of Curvature C		Between F and C	Smaller than the object	Real and Inverted
3.	At the Centre of Curvature C		A to C	Same size	Real and Inverted
4.	Between C and F		Beyond C	Magnified	Real and inverted
5.	At the principal focus F		At infinity	Infinitely large	Real and Inverted
6.	Between the principal focus F and the pole P of the mirror		Behind the mirror	Magnified	Virtual and Erect

Sign convention for measurement of distances

We follow a set of sign conventions called the cartesian sign convention. In this convention the pole (P) of the mirror is taken as the origin. The principal axis is taken as the x axis of the coordinate system (Figure 16).The object is always placed on the left side of the mirror.
All distances are measured from the pole of the mirror.

- Distances measured in the direction of incident light are taken as positive and those measured in the opposite direction are taken as negative.
- All distances measured perpendicular to and above the principal axis are considered to be positive.
- All distances measured perpendicular to and below the principal axis are considered to be negative.

Type of mirror	u	v		f	R	Height of the subject	Height of the image	
		real	virtual				real	virtual
Concave mirror	-	-	+	-	-		-	+
Convex mirror	-	No real image	+	+	+		No real image	+

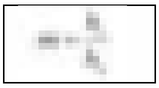
Mirror equation

The expression relating the distance of the object u, distance of image v and focal length f of a spherical mirror is called the mirror equation. It is given as:

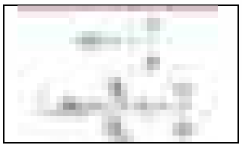
$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

Linear magnification (m)

Magnification produced by a spherical mirror gives the how many times the image of an object is magnified with respect to the object size.
It can be defined as the ratio of the height of the image (//.) to the height of the object (h).



The magnification can be related to object distance (u) and the image distance (v)



Note: A negative sign in the value of magnification indicates that the image is real. A positive sign in the value of magnification indicates that the virtual image.

Uses of concave mirror

Dentist's head mirror:

In dentist's head mirror, a parallel beam of light is made to fall on the concave mirror. This mirror focuses the light beam on a small area of the body (such as teeth, throat etc.).

Make-up mirror:

When a concave mirror is held near the face, an upright and magnified image is seen. Here, our face will be seen magnified.

Other applications:

Concave mirrors are also used as reflectors in torches, head lights in vehicles and search lights to get powerful beams of light. Large concave mirrors are used in solar heaters.

Stellar objects are at an infinite distance. Therefore, the image formed by a concave mirror would be diminished, and inverted. Yet, astronomical telescopes use concave mirrors

Convex Mirror

Image Formation

Any two rays can be chosen to draw the position of the image in a convex mirror (Figure 6.10): a ray that is parallel to the principal axis (rule 1) and a ray that appears to pass through the centre of curvature (rule 2).

Note: All rays behind the convex mirror shall be shown with dotted lines.

The ray OA parallel to the principal axis is reflected along AD. The ray OB retraces its path. The two reflected rays diverge but they appear to intersect at I when produced backwards. Thus II' is the image of the object OO'. It is virtual, erect and smaller than the object.

Uses of convex mirrors

Convex mirrors are used as rear-view mirrors in vehicles. It always forms a virtual, erect, small-sized image of the object. As the vehicles approach the driver from behind, the size of the image increases. When the vehicles are moving away from the driver, then image size decreases. A convex mirror provides a much wider field of view (it is the observable area as seen through eye / any optical device such as mirror) compared to plane mirror. Convex mirrors are installed on public roads as traffic safety device. They are used in acute bends of narrow roads such as hairpin bends in mountain passes where direct view ofoncoming vehicles is restricted. It is also used in blind spots in shops.

In the rear view mirror, the following sentence is written. "Objects in the mirror are closer than they appear". Why?

Speed of light

In early seventeenth century the Italian scientist Galileo Galilee (1564–1642) tried to measure the speed of light as it travelled from a lantern on a hill top about a mile (1.6 km) away from where he stood. His attempt was bound to fail, because he had no accurate clocks or timing instruments.

In 1665 the Danish astronomer Ole Roemer first estimated the speed of light by observing one of the twelve moons of the planet Jupiter. As these moons travel around the planet, at a set speed, it would take 42 hours to revolve around Jupiter. Roemer made a time schedule of the eclipses for the whole year. He made first observation in June and second observation in December. Roemer estimated the speed of light to be about 220,000 km per second.

In 1849 the first land based estimate was made by Armand Fizeau. Today the speed of light in vacuum is known to be almost exactly 300,000 km per second.

Refraction of light

This activity explains the refraction of light. The bending of light rays when they pass obliquely from one medium to another medium is called refraction of light.

Cause of refraction

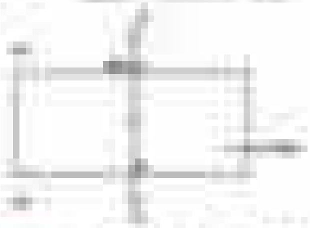
Light rays get deviated from their original path while entering from one transparentmedium to another medium of different optical density. This deviation (change in direction) in the path of light is due to the change in velocity of light in the different medium. The velocity of light depends on the nature of the medium in which it travels. Velocity of light in a rarer medium (low optical density) is more than in a denser medium (high optical density).

Refraction of light from a plane transparent surface

When a ray of light travels from optically rarer medium to optically denser medium, it bends towards the normal. (Figure 22)

When a ray of light travels from an optically denser medium to an optically rarer medium it bends away from the normal. (Figure 23)

A ray of light incident normally on a denser medium goes without any deviation. (Figure 24).



The laws of refraction of light

The incident ray, the refracted ray and the normal to the interface of two transparent media at the point of incidence, all lie in the same plane.

The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for a light of a given colour and for the given pair of media. This law is also known as Snell's law of refraction.

If i is the angle of incidence and r is the angle of refraction, then

$$\frac{\sin i}{\sin r} = \text{constant}$$

This constant is called the refractive index of the second medium with respect to the first medium. It is generally represented by the Greek letter, ${}_1\mu_2$ (mew)

Note: The refractive index has no unit as it is the ratio of two similar quantities

Verification of laws of refraction

Speed of light in different media

Light has the maximum speed in vacuum and it travels with different speeds in different media. The speed of light in some media is given below.

Note: The refractive index of a medium is also defined in terms of speed of light in different media

$$\mu = \frac{speed\ of light\ in\ vacuum\ in\ air(c)}{\text{speed of light in the vacuum (v)}}$$

in general, $1\mu 2 = \frac{speed of light in medium\ 1}{\text{speed of light in medium 2}}$

Total internal reflection

When light travels from denser medium into a rarer medium, it gets refracted away from the normal. While the angle of incidence in the denser medium increases the angle of refraction also increases and it reaches a maximum value of $r = 90^o$ for a particular value. This angle of incidence is called critical angle (Figure 6.12). The angle of incidence at which the angle of refraction is 90^o is called the critical angle. At this angle, the refracted ray grazes the surface of separation between the two media.

When the angle of incidence exceeds the value of critical angle, the refracted ray is not possible. Since $r > 90^o$ the ray is totally reflected back to the same medium. This is called as total internal reflection.

Conditions to achieve total internal reflection

In order to achieve total internal refelection the following conditions must be met.

- Light must travel from denser medium to rarer medium. (Example: From water to air).
- The angle of incidence inside the denser medium must be greater than that of the critical angle.

Total internal reflection in nature

Mirage:

On hot summer days, patch of water may be on the road. This is an illusion. In summer, the air near the ground becomes hotter than the air at higher levels. Hotter air is less dense, and has smaller refractive index than the cooler air. Thus, a ray of light bends away from the normal and undergoes total internal reflection. Total internal reflection is the main cause for the spectacular brilliance of diamonds and twinkling of stars.

Optical fibres:

Optical fibres are bundles of high-quality composite glass/quartz fibres. Each fibre consists of a core and cladding. The refractive index of the material of the core is higher than that of the cladding. Optical fibres work on the phenomenon of total internal reflection. When a signal in the form of light is directed at one end of the fibre at a suitable angle, it undergoes repeated total internal reflection along the length of the fibre and finally comes out at the other end. Optical fibres are extensively used for transmitting audio and video signals through long distances. Moreover, due to their flexible nature, optical fibers enable physicians to look and work inside the body through tiny incisions without having to perform surgery.

An Indian-born physicist NarinderKapany is regarded as the Father of Fibre Optics.

10th Standard
Unit 2: Optics

PROPERTIES OF LIGHT

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

- **Light is a form of energy.**
- **Light always travels along a straight line.**
- **Light does not need any medium for its propagation. It can even travel through vacuum.**
- **The speed of light in vacuum or air is, $c = 3 \times 10^8 ms^{-1}$.**
- **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).**
- **Different coloured light has different wavelength and frequency.**
- **Among the visible light, violet light has the lowest wavelength and red light has the highest wavelength.**
- **When light is incident on the interface between two media, it is partly reflected and partly refracted.**

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

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,

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'.

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

1) **Rayleigh scattering**
2) **Mie scattering**
3) **Tyndall scattering**
4) **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".

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

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.

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

- **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.

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:

IMAGES FORMED DUE TO REFRACTION THROUGH A CONVEX AND CONCAVE LENS

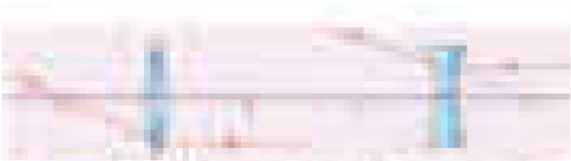
When an object is placed in front of a lens, the light rays from the object fall on the lens. Th e position, size and nature of the image formed can be understood only if we know certain basic rules.

