Standards and units

Laws of physics are expressed in terms of physical quantities such as time, force, temperature, density and numerous other parameters. Physical quantities are often divided into fundamental and derived quantities. Derived quantities arc those whose definitions are based on other physical quantities, e.g., speed, area, density, etc. Fundamental quantities are not defined in terms oL other physical quantities, e.g., length, mass and time.

Physical quantities may, in general, be divided in two classes:

(1) Scalar quantities

(2) Vector quantities.

A scalar quantity is one which has only magnitude. A vector quantity has both magnitude and direction. Thus, when we say that the height of a tree is 20 metres or there is 5 litres of water in a bucket, we are dealing with scalar quantities. On the other hand, when we say that a force of 2 Newton (newton is a unit of force) is acting on a body, the information is incomplete unless we state the direction of force, for instance 2 Newton vertically upwards. Force is therefore a vector quantity. Mass, length, time, volume, speed, energy, work are examples of scalar quantities. Velocity, momentum, force. acceleration are examples of vector quantities.

The measurement of physical quantities involves two steps:

(i) the choice of a standard (unit) and

(ii) the comparison of the standard to the quantity to be measured. Thus a number and a unit determine the measure of a quantity. For example, when we say that the mass of a person is 75 kilograms, it means that his mass is 75 times the unit of mass, kilogram. Thus all measurements in physics require standard units. Earlier, workers in various countries used different systems of units.

In 1960, the General Conference of Weights and Measures recommended that a metric system of measurements called the International System of Units, abbreviated as SI units,be used. The seven fundamental SI units are given in the following table:

Fundamental SI units

Base quantity	Name	Symbol
Length	meter	m
Mass	Kilogram	Kg
Time	Second	S
Electric current	ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Derived SI units

Other quantities, called derived quantities, are defined in terms of the seven base quantities via a system of quantity equations. The SI derived units for these derived quantities are obtained from these equations and the seven SI base units. Examples of such SI derived units are given in the following table, where it should be noted that the symbol 1 for quantities of dimension 1 such as mass fraction is generally omitted.

Some commonly used units other than SI units

• **Light years:** The light year is a unit of length and is equal to the distance travelled by light in one year. It is used to express large astronomical distances like the distance between the sun and earth etc. 1 Light Year = 9.46 X 1015m

• **An Astronomical Unit (A.U)** is the mean distance from the centre of the earth to centre of the sun. 1 A. U = 1.495 X 1011m.

• **F.P.S system** is used in Britain, where length is measured in Foots, mass in Pounds and time in Seconds.

• **In C.G.S system**, length is measured in Centimeter, mass in Grams and time Seconds.
• **Barrel** is the internationally used unit for measuring the volume of crude oil. 1 Barre-; 159 Litres.

Nature of Light: Earlier light was believed to be of wave nature only. At the beginning of the 20th century, it became known that the wave theory of light often becomes inadequate for treatment of the interaction of light with matter, and light often behaves somewhat like a stream of particles. This confusion about the true nature of light continued for some years till a modern quantum theory of light emerged in which light is neither a 'wave' nor a 'particle' — The new theory reconciles the particle properties of light with the wave nature.

Rectiilinear propagation: The formation of shadows with sharp edges'demonstrates the rectilinew propagation of light, i.e., the fact that light travels in straight lines. When an opaque obstacle is placed between a source of light and a screen, a shadow of the obstacle is formed on the screen. The kind of shadow depends on the size of the source of light. If it is a point source (light from a small hole), the shadow obtained is a region of total darkness, called umbra. If an extended source of light, e.g., a bulb, is used, the umbra is surrounded by a region of partial darkness, called penumbra.

Reflection of Light

A highly polished surface, such as a mirror, reflects most of the light falling on it. Reflection is governed by following laws:

• The angle of incidence is equal to the angle of reflection, and

• The incident ray, the normal to the mirror at the point of incidence and the reflected ray, all lie in the same plane.

Reflection of light can be by two types of surfaces

• Plane Mirrors

• Spherical Mirrors

Plane Mirrors:

Image formed by a plane mirror is

• Virtual and erect.

• The size of the image is equal to that of the object.

• The image formed is as far behind the mirror as the object is in front of it. • The image is laterally inverted.