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).

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).

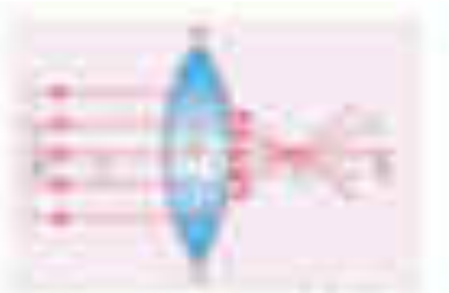


REFRACTION THROUGH A CONVEX LENS

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

Object at infinity

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

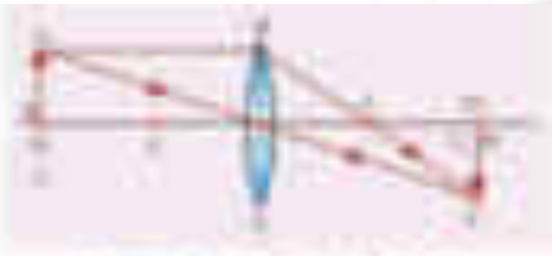


Object placed beyond C (>2F)

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. Th e size of the image is the same as that of the object (Figure 2.7).

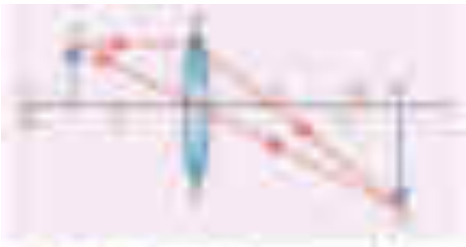
Object placed at C

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



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).



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).

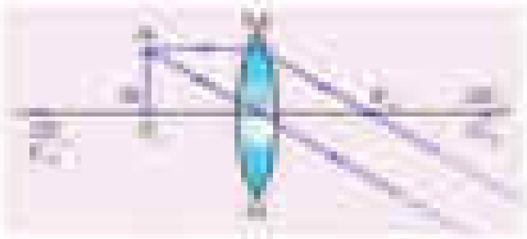


Figure 2.10 Object placed at the principal focus F

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).

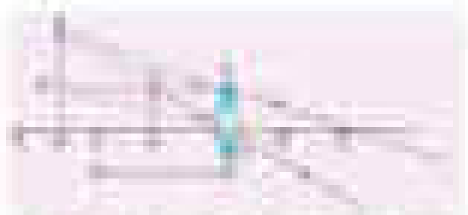


Figure 2.11 Object placed between the principal focus F and optical centre O

APPLICATIONS OF CONVEX LENSES

- **Convex lenses are used as camera lenses**
- **They are used as magnifying lenses**
- **They are used in making microscope, telescope and slide projectors**
- **They are used to correct the defect of vision called hypermetropia**

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).

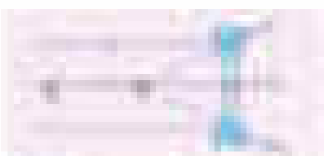
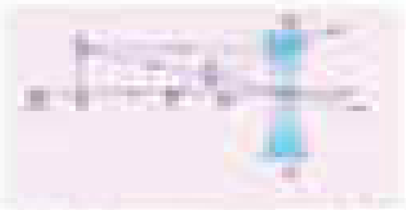


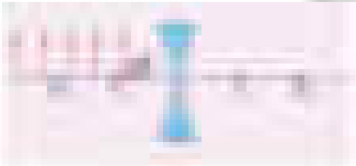
Figure 2.12 Concave lens: Object at infinity

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).



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).



APPLICATIONS OF CONCAVE LENSES

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

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

[illegible]

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.

SIGN CONVENTION

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

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

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 theheight 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,

$$m = \frac{\text{height of the image}}{\text{height of the object}} = \frac{h'}{h} \quad \text{.......} \; [illegible]$$

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

$$m = \frac{\text{Distance of the image}}{\text{Distance of the object}} = \frac{v}{u} \quad \text{.......} \; [illegible]$$

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.

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

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) \text{ ———— [illegible]}$$

where μ is the refractive index of the material of the lens; $R1$ and $R2$ are the radii of curvature of the two faces of the lens; f is the focal length of the lens.

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.

$$P = \frac{1}{f} \text{ ———— [illegible]}$$

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	A concave lens is thinner in the

	middle than at edges.	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.

12th Volume II

Unit 6 – Optics

Example

What is the height of the mirror needed to see the image of a person fully on the mirror?

Solution

Let us assume a person of height h is standing in front of a vertical plane mirror. The person could see his/her head when light from the head falls on the mirror and gets reflected to the eyes. Same way, light from the feet falls on the mirror and gets reflected to the eyes.

If the distance between his head *H* and eye *E* is h_1 and distance between his feet *F* and eye *E* is h_2. The person's total height *h* is, $h = h_1 + h_2$

By the law of reflection, the angle of incidence and angle of reflection are the same in the two extreme reflections. The normals are now the bisectors of angles between incident and reflected rays in the two reflections. By geometry, the height of the mirror needed is only half of the height of the person.

$$\frac{h_1 + h_2}{2} = \frac{h}{2}$$

Refractive index

Refractive index of a transparent medium is defined as the ratio of speed of light in vacuum (or air) to the speed of light in that medium.

$$\text{refractive index, n of a medium} = \frac{\text{speed of light in vacuum (c)}}{\text{speed of light in medium (v)}}$$

$$n = \frac{c}{v}$$

Refractive index of a transparent medium gives an idea about the speed of light in that medium.

Example

One type of transparent glass has refractive index 1.5. What is the speed of light through this glass?

Solution

$$n = \frac{c}{v} \qquad v = \frac{c}{n}$$

$$v = \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \ m\,s^{-1}$$

Light travels with a speed of 2×10^8 ms^{-1}

Refractive index does not have unit. The smallest value of refractive index is for vacuum, which is 1. For any other medium refractive index is greater than 1. Refractive index is also called as optical density of the medium. Higher the refractive index of a medium, greater is its optical density and speed of light through the medium is lesser and vice versa.

Refraction index of different media

Media	Refraction index
Vacuum	1.00
Air	1.0003
Carbon dioxide gas	1.0005
Ice	1.31
Pure Water	1.33
Ethyl alcohol	1.36
Quartz	1.46
Vegetable oil	1.47
Olive oil	1.48
Acrylic	1.49
Table salt	1.51
Glass	1.52
Sapphire	1.77
Zircon	1.92
Qubic zirconia	2.16
Diamond	2.42
Gallium phosphide	3.50

Apparent depth

It is a common observation that the bottom of a tank filled with water appears raised. An equation could be derived for the apparent depth for viewing in the near normal direction.

Light from the object O at the bottom of the tank passes from denser medium (water) to rarer medium (air) to reach our eyes. It deviates away from the normal in the rarer medium at the point of incidence B. The refractive index of the denser medium is $n1$ and rarer medium is $n2$. Here, $n1 > n2$. The angle of incidence in the denser medium is $i$and the angle of refraction in the rarer medium is r. The lines and OD are parallel. Thus angle $\angle DIB$ is also r. The angles $i$and r are very small as the diverging light from O entering the eye is very narrow. The Snell's law in product form for this refraction is,

$$n_1 \sin i = n_2 \sin r$$

As the angles $i$and r are small, we can approximate, sin $i \approx$ tan i;

$$n_1 \tan i = n_2 \tan r$$

In triangles ΔDOB and ΔDIB,

$$\tan(i) = \frac{DB}{DO} \text{ and } \tan(r) = \frac{DB}{DI}$$

$$n_1 \frac{DB}{DO} = n_2 \frac{DB}{DI}$$

DB is cancelled on both sides, DO is the actual depth d and DI is the apparent depth d'.

$$n_1 \frac{1}{d} = n_2 \frac{1}{d'}$$

$$\frac{d'}{d} = \frac{n_2}{n_1}$$

Rearranging the above equation for the apparent depth d',

$$d' = \frac{n_2}{n_1} d$$

As the rarer medium is air and its refractive index $n2$ can be taken as 1, ($n2=1$). And the refractive index $n1$ of denser medium could then be taken as n, ($n1=n$).

In that case, the equation for apparent depth becomes,

$$d' = \frac{d}{n}$$

The bottom appears to be elevated by d– d′

$$d - d' = d - \frac{d}{n} \text{ or } d - d' = d\left(1 - \frac{1}{n}\right)$$

Atmospheric refraction: Due to refraction of light through different layers of atmosphere which vary in refractive index, the path of light deviates continuously when it passes through atmosphere. For example, the Sun is visible a little before the actual sunrise and also until a little after the actual sunset due to refraction of light through the atmosphere. By actual sunrise what we mean is the actual crossing of the sun at the horizon. Figure shows the actual and apparent positions of the sun with respect to the horizon. The figure is highly exaggerated to show the effect. The apparent shift in the direction of the sun is around half a degree and the corresponding time difference between actual and apparent positions is about 2 minutes. Sun appears flattened (oval shaped) during sun rise and sunset due to the same phenomenon.
The same is also applicable for the positions of stars as shown in Figure. The stars actually do not twinkle. They appear twinkling because of the movement of the atmospheric layers with varying refractive indices which is clearly seen in the night sky.

Effects due to total internal reflection
Glittering of diamond

Diamond appears dazzling because the total internal reflection of light happens inside the diamond. The refractive index of only diamond is about 2.417. It is much larger than that for ordinary glass which is about only 1.5. The critical angle of diamond is about 24.4°. It is much less than that of glass. A skilled diamond cutter makes use of this larger range of angle of incidence (24.4° to 90° inside the diamond), to ensure that light entering the diamond is total internally reflected from the many cut faces before getting out. This gives a sparkling effect for diamond.

Mirage and looming

The refractive index of air increases with its density. In hot places, air near the ground is hotter than air at a height. Hot air is less dense. Hence, in still air the refractive index of air increases with height. Because of this, light from tall objects like a tree, passes through a medium whose refractive index decreases towards the ground. Hence, a ray of light successively deviates away from the normal at different layers of air and undergoes total internal reflection when the angle of incidence near the ground exceeds the critical angle. This gives an illusion as if the light comes from somewhere below the ground. For of the shaky nature of the layers of air, the observer feels as if the object is getting reflected by a pool of water or wet surface beneath the object. This phenomenon is called mirage.

In the cold places the refractive index increases towards the ground because the temperature of air close to the ground is lesser than the temperature above the surface of earth. Thus, the density and refractive index of air near the ground is greater than at a height. In the cold regions like glaciers and frozen lakes and seas, the reverse effect of mirage will happen. Hence, an inverted image is formed little above the surface. This phenomenon is called looming.

Prisms making using of total internal reflection

Prisms can be designed to reflect light by 90^0 or by 180^0 by making use of total internal reflection. In the first two cases, the critical angle ic for the material of the prism must be less than 45^0. This is true for both crown glass and flint glass. Prisms are also used to invert images without changing their size.

Radius of illumination (Snell's window)

When a light source like electric bulb is kept inside a water tank, the light from the source travels in all direction inside the water. The light that is incident on the water surface at an angle less than the critical angle will undergo refraction and emerge out from the water. The light incident at an angle greater than critical angle will undergo total internal reflection. The light falling particularly at critical angle graces the surface.

On the other hand, when light entering the water from outside is seen from inside the water, the view is restricted to a particular angle equal to the critical angle ic. The restricted illuminated circular area is called Snell's window.

The angle of view for water animals is restricted to twice the critical angle 2*ic*. The critical angle for water is 48.6^0. Thus the angle of view is 97.2^0. The radius R of the circular area depends on the depth d from which it is seen and also the refractive indices of the media. The radius of Snell's window can be deduced with the illustration.

Light is seen from a point A at a depth d. The Snell's law in product form, equation for the refraction happening at the point B on the boundary between the two media is,

[illegible]

[illegible] [illegible]

$$\sin i_c = \frac{n_2}{n_1}$$

From the right angle triangle ΔABC

$$\sin i_c = \frac{CB}{AB} = \frac{R}{\sqrt{d^2 + R^2}}$$

Equating the above two equations [illegible]

and equation [illegible], $\frac{R}{\sqrt{d^2 + R^2}} = \frac{n_2}{n_1}$

Squaring on both sides, $\frac{R^2}{R^2 + d^2} = \left(\frac{n_2}{n_1}\right)^2$

Taking reciprocal, $\frac{R^2 + d^2}{R^2} = \left(\frac{n_1}{n_2}\right)^2$

On further simplifying,

$$1 + \frac{d^2}{R^2} = \left(\frac{n_1}{n_2}\right)^2; \quad \frac{d^2}{R^2} = \left(\frac{n_1}{n_2}\right)^2 - 1;$$

$$\frac{d^2}{R^2} = \frac{n_1^2}{n_2^2} - 1 = \frac{n_1^2 - n_2^2}{n_2^2}$$

Again taking reciprocal and rearranging,

$$\frac{R^2}{d^2} = \frac{n_2^2}{n_1^2 - n_2^2}; \quad R^2 = d^2\left(\frac{n_2^2}{n_1^2 - n_2^2}\right)$$

The radius of illumination is,

$$R = d\sqrt{\frac{n_2^2}{(n_1^2 - n_2^2)}} \qquad \text{([illegible])}$$

If the rarer medium outside is air, then, $n_2 = 1$, and we can take $n_1 = n$

$$R = d\left(\frac{1}{\sqrt{n^2 - 1}}\right) \quad \text{(or)} \quad R = \frac{d}{\sqrt{n^2 - 1}}$$

Optical Fiber

Transmitting signals through optical fibres is possible due to the phenomenon of total internal reflection. Optical fibres consists of inner part called core and outer part called cladding (or) sleeving. The refractive index of the material of the core must be higher than that of the cladding for total internal reflection to happen. Signal in the form of light is made to incident inside the core-cladding boundary at an angle greater than the critical angle. Hence, it undergoes repeated total internal reflections along the length of the fibre without undergoing any refraction. The light travels inside the core with no appreciable loss in the intensity of the light. Even while bending the optic fiber, it is done in such a way that the condition for total internal reflection is ensured at every reflection.

Acceptance angle in optical fibre

To ensure the critical angle incidence in the core-cladding boundary inside the optical fibre, the light should be incident at a certain angle at the end of the optical fiber while entering in to it. This angle is called *acceptance angle*. It depends on the refractive indices of the core $n1$, cladding $n2$ and the outer medium $n3$. Assume the light is incident at an angle called acceptance angle iaat the outer medium and core boundary at A.

The Snell's law in the product form, equation (6.19) for this refraction at the point A.

$$n_3 \sin i_a = n_1 \sin r_a$$

To have the total internal reflection inside optical fibre, the angle of incidence at the core-cladding interface at B should be atleast critical angle ic. Snell's law in the product form, equation (6.19) for the refraction at point B is,

$$n_1 \sin i_c = n_2 \sin 90^\circ$$

$$n_1 \sin i_c = n_2 \qquad \because \sin 90^\circ = 1$$

$$\sin i_c = \frac{n_2}{n_1}$$

From the right angle triangle ΔABC,

$$i_c = 90^\circ - r_a$$

Now, equation (6.95) becomes,

$$\sin(90^\circ - r_a) = \frac{n_2}{n_1}$$

Using trigonometry, $\cos i_c = \frac{n_2}{n_1}$

$$\sin i_c = \sqrt{1 - \cos^2 i_c}$$

Substituting for $\cos i_c$

$$\sin i_c = \sqrt{1 - \left(\frac{n_2}{n_1}\right)^2} = \sqrt{\frac{n_1^2 - n_2^2}{n_1^2}}$$

Substituting this in equation

$$n_3 \sin i_a = n_1 \sqrt{\frac{n_1^2 - n_2^2}{n_1^2}} = \sqrt{n_1^2 - n_2^2}$$

On further simplification,

$$\sin i_a = \frac{\sqrt{n_1^2 - n_2^2}}{n_3} \text{ (or) } \sin i_a = \sqrt{\frac{n_1^2 - n_2^2}{n_3^2}}$$

$$i_a = \sin^{-1}\left(\sqrt{\frac{n_1^2 - n_2^2}{n_3^2}}\right)$$

If outer medium is air, then n3 = 1. The acceptance angle ia becomes,

$$i_a = \sin^{-1}\left(\sqrt{n_1^2 - n_2^2}\right)$$

Light can have any angle of incidence from 0 to ia with the normal at the end of the optical fibre forming a conical shape called acceptance cone called numerical aperture NA of the optical fibre.

$$NA = n_3 \sin i_a = \sqrt{n_1^2 - n_2^2}$$

If outer medium is air, then *n*3 = 1. The numerical aperture *NA* becomes,

An endoscope is an instrument used by doctors which has a bundle of optical fibres that are used to see inside a patient's body. Endoscopes work on the phenomenon of total internal reflection. The optical fibres are inserted in to the body through mouth, nose or a special hole made in the body. Even operations could be carried out with the endoscope cable which has the necessary instruments attached at their ends

Dispersion of white light through prism

So far the angle of deviation produced by a prism is discussed for monochromatic light (i.e. light of single colour). When white light enter in to a prism, the effect called dispersion takes place. Dispersion is splitting of white light into its constituent colours. This band of colours of light is called its spectrum. When a narrow beam of parallel rays of white light is incident on the face of a prism and the refracted beam is received on a white screen, a band of colours is obtained in the order, recollected by the word: VIBGYOR i.e., Violet, Indigo, Blue, Green, Yellow, Orange and Red.Violet is the most deviated and red is the least deviated colour.

The colours obtained in a spectrum depend on the nature of the source of the light used. Each colour of light is associated with a definite wavelength. Red light is at the longer wavelength end (700 nm) while the violet light is at the shorter wavelength end (400 nm). Therefore the violet ray travels with a smaller velocity in glass prism than red ray.

Dispersion takes place because light of different wave lengths travel with different speeds inside the prism. In other words, the refractive index of the material of the prism is different for different colours. For violet, the refractive index is high and for red the refractive index is the low. In Vacuum, all the colours travel with the same speed.

The speed of light is independent of wavelength in vacuum. Therefore, vacuum is a non-dispersive medium in which all colours travel with the same speed.

Refractive indices for different wavelengths

Colour	Wavelength (nm)	Crown glass	Flint glass
Violet	396.9	1.533	1.663
Blue	486.1	1.523	1.639
Yellow	589.3	1.517	1.627
Red	656.3	1.515	1.622

Scattering of sunlight

When sunlight enters the atmosphere of the earth, the atmospheric particles present in the atmosphere change the direction of the light. This process is known as scattering of light.