Kaleidoscope: The kaleidoscope is a toy in which multiple images are formed by two strips of plane minors placed at an angle of 600 inside a tube. Small, bright-coloured glass pieces are scattered on a ground-glass plate at the bottom of the tube. When viewed from the other end of the tube, beautiful symmetrical patterns, formed by the coloured glass pieces and their five images, are seen.

Spherical Mirrors: The reflecting surface of such mirrors can be considered to form ra part of the surface of a sphere. The reflecting surface of a spherical mirror may be curved inwards or °outwards. A spherical mirror, whose reflecting surface is curved inwards, that is, faces towards the centre of the sphere, is called a concave mirror. A spherical mirror, whose reflecting surface is curved outwards, is called a convex mirror.

Important terms associated with Spherical mirrors — Pole: The centre of the reflecting surface of a spherical. It lies on the surface of the mirror. The pole is usually represented by the letter P.

Centre: The reflecting surface of a spherical mirror forms a part of a sphere.

This sphere has a centre. This point is called the centre of curvature of the spherical mirror. It has represented by the letter C in the figure. The centre of curvature is not a part of the mirror. It lies outside curvature of a concave mirror lies in front of it. However, it lies behind the mirror in case of a convex mirror.

Radius of Curvature: The radius of the sphere of which the reflecting surface of a spherical mirror forms a part, is called the radius of curvature of the mirror. It is represented by the letter R. In the fig, PC is the Radius of Curvature.

Principle Axis: The imaginary straight line passing through the pole and the centre of curvature of a .spherical mirror is called the principal axis. It is normal to the mirror at its pole.

Focus: The point where the incident rays which are parallel to the principal axis converge to form an image or appear to be emerging from, in case of concave mirror)is called focus. In the fig, F is the focus.

Focal Length: The distance of focus from the position of the mirror gives the focal length of the mirror. In the fig, PF is the focal length.

Aperture: The reflecting surface of a spherical mirror is by and large spherical. The surface, then, has a circular outline. The diameter of the reflecting surface of spherical mirror is called its aperture. For spherical mirrors of small apertures, the radius of curvature is found to be equal **to twice the focal length.** This implies that the principal focus of a spherical mirror lies midway between the pole and centre of curvature.

Uses of Concave Mirrors

• Concave mirrors are commonly used in torches, search-lights and vehicles headlights to get powerful parallel beams of light.
• They are often used as shaving mirrors to see a larger image of the face.
• The dentists use concave mirrors to see large images of the teeth of patients.

• Large concave mirrors are used to concentrate sunlight to produce heat in solar furnaces.

Uses of Convex Mirror

Convex mirrors are commonly used as rear-view (wing) mirrors in vehicles. These mirrors are fitted on the sides of the vehicle, enabling the driver to see traffic behind him/her to facilitate safe driving. Convex mirrors are preferred because they always give an erect, though diminished, image. Also, they have a wider field of view as they are curved outwards. Thus, convex mirrors enable the driver to view much larger area than would be possible with a plane mirror.

Refraction of Light

When a ray of light passes from one medium to another, it suffers a change in direction at the boundary separating the two media. This phenomenon is called refraction. The following are the laws of refraction of light.

(i) 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.

(ii) The ratio of sine of angle of incidence to the sine of angle of refraction is a constant, for the light of a given colour and for the given pair of media. This law is also known as **refraction**.

If i is the angle of incidence and r is the angle of refraction, then,

Sin i / Sin r = constant

This constant value is called the refractive index of the second medium with respect to the first.

The refractive Index

The extent of the change in direction that takes place when a ray of light travels from one media to the other, is expressed in terms of the refractive index. The value of the refractive index for a given pair of media depends upon the speed of light in the two media. Consider a ray of light travelling from medium 1 into medium 2. Let v1 be the speed of light in medium 1 and v2 be the speed of light in medium 2. The refractive index of medium 2 with respect to medium 1 is given by the ratio of the speed of light in medium 1 and the speed of light in medium 2. This is usually represented by the symbol n21.

The absolute refractive index of a medium is simply called its refractive index. In comparing two media, the one with the larger refractive index is optically denser medium than the other. The other medium of lower refractive index is optically rarer. The speed of light is higher in a rarer medium than a denser medium. Thus, a ray of light travelling from a rarer medium to a denser medium slows down and bends towards the normal. When it travels from a denser medium to a rarer medium, it speeds up and bends away from the normal.