If the scattering of light is by atoms and molecules which have size a very less than that of the wave length λ of light a<<λ, the scattering is called Rayleigh's scattering. The intensity of Rayleigh's scattering is inversely proportional to fourth power of wavelength.

$$I \propto \frac{1}{\lambda^4}$$

According to equation 6.114, violet colour which has the shortest wavelength gets much scattered during day time. The next scattered colour is blue. As our eyes are more sensitive to blue colour than violet colour the sky appears blue during day time. But, during sunrise and sunset, the light from sun travels a greater distance through the atmosphere. Hence, the blue light which has shorter wavelength is scattered away and the less-scattered red light of longer wavelength manages to reach our eye. This is the reason for the reddish appearance of sky during sunrise.

Rainbow is an example of dispersion of sunlight through droplets of water during rainy days. Rainbow is observed during a rainfall or after the rainfall or when we look at a water fountain provided the sun is at the back of the observer. When sunlight falls on the water drop suspended in air, it splits (or dispersed) into its constituent seven colours. Thus, water drop suspended in air behaves as a glass prism. Primary rainbow is formed when light entering the drop undergoes one total internal reflection inside the drop before coming out from the drop as shown in figure. The angle of view for violet to red in primary rainbow is 40^0 to 42^0. A secondary rainbow appears outside of a primary rainbow and develops when light entering a raindrop undergoes two internal reflections. The angle of view for red to violet in a secondary rainbow is, 52^o to 54^o.

If light is scattered by large particles like dust and water droplets present in the atmosphere which have size a greater than the wavelength λ of light, a >> λ, the intensity of scattering is equal for all the wavelengths. It is happening in clouds which contains large amount of dust and water droplets. Thus, in clouds all the colours get equally scattered irrespective of wavelength. This is the reason for the whitish appearance of cloud. But, the rain clouds appear dark because of the condensation of water droplets on dust particles that makes the cloud become opaque.

If earth has no atmosphere there would not have been any scattering and the sky would appear dark. That is why sky appears dark for the astronauts who could see the sky from above the atmosphere.

Theories on light

Light is a form of energy that is transferred from one place to another. A glance at the evolution of various theories of light put forward by scientists will give not only an over view of the nature of light but also its propagation and some phenomenon demonstrated by it.

Corpuscular theory

Sir Isaac Newton (1672) gave the corpuscular theory of light which was also suggested earlier by Descartes (1637) to explain the laws of reflection and refraction. According this theory, light is emitted as tiny, massless (negligibly small mass) and perfectly elastic particles called corpuscles. As the corpuscles are very small, the source of light does not suffer appreciable loss of mass even if it emits light for a long time. On account of high speed, they are unaffected by the force of gravity and their path is a straight line in a medium of uniform refractive index. The energy of light is the kinetic energy of these corpuscles. When these corpuscles impinge on the retina of the eye, the vision is produced. The different size of the corpuscles is the reason for different colours of light. When the corpuscles approach a surface between two media, they are either attracted or repelled. The reflection of light is due to the repulsion of the corpuscles by the medium and refraction of light is due to the attraction of the corpuscles by the medium.

This theory could not explain the reason why the speed of light is lesser in denser medium than in rarer medium and also the phenomena like interference, diffraction and polarisation.

Wave theory

Christian Huygens (1678) proposed the wave theory to explain the propagation of light through a medium. According to him, light is a disturbance from a source that travels as longitudinal mechanical waves through the ether medium that was presumed to pervade all space as mechanical wave requires medium for its propagation. The wave theory could successfully explain phenomena of reflection, refraction, interference and diffraction of light.

Later, the existence of ether in all space was proved to be wrong. Hence, this theory could not explain the propagation of light through vacuum. The phenomenon of polarisation could not be explained by this theory as it is the property of only transverse waves.

Electromagnetic wave theory

Maxwell (1864) proved that light is an electromagnetic wave which is transverse in nature carrying electromagnetic energy. He could also show that no medium is necessary for the propagation of electromagnetic waves. All the phenomenon of light could be successfully explained by this theory.

Nevertheless, the interaction phenomenon of light with matter like photoelectric effect, Compton effect could not be explained by this theory.

Quantum theory

Albert Einstein (1905), endorsing the views of Max Plank (1900), was able to explain photoelectric effect (discussed in Unit 7) in which light interacts with matter as photons to eject the electrons. A photon is a discrete packet of energy. Each photon has energy E of,

$$E = hv$$

Where, h is Plank's constant (h = 6.625 × 10^{-34} J s) and v is frequency of electromagnetic wave.

As light has both wave as well as particle nature it is said to have dual nature. Thus, it is concluded that light propagates as a wave and interacts with matter as a particle.

Wave Nature of Light

Light is a transverse, electromagnetic wave. The wave nature of light was first illustrated through experiments on interference and diffraction. Like all electromagnetic waves, light can travel through vacuum. The transverse nature of light is demonstrated in polarization.

Wave optics

Wave optics deals with the wave characteristics of light. With the help of wave optics, we are going to learn in details the phenomena of interference, diffraction and polarization. Even the law of reflection and refraction are proved only with the help of wave optics. Though light propagates as a wave, its direction of propagation is still represented as a ray.

An example for wave propagation is the spreading of circular ripples on the surface of still water from a point at which a stone is dropped. The molecules or particles of water are moving only up and down (oscillate) when a ripple passes out that part. All these particles on the circular ripple are in the same phase of vibration as they are all at the same distance from the center. The ripple represents a wave front. A wave front is the locus of points which are in the same state or phase of vibration. When a wave propagates it is treated as the propagation of wave front. The wave front is always perpendicular to the direction of the propagation of the wave. As the direction of ray is in the direction of propagation of the wave, the wave front is always perpendicular to the ray.

The shape of a wavefront observed at a point depends on the shape of the source and also the distance at which the source is located. A point source located at a finite distance gives spherical wavefronts. An extended (or) line source at finite distance gives cylindrical wavefronts. The plane wavefronts are received from any source that is located at infinity.

Huygens' Principle

Huygens principle is a geometrical construction which gives the shape of the wave front at any time if we know its shape at t = 0. According to Huygens principle, each point of the wave front is the source of secondary wavelets emanating from these points spreading out in all directions with the speed of the wave. These are called as secondary wavelets. The common tangent, in other words the envelope to all these wavelets gives the position and shape of the new wave front at a later time. Thus, Huygens'principle explains the propagation of a wave front.

The propagation of a spherical and plane wave front is explained in using Huygens' principle. Let, AB be the wave front at a time, t = 0. According to Huygens' principle, every point on AB acts as a source of secondary wavelet which travels with the speed of the wave (speed of light c). To find the position of the wave front after a time t, circles of radius equal to ct are drawn with points P, Q, R ... etc., as centers on AB. The tangent or forward envelope of the small circles is the new wave front at that instant. The wave front will be a spherical wave front from a point object which is at a finite distance and it is a plane wave front if the source of light is at a large distance (infinity).

There is one shortcoming in the above Huygens' construction for propagation of a wave front. It could not explain the absence of back wave which also arises in the above construction. According to electromagnetic wave theory, the back wave is ruled out inherently. However, Huygens' construction diagrammatically explains the propagation of the wave front.

Optical Instruments
Simple microscope

A simple microscope is a single magnifying (converging) lens of small focal length. The idea is to get an erect, magnified and virtual image of the object. For this the object is placed between F and P on one side of the lens and viewed from other side of the lens. There are two magnifications to be discussed for two kinds of focussing.

- Near point focusing – The image is formed at near point, i.e. 25 cm for normal eye. This distance is also called as least distance D of distinct vision. In this position, the eye feels comfortable but there is little strain on the eye. This is shown.

- Normal focusing – The image is formed at infinity. In this position the eye is most relaxed to view the image.

Magnification in near point focusing

The near point focusing is shown. Object distance u is less than f. The image distance is the near point D. The magnification m is given by the relation,

$$m = \frac{v}{u}$$

With the help of lens equation, $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ the magnification can further be written as,

$$m = 1 - \frac{v}{f} \qquad (6.77)$$

Substituting for v with sign convention, $v = -D$

$$m = 1 + \frac{D}{f} \qquad (6.78)$$

Magnification in normal focusing (angular magnification)

The normal focusing is shown. We will now find the magnification for the image formed at infinity. If we take the ratio of height of image to height of object

$\left(m = \frac{h'}{h}\right)$ to find the magnification, we will not get a practical relation, as the image will also be of infinite size when the image is formed at infinity. Hence, we can practically use the angular magnification. The angular magnification is defined as the ratio of angle subtended by the image with aided eye to the angle subtended by the object with unaided eye.

$$m = \frac{\theta_i}{\theta_o}$$

$$\tan\theta_o \approx \theta_o = \frac{h}{D}$$

$$\tan\theta_i \approx \theta_i = \frac{h}{f}$$

[illegible]

$$[illegible]$$

$$[illegible]$$

This is the magnification for normal focusing.

The magnification for normal focusing is one less than that for near point focusing. But, the viewing is more comfortable in normal focusing than near point focusing. For large values of D/f, the difference in magnification is usually small. In subsequent discussions, we shall only consider the normal focusing.

Resolving power of microscope

The diagram related to the calculation of resolution of microscope is illustrated. A microscope is used to see the details of the object under observation. The ability of microscope depends not only in magnifying the object but also in resolving two points on the object separated by a small distance *dmin*. Smaller the value of *dmin*better will be the resolving power of the microscope.

The radius of central maxima is already derived as equation

$$[illegible]$$

In the place of focal length f we have the image distance v. If the difference between the two points on the object to be resolved is d_{min}, then the magnification m is,

Compound microscope

The diagram of a compound microscope is shown. The lens near the object, called the objective, forms a real, inverted, magnified image of the object. This serves as the object for the second lens which is the eyepiece. Eyepiece serves as a simple microscope that produces finally an enlarged and virtual image. The first inverted image formed by the objective is to be adjusted close to, but within the focal plane of the eyepiece so that the final image is formed nearly at infinity or at the near point. The final image is inverted with respect to the original object. We can obtain the magnification for a compound microscope.

Magnification of compound microscope

From the ray diagram, the linear magnification due to the objective is,

Here, the distance L is between the first focal point of the eyepiece to the second focal point of the objective. This is called the tube length L of the microscope as f_o and f_e are comparatively smaller than L.

If the final image is formed at P (near point focussing), the magnification m_e of the eyepiece is,

$$m_e = 1 + \frac{D}{f_e}$$

The total magnification m in near point focusing is,

$$m = m_o m_e = \left(\frac{L}{f_o}\right)\left(1 + \frac{D}{f_e}\right)$$

If the final image is formed at infinity (normal focusing), the magnification me of the eyepiece is,

$$m_e = \frac{D}{f_e}$$

The total magnification m in normal focusing is,

$$m = m_o m_e = \left(\frac{L}{f_o}\right)\left(\frac{D}{f_e}\right)$$

Astronomical telescope

An astronomical telescope is used to get the magnification of distant astronomical objects like stars, planets, moon etc. The image formed by astronomical telescope will be inverted. It has an objective of long focal length and a much larger aperture than the eyepiece as shown. Light from a distant object enters the objective and a real image is formed in the tube at its second focal point. The eyepiece magnifies this image producing a final inverted image.

Magnification of astronomical telescope

The magnification m is the ratio of the angle β subtended at the eye by the finalimage to the angle α which the object subtends at the lens or the eye.

The length of the telescope is approximately, $L = f_o + f_e$

Terrestrial telescope

A terrestrial telescope is used to see object at long distance on the surface of earth. Hence, image should be erect. A terrestrial telescope has an additional erecting lens to make the final image erect as shown.

Reflecting telescope

Modern telescopes use a concave mirror rather than a lens for the objective. It is rather difficult and expensive to make lenses of large size which form images that are free from any optical defect. Telescopes with mirror objectives are called reflecting telescopes. They have several advantages. Only one surface it to be polished and maintained. Support can be given from the entire back of the mirror rather than only at the rim for lens. Mirrors weigh much less compared to lens. But the one obvious problem with a reflecting telescope is that the objective mirror would focus the light inside the telescope tube. One must havean eye piece inside obstructing some light. This problem could also be overcome by introducing a secondary mirror which would take the light outside the tube for view as shown.

Spectrometer

The spectrometer is an optical instrument used to study the spectra of different sources of light and to measure the refractive indices of materials. It is shown. It consists of basically three parts. They are (i) collimator (ii) prism table and (iii) Telescope.

Collimator

The collimator is an arrangement to produce a parallel beam of light. It consists of a long cylindrical tube with a convex lens at the inner end and a vertical slit at the outer end of the tube. The distance between the slit and the lens can be adjusted such that the slit is at the focus of the lens. The slit is kept facing the source of light. The width of the slit can be adjusted. The collimator is rigidly fixed to the base of the instrument.

Prism table

The prism table is used for mounting the prism, grating etc. It consists of two circular metal discs provided with three levelling screws. It can be rotated about a vertical axis passing through its centre and itspositioncan be read with verniers V_1 and V_2 . The prism table can be raised or lowered and can be fixed at any desired height.

Telescope

The telescope is an astronomical type. It consists of an eyepiece provided with cross wires at one end and an objective lens at its other end. The distance between the objective lens and the eyepiece can be adjusted so that the telescope forms a clear image at the cross wires, when a parallel beam from the collimator is incident on it.

The telescope is attached to an arm which is capable of rotation about the same vertical axis as the prism table. A circular scale graduated in half degree is attached to it. Both the telescope and prism table are provided with radial screws for fixing them in a desired position and tangential screws for fine adjustments.

Adjustments of the spectrometer

The following adjustments must be made before doing the experiment using spectrometer.

- **Adjustment of the eyepiece**The telescope is turned towards an illuminated surface and the eyepiece is moved to and fro until the cross wires are clearly seen.
- **Adjustment of the telescope** The telescope is adjusted to receive parallel rays by turning it towards a distant object and adjusting the distance between the objective lens and the eyepiece to get a clear image on the cross wire.
- **Adjustment of the collimator**The telescope is brought along the axial line with the collimator. The slit of the collimator is illuminated by a source of light. The distance between the slit and the lens of the collimator is adjusted until a clear image of the slit is seen atthe cross wire of the telescope. Since the telescope is already adjusted for parallel rays, a well-defined image of the slit can be formed, only when the light rays emerging from the collimator are parallel.

- **Levelling the prism table**The prism table is adjusted or levelled to be in horizontal position by means of levelling screws and a spirit level.

Determination of refractive index of material of the prism

The preliminary adjustments of the telescope, collimator and the prism table of the spectrometer are made. The refractive index of the prism can be determined by knowing the angle of the prism and the angle of minimum deviation.

The prism is placed on the prism table with its refracting edge facing the collimator as shown. The slit is illuminated by a sodium light (monochromotic light). The parallel rays coming from the collimator fall on the two faces AB and AC. The telescope is rotated to the position T_1 until the image of the slit formed by the reflection at the face AB is made to coincidewith the vertical cross wire of the telescope. The readings of the verniers are noted. The telescope is then rotated to the position $T_2$where the image of the slit formed by the reflection at the face AC coincideswiththe vertical cross wire. The readings are again noted.

The difference between these two readings gives the angle rotated by the telescope, which is twice the angle of the prism. Half of this value gives the angle of the prism A.

Angle of minimum deviation (D)

The prism is placed on the prism table so that the light from the collimator falls on a refracting face, and the refracted image is observed through the telescope as shown. The prism table is now rotated so that the angle of deviation decreases. A stage comes when the image stops for a moment and if we rotate the prism table further in the same direction, the image is seen to recede and the angle of deviation increases. The vertical cross wire of the telescope is made to coincide with the image of the slit where it turns back. This gives the minimum deviation position.

The readings of the verniers are noted. Now, the prism is removed and the telescope is turned to receive the direct ray and the vertical cross wire is made to coincide with theimage. The readings of the verniers are noted. The difference between the two readings gives the angle of minimum deviation D. The refractive index of the material of the prism n is calculated using the formula,

$$n = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

The refractive index of a liquid may be determined in the same way using a hollow glass prism filled with the given liquid.

The eye

Eye is a natural optical instrument given by God to the human beings. The internal structure and the Physics aspect of the functioning of different parts of human eye. As the eye lens is flexible, its focal length can be changed to some extent. When the eye is fully relaxed, the focal length is maximum and when it is strained the focal length is minimum. The image must be formed on the retina for a clear vision. The diameter of eye for a normal adult is about 2.5 cm. Hence, the image-distance, in other words, the distance between eye lens and retina is fixed always at 2.5 cm for a normal eye. We can just discuss the optical functioning of eye without giving importance to the refractive indices of the two liquids, aqueous humor and virtuous humor present in the eye A person with normal vision can see objects kept at infinity in the relaxed condition with maximum focal length f_{max} of the eye as shown. Also at a distance of 25 cm in the strained conditionwith minimum focal length f_{min} of the eye as shown.

Let us find fmax and fmin of human eye from the lens equation given below.

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

[illegible]

[illegible]

When the object is at near point, u = –25 cm, and v = 2.5 cm, the eye can see the object in strained condition with f_{min}. Substituting these values in the lens equation gives,

[illegible]

See, the small variation of $f_{max} - f_{min}$ = 0.23cm of the focal length of eye lens makes objects visible from infinity to near point for a normal person. Now, we can discuss some common defects of vision in the eye.

Nearsightedness (myopia)

A person suffering from nearsightedness or myopia cannot see distant objects clearly. This may result because the lens has too short focal length due to thickening of the lens or larger diameter of the eyeball than usual. These people have difficulty in relaxing their eye more than what is needed to overcome this difficulty. Thus, they need correcting lens.

The parallel rays coming from the distant object get focused before reaching the retina as shown. But, these persons can see objects which are nearer. Let x be the maximum distance up to which a person with nearsightedness can see as shown. To overcome this difficulty, the virtual image of the object at infinity should be formed at a distance x from the eye using a correcting lens as shown.

The focal length of the correcting lens for a myopic eye can be calculated using the lens equation.

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

Here, u = –∞, v = –x. Substituting these values in the lens equation gives,

$$\frac{1}{f} = \frac{1}{-x} - \frac{1}{-\infty}$$

Focal length f of the correcting lens is,
$f = -x$

The negative sign in the above result suggests that the lens should be a concave lens. Basically, the concave lens slightly diverges the parallel rays from infinity and makes them focus now at the retina which got earlier focused before reaching retina in the unaided condition.

Farsightedness (hypermetropia)

A person suffering from farsightedness or hypermetropia or hyperopia cannot clearly see objects close to the eye. It occurs when the eye lens has too long focal length due to thining of eye lens or shortening of the eyeball than normal. The least distance for clear vision for these people is appreciably more than 25 cm and the person has to keep the object inconveniently away from the eye. Thus, reading or viewing smaller things held in the hands is difficult for them. This kind of farsightedness arising due to aging is called presbyopia as the aged people cannot strain their eye more to reduce the focal length of the eye lens.