Some effects of.refraction

• The bottom of a tank or a pond containing water appears to be raised.

• When a thick glass slab is placed over some printed matter, the letters appear raised when viewed through the glass slab.

• A pencil partly immersed in water in a glass tumbler appears to be displaced at the interface of air and water.

• An object kept in water in a glass tumbler appears to be bigger than its actual size, when viewed from the sides.

• A coin kept in a bowl and is not visible initially becomes visible on pouring water into the bawl.

• The apparent random wavering or flickering of objects seen through a turbulent stream of hot air rising above a fire- or a radiator due to refraction between the hot air just above the fire and the surrounding cold air.

• The **twinkling of stars** is due to atmospheric refraction of starlight. The starlight, on entering the earth's atmosphere, undergoes refraction continuously before it reaches the earth due to gradually changing refractive index.

• The Sun is visible to us about 2 minutes before the actual sunrise, and about 2 minutes after the actual sunset because of atmospheric refraction.

Refraction by Spherical Lenses

A transparent material bound by two surfaces, of which one or both surfaces are spherical, forms a lens. A lens may have two spherical surfaces, bulging outwards. Such a lens is called a double convex lens. It is simply called a convex lens. It is thicker at the middle as compared to the edges. Convex lens converges light rays as shown in the figure. Hence convex lenses are called converging lenses. Similarly, a double concave lens is bounded by two spherical surfaces, curved inwards. It is thicker at the edges than at the middle. Such lenses diverge light rays as shown in figure. Such lenses are called diverging lenses. A double concave lens is simply called a concave lens. A lens, either a convex lens or a concave lens, has two spherical surfaces. Each of these surfaces forms a part of a sphere. The centres of these spheresare called centres of curvature of the lens. The centre of curvature of a lens is usually represented by the letter C. There are two centres of curvature, one for each curved surface. An imaginary straight line passing through the two centres of cun/ature of a lens is called its **principal axis**.

Power of a lens

The degree of convergence or divergence of light rays achieved by a lens is expressed in terms of its power. The power of a lens is defined as the reciprocal of its focal length. It is represented by the letter P. The power P of a lens oflfocal length f is given by P. If. The SI unit of power of a lens is 'dioptrei. lt is denoted by the letter D. The power of a convex lens is positive and that of a concave lens is negative.

Refraction and Dispersion of Light through a Prism

A prism has two triangular bases and three rectangular lateral surfaces. These sun'aces are inclined to each other. The angle between its two lateral faces is called the angle of the prism. A prism splits the incident white light into a band of colours.

The various colours seen are Violet, Indigo, Blue, first Green, Yellow, Orange and Red splitting of light into its component colours is called dispersion. Different colours of light have different refractive indices and hence bend through different angles with respect to the incident ray as they pass through a prism, causing a spectrum of colours. The red light bends the least while the violet the most.

Rainbow: A rainbow is a natural spectrum appearing in the sky after a rain shower. lt is caused by dispersion of sunlight by tiny water droplets, present in the atmosphere. A rainbow is always formed in a direction opposite to that of the Sun. The water droplets act like small prisms. They refract and disperse the incident sunlight, then reflect it ,, internally, and finally refract it again when it comes out of A the raindrop. Due to the dispersion of light and internal reflection, different colours reach the obsener s eye.
Total Internal Reflection Light can always pass from one medium to an optically denser medium but it cannot always pass into a rarer medium. If the angle of incidence of light in the denser medium is greater than a particular angle (known as the critical angle for that medium), the light is not at all refracted into the rarer medium but is totally reflected. This is known as Total Internal Reflection.

Applications of Total Internal Reflection:

• **Optical fibers:** When light is incident at one end of the fiber, it undergoes repeated total internal reflections and emerges at the other end (Details are covered in the section on Fiber Optics)

• **Mirage:** 4t is usually associated with hot deserts. The air in the desert is hot near the ground and cools rapidly with height. The hotter air is optically less dense. Rays of light from the top of a tree (or the sky) suffer successive bending as they pass through the warmer layers of decreasing density. This results in the gradual increase of the angle of incidence. Eventually, a stage comes when the angle of incidence exceeds the critical angle and, therefore, total internal reflection takes place. After this the rays start bending upwards. An observer sees the tree upside down (as well as the actual tree) as if he were seeing the reflection on a surface of water (See fig).On hot summer days, motorists quite often see similar mirages on the roads.