The rays coming from the object at near point get focused beyond the retina as shown. But, these persons can see objects which are far say, more than 25 cm. Let y be the minimum distance from the eye beyond which a person with farsightedness can see as shown. To overcome this difficulty, the virtual image of the object at y should be formed at a distance of 25 cm (near point) from the eye using a correcting lens as shown.

The focal length of the correcting lens for a hypermetropic eye can be calculated using the lens equation.

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

Here, u = –y, v = –25 cm. Substituting these values in the lens equation gives,

$$\frac{1}{f} = \frac{1}{-y} - \frac{1}{-25cm}$$

Simplifying the above equation gives,

$$\frac{1}{f} = \frac{1}{25cm} - \frac{1}{y} = \frac{y - 25cm}{y \times 25cm}$$

$$f = \frac{y \times 25cm}{y - 25cm}$$

The focal length calculated using above formula will be positive as y is always greater than 25 cm. The positive sign of the focal length suggests that the lens should be a convex lens. In principle, the convex lens slightly converges the rays coming from beyond y and makes them focus now at the retina which got earlier focused beyond retina for the unaided eye.

Astigmatism

Astigmatism is the defect arising due to different curvatures along different planes in the eye lens. Astigmatic person cannot see all the directions equally well. The defect due to astigmatism is more serious than myopia and hyperopia. The remedy to astigmatism is using of lenses with different curvatures in different planes to rectify the defect. In general, these specially made glasses with different curvature for different planes are called as cylindrical lenses.

Due to aging people may develop combination of more than one defect. If it is the combination of nearsightedness and farsightedness then, such persons may need a converging glass for reading purpose and a diverging glass for seeing at a distance. Bifocal lenses and progressive lenses provide solution for these problems.

Sound

8th term – 3

Unit 1

SOUND

Production of Sound

Sound is produced when an object is set tovibrate. Vibration means a kind of rapid to and fromotion of an object. This to and fro motion of thebody causes the substances around it to vibrate.Thus sound spreads to the surroundings. The substance through which sound is transmitted is called medium. Sound moves through a medium from the point of generation to the listener. We can understand the production of sound with the help of some activities.

On plucking the rubber band, it starts vibrating. You can hear a feeble humming sound as long as the rubber band is vibrating. The humming sound stops as soon as the rubber band stops vibrating. This confirms that sound is produced by vibrating bodies. You can see this kind of vibrations in stringed musical instruments, such as guitar and sitar also.

This activity shows that vibrating pan produces sound. In this case vibrations can be felt by touching the pan. But in some cases vibrations are visible.

The above activities show that sound is produced when an object is set to vibrate. The sound produced by vibration is propagated from one location to another. When it reaches our ear we hear the sound.

Propagation of Sound

When you call your friend who is standing at a distance, your friend is able to hear your voice. How your friend is able to hear your voice? He is able to hear because your sound travels from one place to another. As we saw earlier sound is a form of energy and it needs a medium to travel. This can be understood from the activity given below.

> Thomas Alva Edison, in 1877 invented the phonograph, a device that played the recorded sound.

It is clear from this experiment that sound cannot travel in vacuum and it needs a medium like air. Sound travels in water and solids also. The speed of sound is more in solids than in liquids and it is very less in gases.

The speed of sound is the distance travelled by it in on We second. It is denoted by ‘v’. It is represented by the expression, $v = n \lambda$, where ‘n’ is the frequency and ‘λ’ is the wavelength.

Problem 1

A sound has a frequency of 50 Hz and a Wave length of 10 m. What is the speed of the sound

Solution

Problem 2

A sound has a frequency of 5 Hz and a speed of 25 ms-1. What is the wavelength of the sound?

Solution

The speed of sound depends on the properties of the medium through which it travels, like temperature, pressure and humidity. In any medium, as the temperature increases the speed of sound also increases. For example, the speed of sound in air is 331 ms-1 at 0°C and 344 ms-1 at 22°C. The speed of sound at a particular temperature in various media are listed in Table.

State	Substance	Speed (ms-1)
Speed (ms-1)	Aluminum	6420
	Steel	5960
	Iron	5950
Liquid	Sea Water	1530
	Distilled Water	1498
Gases	Aluminum	6420
	Steel	965
	Iron	346
	Iron	316

We saw that sound travels in different medium with different speed. Now let us see how it travels in a medium. When a body vibrates, the particle of the medium in contact with the vibrating body is first displaced from its equilibrium position. It then exerts a force on the adjacent particle. This process continues in the medium till the sound reaches the ear of the person. In order to understand this let us consider a vibrating tuning fork. When a vibrating tuning fork moves forward, it pushes and compresses the air in front of it, creating a region of high pressure. This region is called a compression (C), as shown in. When it moves backward, it creates a region of low pressure called rarefaction (R). These compressions and rarefactions produce the sound wave, which propagates through the medium.

Vibrating tuning fork

Sound Waves

Sound is a form of energy. It is transferred through the air or any other medium, in the form of mechanical waves. Mechanical wave is a disturbance, which propagates in a medium due to the repeated periodic motion of the particles of the medium, from their mean position. The disturbance which is caused by the vibrations of the particles is passed over to the next particle. It means that the energy is transferred from one particle to another as a wave motion.

Characteristic of wave motion

1. **In wave motion, only the energy is transferred not the particles.**
2. **The velocity of the wave motion is different from the velocity of the vibrating particle.**
3. **For the propagation of a mechanical wave, the medium must possess the properties of inertia, elasticity, uniform density and minimum friction among the particles.**

How do astronauts communicate with each other? The astronauts have devices in their helmets which transfer the sound waves from their voices into radio waves and transmit it to the ground (or other astronauts in space). This is exactly the same as how radio at your home works.

Types of mechanical wave

There are two types of mechanical wave. They are

1. Transverse wave

2. Longitudinal wave

Transverse wave

In a transverse wave the particles of the medium vibrate in a direction, which is perpendicular to the direction of propagation of the wave. E.g. Waves in strings, light waves, etc. Transverse waves are produced only in solids and liquids.

Transverse wave

Longitudinal wave

In a longitudinal wave the particles of the medium vibrate in a direction, which is parallel to the direction of propagation of the wave. E.g. Waves in springs, sound waves in a medium. Longitudinal waves are produced in solids, liquids and also in gases.

Longitudinal wave

Properties of Sound

All sounds that you hear are not the same. There are some properties that differentiate one kind of sound from another. We will study about these properties now.

Loudness

It is defined as the characteristic of a sound that enables us to distinguish a weak or feeble sound from a loud sound. The loudness of a sound depends on its amplitude. Higher the amplitude louder will be the sound and viceversa. When a drum is softly beaten, a weak sound is produced. However, when it is beaten strongly, a loud sound is produced. The unit of loudness of sound is decibel (dB).

Pitch

The pitch is the characteristic of sound that enables us to distinguish between a flat sound and a shrill sound. Higher the frequency of sound, higher will be the pitch. High pitch adds shrillness to a sound. The sound produced by a whistle, a bell, a flute and a violin are high pitch sounds.

Normally, the voice of a female has a higher pitch than a male. That is why a female's voice is shriller than a male's voice. Some examples of low pitch sound are the roar of a lion and the beating of a drum.

Quality or Timbre

The quality or timbre is the characteristic of sound that enables us to distinguish between two sounds that have the same pitch and amplitude. For example in an orchestra, the sounds produced by some musical instruments may have the same pitch and loudness. Yet, you can distinctly identify the sound produced by each instrument.

Audibility and Range

According to the frequency we can classify the sound into three types. They are:

- Audible sound
- Infrasonic sound
- Ultrasonic sound

Audible sound

Sound with frequency ranging from 20 Hz to 20000 Hz is called sonic sound or audible sound. These sounds can be heard by the human beings only. Human ears cannot hear sounds with frequencies below 20 Hz or above 20000 Hz. So, the above range is called as audible range of sound.

Infrasonic sound

A sound with a frequency below 20 Hz is called as subsonic or infrasonic sound. Humans cannot hear the sound of this frequency, but some animals like dog, dolphin, etc., can hear. Uses of infrasonic sound are given below.

- **It is employed in the Earth monitoring system.**
- **It is also used in the study of the mechanism of the human heart.**

Ultrasonic sound

A sound with a frequency greater than 20000 Hz is called as ultrasonic sound. Animals such as bats, dogs, dolphins, etc., are able to hear certain ultrasonic sounds as well. Some of the uses of ultrasonic sounds are given below.

- **It is extensively used in medical applications like 'sonogram'.**
- **It is used in the SONAR system to detect the depth of the sea and to detect enemy submarines.**
- **It is also employed in dish washers.**
- **Another important application of ultra sound is the Galton's whistle. This whistle is inaudible to the human ear, but it can be heard by the dogs. It is used to train the dogs for investigation.**

A bat can hear the sounds of frequencies higher than 20,000 Hz. Bats produce ultrasonic sound during screaming. These ultrasonic waves help them to locate their way and the prey.

Musical Instruments

Some sounds are pleasing to the ear and make you happy. The sound that provides a pleasing sensation to the ear is called 'music'. Music is produced by the regular patterns of vibrations. Musical instruments are categorized into four types as given below.

- Wind instruments
- Reed instruments
- Stringed instruments
- Percussion instruments

Wind instruments

In a wind instrument the sound is produced by the vibration of air in a hollow tube. The frequency is varied by changing the length of the vibrating air column. Trumpet, Flute, Shehnai and Saxophone are some well-known wind instruments.