Scattering of Light

If the molecules of a medium, after absorbing incoming radiations, emit them in all possible directions, the process is called scattering.

Rayleigh has shown that the intensity of scattered light is inversely proportional to fourth power of wavelength (or directly proportional to fourth power of frequency).

Some effects of scattering

Tyndall effect: When a beam of light strikes the fine particles of atmosphere or any colloidal solution, the path of the beam becomes visible. This is due to the scattering of light by the colloidal particles and is called Tyndall effect.

Blue Colour of sky: When sunlight passes through the atmosphere, the fine particles in air scatter the blue colour (shorter wavelengths) more strongly than red. The scattered blue light enters our eyes, thus making sky look blue to us.

Danger signal lights are red in colour as red is least scattered by fog or smoke. Therefore, it can be seen in the same colour at a distance.

Reddish appearance of sun at

light and shorter wavelengths are scattered away by the particles. Therefore, the light that reaches our eyes is of longer wavelengths, giving rise to the reddish appearance of the Sun. However, light from the Sun overhead travets relatively shorter distance through atmosphere and hence only little scattering occurs at noon.

Some other effect associated with Light

Interference: The superposition of two (or more) waves of the same kind that pass the same point in space at the same time is called interference. If the waves are in the same phase, e.g., crest on crest, their amplitudes combine to produce a strong wave (bright spot). This is called constructive interference. If the waves are out of phase, e.g., if crests of one are superposed on the troughs of another, we get destructive interference (dark spot). Thus interference generally produces alternate dark and bright bands on a screen if monochromatic light is used. For white light, coloured bands are obtained.
Beautiful colours seen in soap bubbles and oil films on water are also produced due to the interference of white light reflected by these surfaces.

Diffraction: When a beam of light passes through a narrow slit or an aperture, it spreads out to a certain extent into the region of geometrical shadow. This is called diffraction which in other words is the failure of light to travel in a straight line. Diffraction is a particular case of interference and is due to the wave nature of light. A diffraction grating is a device used to cause diffraction. Gratings may be prepared by ruling equidistant parallel lines on to a glass (transmission grating) or metal surface (reflection grating).

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• The data on a CD are in the form of pits arranged in a spiral. The spiral has its turns so closely wound that a CD acts like a reflection grating. So when a CD is viewed in white light one sees rainbow like colours due to reflection and diffraction.

• **Holography:** It is the technique of recording and reproducing three dimensional images. A laser beam partly reflected from an object and partly from a mirror produces interference fringes on a photographic plate, which then becomes a hologram. When laser light is transmitted through the hologram, one can see a three-dimensional virtual image of the object.

Fiber Optics An interesting use of the total internal reflection is in optical fibers, which are fine strands of high quality glass about the diameter of a human hair. When light is incident at one end of the fiber, it undergoes repeated total internal reflections and v ---z-z emerges at the other end without suffering from any Basic structure of an optical fiber The basic structure of an optical fiber consists of three parts; the core, the cladding, and the coating or buffer as shown in the figure.

The core is a cylindrical rod of dielectric material. Dielectric material conducts no electricity. Light propagates mainly along the core of the fiber. The core FISFF is generally made of glass. The core is surrounded by a layer of material called the cladding. The index of refraction of the cladding material is less than that of the core material so that total internal reflection may occur. For extra protection, the cladding is enclosed in an additional layer called the coating or buffer. The coating or buffer is a layer of material used to protect an optical fiber from physical damage. The material used for a buffer is a type of plastic.

Types of Optical Fibers

Single Mode Fibers: They have small cores but tremendous carrying capacity and low intrinsic transmission losses which makes them an ideal transmission medium for long distances.

Multi Mode Fibers: They have a larger core than single mode fibers but have a lower capacity in terms of information transmitted and hence are used in systems with short transmission distances.

Advantages of Optical Fibers over conventional copper cables

Less Attenuation - lt is especially advantageous for long-distance cornmunications, because light propagates through the fiber with little attenuation compared to electrical cables.