Reed instruments

A reed instrument contains a reed. Air, which is blown through the instrument, causes the reed to vibrate, which in turn produces the specific sound. Examples of reed instruments include Harmonium and Mouth Organ.

Stringed instruments

Stringed instruments make use of a string or wire to produce vibrations and hence the specific sound. These instruments also have hollow boxes that amplify the sound that is produced. The frequency of sound is varied by varying the length of the vibrating wire. Violin, Guitar, Sitar are some of the examples of stringed instruments.

A guitar string has a number of frequencies at which it will naturally vibrate. These natural frequencies are known as the harmonics of the guitar string. The natural frequency, at which an object vibrates, depends upon the tension of the string, the linear density of the string and the length of the string.

Musical instruments

Percussion instruments

Percussion instruments produce a specific sound when they are struck, scrapped or clashed together. They are the oldest type of musical instruments. There is an amazing variety of percussion instruments all over the world. Percussion instruments like the drum and tabla consist of a leather membrane, which is stretched across a hollow box called the resonator. When a membrane is hit, it starts vibrating and produces the sound.

Sound produced by Humans

In a human being, the sound is produced in the voice box, called the larynx, which is present in the throat. It is located at the upper end of the windpipe. The larynx has two ligaments called 'vocal cords', stretched across it. The vocal cords have a narrow slit through which air is blown in and out. When a person speaks, the air from the lungs is pushed up through the trachea to the larynx. When this air passes through the slit, the vocal cords begin to vibrate and produce a sound. By varying the thickness of the vocal cords, the length of the air column in the slit can be changed. This produces sounds of different pitches. Males generally have thicker and longer vocal cords that produce a deeper, low pitch sound in comparison with females.

Structure of Larynx

Mechanism of Human Ear

The ear is the important organ for all animals to hear a sound. We are able to hear sound through our ears. The human ear picks up and interprets high frequency vibrations of air. Ears of aquatic animals are designed to pick up high frequency vibrations in water. The outer and visible part of the human ear is called pinna (curved in shape). It is specially designed to gather sound from the environment, which then reaches the ear drum (tympanic membrane) through the ear canal. When the sound wave strikes the drum, the ossicles move inward and outward to create the vibrations. These vibrations are then picked up by special types of cells in the inner ear. From the inner ear the vibrations are sent to the brain in the form of signals. The brain perceives these signals as sounds.

Human EarNoise Pollution

Any sound that is unpleasant to the ear is called noise. It is the unwanted, irritating and louder sound. Noise is produced by the irregular and non-periodic vibrations. Noise gives you stress. The disturbance produced in the environment by loud and harsh sounds from various sources is known as noise pollution. Busy roads, airplanes, electrical appliances such as mixer grinder, washing machine and un-tuned radio cause noise pollution. Use of loudspeakers and crackers during the festivals also contributes to the noise pollution. The major source of noise pollution is from the industries. Noise pollution is the bi-product of industrialisation, urbanisation and modern civilisation.

Health hazards due to noise pollution

Noise creates some health hazards. Some of them are listed below.

- **Noise may cause irritation, stress, nervousness and headache.**
- **Long term exposure to noise may change the sleeping pattern of a person.**
- **Sustained exposure to noise may affect hearing ability. Sometimes, it leads to loss of hearing.**
- **Sudden exposure to louder noise may cause a heart attack and unconsciousness.**
- **It causes lack of concentration in one's work. Noise of horns, loud speakers, etc., cause disturbances leading to lack of concentration.**
- **Noise pollution affects a person's peace of mind. It adds to the existing tensions of modern living. These tensions results in disease like high blood pressure or short tempered nature.**

Controlling noise pollution

We studied about the harmful effects of noise pollution. Hence, it becomes necessary for us to reduce it. Noise pollution can be significantly reduced by adopting the following steps.

- **Strict guidelines should be set for the use of loudspeakers on social, religious and political occasions.**
- **All automobiles should have effective silencers.**
- **People should be encouraged to refrain from excessive honking while driving.**
- **Industrial machines and home appliances should be properly maintained.**
- **All communication systems must be operated in low volumes.**
- **Residential areas should be free from heavy vehicles.**
- **Green corridor belt should be set up around the industries as per the regulations of the pollution control board.**
- **People working in noisy factories should wear ear plugs.**
- **People should be encouraged to plant trees and use absorbing materials like curtains and cushions in their home.**

Hearing Loss

You may have hearing loss without realizing it. The following are the symptoms of hearing loss.

- Ear ache
- A feeling of fullness or fluid in the ear.
- Ringing in your ears

Hearing loss is caused by various reasons. Some of them are listed below.

- Aging
- Ear infections if not treated
- Certain medicines
- Genetic disorders
- A severe blow to the head
- Loud noise

Unit – 8 Sound

Production of sound

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

- When you strike the tuning fork on the rubber pad, it starts vibrating. These vibrations cause the nearby molecules to vibrate. Thus, vibrations produce sound.

Propagation of Sound Waves

Sound needs a medium for propagation

- 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 8.1. 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).

Sound is a wave

- 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 not the particles of the medium. All the particles of the medium restrict themselves with only a small to and fro motion called vibration whichenables the disturbance to be carried forward. This disturbance which is carried forward in a medium is called wave.

Longitudinal nature of sound waves

- From the above activity you can see 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 waves 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 also is 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 spread apart. A sound wave is an example of a longitudinal mechanical wave. Figure 8.2 represents the longitudinal nature of sound wave in the medium.

Characteristics of a Sound Wave

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

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 calledfrequency 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.

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.

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)

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 amplitudeof 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 8.4 shows the wave shapes of a soft and loud sound of the same frequency.

- 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.

2. Pitch

- Pitch is one of 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 8.6 consists of two waves representing low pitch and high pitch sounds.

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.

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.

$$\textbf{speed (v)} = \frac{Distance}{Time}$$

- 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

$$\textbf{speed (V)} = \frac{onewavelengh\ (\gamma)}{onetimeperiod\ (T)} \quad \textbf{(or)} \quad \textbf{v} = \frac{\gamma}{T}$$

As, $T = \frac{1}{n}$, the speed (v) of sound is also written as, v = n λ.
The speed of sound remains almost the same for all frequencies in a given medium under the same physical conditions.

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 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 8.1.

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

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 can talk to each other very easily through the sea water.

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 it is reflected.
- Direction of incident sound, the reflected sound and the normal are in the same plane.

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.

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.

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.

- 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. 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.

- 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.

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 oftheir sound absorbing properties. There is aseparate branch in physics called acoustics which takes these aspects of sound in to account while designing auditoria, opera halls, theaters etc.

Ultrasonic Sound or Ultrasound

- Ultrasonic sound is the term used for soundwaves 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 in 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 inexamining inner parts of the body. 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 usedas a medical diagnostic tool. Ultrasonic sound is having application in marine surveying also.

Applications of ultrasonic waves

- **Ultrasounds 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.**

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'. Then, the speed of sound through sea water is $2d / t = v$

- 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.

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.

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.

10^th^ standard

Unit – 5 ACOUSTICS

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
- Suppose you and your friend are on theMoon. Will you be able to hear any sound produced by your friend? As the Moon doesnot have air, you will not be able to hear anysound produced by your friend. Hence, youunderstand that the sound produced due to the vibration of different bodies needs a material medium like air, water, steel, etc, forits propagation. Hence, sound can propagate through a gaseous medium or a liquid medium or a solid medium.

Longitudinal Waves

- Sound waves are longitudinal waves that can travel through any medium (solids,liquids, gases) with a speed that dependson the properties of the medium. As soundtravels through a medium, the particles of the medium vibrate along the direction ofpropagation 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.

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., wavesproduced by bats.

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 ms^{-1} at NTP	Light waves travel in air with a speed of 3×10^{8} ms^{-1}.

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 ms^{-1}.

Particle velocity:

- The velocity with which the particles of the medium vibrate in order to transfer the energyin 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.

∴ Velocity =Distance/Time taken

- If the distance travelled by one wave istaken 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

$$\therefore V = \lambda / T \quad (5.1)$$

- Therefore, velocity can be defined as the distance travelled per second by a sound wave.Since, Frequency (n) =1/T, equation 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, $v_S > v_L > v_G$

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.

$v / \sqrt{1d}$

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:

$v_T = (v_o + 0.61\ T)\ ms^{-1}$

- Here, v_o is the velocity of sound in the gas at 0° C. For air, $v_o = 331\ ms^{-1}$. Hence, the velocity of sound changes by $0.61\ ms^{-1}$ 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

s.no	Nature of the medium	Name of the medium	Speed of sound (in ms^{-1})
1		Copper	5010
2	Solid	Iron	5950
3		Aluminium	6420
4		Kerosene	1324
5	Liquid	Water	1493
6		Sea water	1533
7	Gas	Air	331
8		Air	343

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 ischaracterized 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.

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.

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.

- 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.
- The sound waves that travel towards the reflecting surface are called the incident waves. The sound wavesbouncing 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 reflectingsurface.
- 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'.

Reflection at the boundary of a denser medium

- A longitudinal wave travels in a medium in the form of compressions and rarefactions. Suppose a compression travelling in air from left to right reaches a rigid wall. The compression exerts a force F on the rigid wall. In turn, the wall exerts an equal and opposite reaction R = - F on the air molecules.

- This results in a compression near the rigid wall Thus, a compression travelling towards the rigid wall is reflected back as a compression. That is the direction of compression is reversed

Reflection at the boundary of a rarer medium

- Consider a wave travelling in a solid medium striking on the interface between the solid and the air. The compression exerts a force F on the surface of the rarer medium. As a rarer medium has smaller resistance for any deformation, the surface of separation is pushed backwards. As the particles of the rarer medium are free to move, a rarefaction is produced at the interface.Thus, a compression is reflected as a rarefaction and a rarefaction travels from right to left.

More to know: What is meant by rarer and denser medium? The medium in which the velocity of sound increases compared to other medium is called rarer medium. (Water is rarer compared to air for sound).The medium in which the velocity of sound decreases compared to other medium is called denser medium. (Air is densercompared to water for sound)

Reflection of sound in plane and curved surfaces

- When sound waves are reflected from aplane surface, the reflected waves travel in adirection, according to the law of reflection.The intensity of the reflected wave is neither decreased nor increased. But, when the sound waves are reflected from the curved surfaces,the intensity of the reflected waves is changed.When reflected from a convex surface, the reflected waves are diverged out and the intensity is decreased. When sound is reflected from a concave surface, the reflected waves are converged and focused at a point. So the intensity of reflected waves is concentrated at a point. Parabolic surfaces are used when it is required to focus the sound at a particular point.

- Hence, many halls are designed with parabolic reflecting surfaces. In elliptical surfaces, sound from one focus will always be reflected to the other focus, no matter where it strikes the wall.

- This principle is used in designing whispering halls. In a whispering hall, the speech of a person standing in one focus can be heard clearly by a listener standing at the other focus.

Whispering Gallery

One of the famous whispering galleries is in St. Paul's cathedral church in London. It is built with elliptically shaped walls. When a person is talking at one focus, his voice can be heard distinctly at the other focus. It is due to the multiple reflections of sound waves from the curved walls.

ECHOES

- An echo is the sound reproduced due to the reflection of the original sound from various rigid surfaces such as walls, ceilings, surfaces of mountains, etc.

- If you shout or clap near a mountain or near a reflecting surface, like a building you can hear the same sound again. The sound, which you hear is called an echo. It is dueto the reflection of sound. One does not experience any echo sound in a small room.This does not mean that sound is not reflected in a small room. This is because smaller rooms do not satisfy the basic conditions for hearing an echo.

Conditions necessary for hearing echo

1. The persistence of hearing for human ears is 0.1 second. This means that you can hear two sound waves clearly, if the time interval between the two sounds is at least 0.1 s. Thus, the minimum time gap
between the original sound and an echo must be 0.1 s.

2. The above criterion can be satisfied only when the distance between the source of sound and the reflecting surface would satisfy the following equation:

Velocity = distance travelled by sound / time taken

$$V = 2d/t$$

$$d = vt/2$$

Since, t = 0.1 second, then $d = v \times 0.1/2 = v/20$

- Thus the minimum distance required to hear an echo is 1/20th part of the magnitude of the velocity of sound in air. If you consider the velocity of sound as 344 ms^{-1},the minimum distance required to hear anecho is 17.2 m.

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Applications of echo

- Some animals communicate with each other over long distances and also locate objects by sending the sound signals and receiving the echo as reflected from the targets.

- The principle of echo is used in obstetric ultrasonography, which is used to create real-time visual images of the developingEmbryo or fetus in the mothers uterus.This is a safe testing tool, as it does not useany harmful radiations.

- Echo is used to determine the velocity of sound waves in any medium.

Measuring velocity of sound by echo method Apparatus required:

- A source of sound pulses, a measuring tape, a sound receiver, and a stop watch.

Procedure:

1. Measure the distance 'd' between the source of sound pulse and the reflecting surface using the measuring tape.

2. The receiver is also placed adjacent to the source. A sound pulse is emitted by the source.

3. The stopwatch is used to note the time interval between the instant at which the sound pulse is sent and the instant at which the echo is received by the receiver. Note the time interval as 't'.

4. Repeat the experiment for three or four times. The average time taken for the given number of pulses is calculated.

Calculation of speed of sound:

- The sound pulse emitted by the source travels a total distance of 2d while travelling from the source to the wall and then back to the receiver. The time taken for this has been observed to be 't'. Hence, the speed of soundwave is given by:

Speed of sound =distance travelled/time taken = 2d/t.

APPLICATIONS REFLECTION OF SOUND
Sound board

- These are basically curved surfaces (concave), which are used in auditoria and halls to improve the quality of sound. This board is placed such that the speaker is at the focus of the concave surface. The sound of the speaker is reflected towards the audience thus improving the quality of sound heard by the audience.

Ear trumpet

- Ear trumpet is a hearing aid, which is useful by people who have difficulty in hearing.In this device, one end is wide and the other end is narrow. The sound from the sources fall into the wide end and are reflected by its walls into the narrow part of the device. This helps in concentrating the sound and the sound enters the ear drum with more intensity. This enables a person to hear the sound better.

Mega phone

- A megaphone is a horn-shaped device used to address a small gathering of people. Its one end is wide and the other end is narrow. When a person speaks at the narrow end, the sound of his speech is concentrated by the multiple reflections from the walls of the tube.Thus, his voice can be heard loudly over a long distance.

DOPPLER EFFECT

- The whistle of a fast moving train appears to increase in pitch as it approaches a stationary listener and it appears to decreaseas the train moves away from the listener.

- This apparent change in frequency was first observed and explained by Christian Doppler (1803-1853), an Austrian Mathematician and Physicist. He observed that the frequency of the sound as received by a listener is different from the original frequency produced by thesource whenever there is a relative motion between the source and the listener.

- This is known as Doppler effect This relative motion could be due to various possibilities as follows:

(i) **The listener moves towards or away from a stationary source**
(ii) The source moves towards or away from a stationary listener
(iii) Both source and listener move towards or away from one other
(iv) The medium moves when both source and listener are at rest

- For simplicity of calculation, it is assumed that the medium is at rest. That is the velocityof the medium is zero.Let S and L be the source and the listener moving with velocities vS and vL respectively.

- Consider the case of source and listener moving towards each other (Figure 5.7). As the distance between them decreases, the apparentfrequency will be more than the actual source frequency.

- Let n and n' be the frequency of the sound produced by the source and the sound observed by the listener respectively. Then,the expression for the apparent frequency n' is

$$n' = (v + v L / v - vs)n$$

- Here, v is the velocity of sound waves in the given medium. Let us consider different possibilities of motions of the source and the listener. In all such cases, the expression for the apparent frequency

s.no	Position of source and listener	Note	Expression for apparent frequency
1	1.Both source and listener move 2.They move towards each other	a)Distance between source and listener decreases. b)Apparent frequency is more than actual frequency	$n' =(v+vL/v-vs)n$
2	1.Both source and listener move 2.They move away from each other	Distance between source and listener increases. b) Apparent frequency is less than actual frequency. c) vS and vL become opposite to that in case-1.	$n'=v-(vL/v+vs)n$
3	Both source and listener move They move one behind the other Source follows the listener	a)Apparent frequency depends on the velocities of the source and the listener. b) vS becomes opposite to that in case-2.	$n' = (v - vL/v - vs)n$
4	Both source and listener move They move one behind the other Listener follows the source	a)Apparent frequency depends on the velocities of the source and the listener. b)vS and vL become opposite to that in case-3.	$n' =(v + Vl/v + vs)n$
5	Source at rest Listener moves towards the source	a)Distance between source and listener decreases. b)Apparent frequency is more than actual frequency.	$n' =(v + vL/v) n$

		c) vS = 0 in case-1.	
6	Source at rest Listener moves away from the source	a)Distance between source and listener increases. b)Apparent frequency is less than actual frequency. c) vS = 0 in case-2.	$n' = (v - vL/v)\ n$
7	Listener at rest Source moves towards the listener	a)Distance between source and listener decreases. b)Apparent frequency is more than actual frequency. c) vL = 0 in case-1.	$n' = (v/v - vs)n$
8	Listener at rest Source moves away from the listener	a) Distance between source and listener increases. b) Apparent frequency is less than actual frequency. c) vL = 0 in case-2.	$n' = (v/v + vs)n$

- Suppose the medium (say wind) is moving with a velocity W in the direction of the propagation of sound. For this case, the velocity of sound, 'v' should be replaced with (v + W). If the medium moves in a direction opposite to the propagation of sound, then 'v' should be replaced with (v - W).

Conditions for no Doppler effect

- Under the following circumstances, there will be no Doppler effect and the apparent frequency as heard by the listener will be thesame as the source frequency.

(i) **When source (S) and listener (L) both areat rest.**
(ii) When S and L move in such a way that distance between them remains constant.
(iii) When source S and L are moving in mutually perpendicular directions.
(iv) If the source is situated at the center of the circle along which the listener is moving.

Applications of Doppler effect

(a) To measure the speed of an automobile

- An electromagnetic wave is emitted by a source attached to a police car. The wave is reflected by a moving vehicle, which acts as a moving source. There is a shift in the frequency of the reflected wave. From the frequency shift, the speed of the car can be determined. This helps to track the over speeding vehicles

(b) Tracking a satellite

- The frequency of radio waves emitted bya satellite decreases as the satellite passes away from the Earth. By measuring the change in the frequency of the radio waves, the location

of the satellites is studied.

(c) RADAR (Radio Detection And Ranging)

- In RADAR, radio waves are sent, and the reflected waves are detected by the receiver of the RADAR station. From the frequencychange, the speed and location of the aeroplanes and aircrafts are tracked.

(d) SONAR

- In SONAR, by measuring the change in the frequency between the sent signal and received signal, the speed of marine animals and submarines can be determined.