Immunity to Electromagnetic Interference - Fiber optics are immune to any Electromagnetic interference since signals are transmitted as light instead of current. "

Data Security - Magnetic fields and current induction in copper cables let the information on the conductor to be leaked out. There are no radiated magnetic fields around optical fibers; the electromagnetic fields are confined within the fiber. That makes it impossible to tap the signal being transmitted through a fiber.

No Spark Hazards - ln some cases, transmitting signals electrically can be extremely dangerous. Most electric potentials create small sparks. Fiber optic cables do not produce sparks since they do not carry current.

Ease Of Installation - increasing transmission capacity of wire cables generally makes them thicker and more rigid. Such thick cables can be difficult to install in existing buildings where they must go through walls and cable ducts. Fiber cables are easier to install since they are smaller and more flexible.

High Bandwidth Over Long Distances - Fiber optics have a large capacity to carry high speed signals over longer distances without repeaters than other types of cables. As they are thinner than copper cables, so more fibers can be bundled into given diameter cable, thus increasing the information carrying capacity or bandwidth.

Disadvantages of Optical Fibers:

- Limited physical arc of cable. it bent too much, it will break.
- It is difficult to splice.
- Physical vibrations of the cable will show up as signal noise.
- Loss of light in fiber due to scattering and other effects takes place.

Uses and Applications of Opticai Fibers

- **Telecommunications industry -** in telecommunication systems, information, which can be either in the analog or digital form reaches the transmitter through a coder.

The coder converts information into a sequence of pulses (bits). The transmitter is usually a semiconductor laser or LED which is modulated by an information bearing signal and converts electrical signals into light. After passing through the fiber, this light reaches the receiver that converts optical signal into the information bearing signal. This electrical signal after demodulation in decoder produces the audio signal.

• **Medicine Industry -** Bundles of tiny optical fibers are used by doctors to see the inside of a patient's stomach. Light is piped down some of the fibers to illuminate the inside of the stomach and is reflected back along some other fibers. This procedure is called endoscopy.

• **Mechanical Imaging —** It can be used for inspecting pipes, engines, airplanes etc. Fiber scope is a flexible fiber optic bundle with eye piece and lens at the other end used for inspection works to examine components in a tightly packed environment.

Other Uses - Optical fibers can be used for the purposes of illumination, often carrying light from outside to rooms in the interiors of large buildings. Another important application of optical fibers is in sensors. If a fiber is stretched or Squeezed, heated or cooled or subjected to some other change of environment, there is usually a small but measurable change in light transmission. Hence, a rather cheap sensor can be made. Fiber optics are also used to carry high power laser beams from fixed installations within factories to the point of use of the laser light for welding, cutting or drilling.

Lasers

A laser is an optical device that produces an intense beam of coherent monochromatic light. A laser is not a source of energy. it is simply a converter of energy taking advantage of stimulating emission to concentrate a certain fraction of energy (commonly 1 %) into radiation of a single frequency, moving in a single direction. Although Albert Einstein gave the idea of laser (without using this acronym) in 1917, scientists began work on the idea only in 1950. American scientist Gordon Gould suggested the name Laser in 1957. The first working laser was built in 1960 by the American scientist Theodore Maiman.

Components of Laser A laser consists of A gain medium A mechanism to supply energy to it Optical feedback mechanism is The gain medium is a material with properties that allow it to amplify light by stimulated is emission. Light of a specific wavelength that passes through the gain medium is amplified (increases in power) from an optical cavity~a pair of mirrors on either end of the gain medium. Light bounces back and forth between the mirrors, passing through the gain medium and being amplified each time. Typically one of the two mirrors, the output coupler, is partially transparent. Some of the light escapes through this mirror.

Some common applications of lasers

Communications - Communications can be carried in a laser beam directed through space, through atmosphere, or through optical fibers that can bend like cables.

Computers and Electronics

- Lasers are used for recording and storing information including recording ol music, motion pictures, computer data etc on a CD in the pattern of tiny pits. A highly focused laser beam allows much more information to be stored on a CD (7OOMB) by using infra red laser, DVD (4.7GB) using red laser and Blue ray disc using blue laser, with a storage capacity of 25 GB or even more.
- Lasers can also read and play back the information recorded on a disc. In a CD or DVD player, a laser beam reflects off the pattern of pits s the CD spins and

other devices in the player change the reflections into electrical signals and decode them into music.

- Lasers also greatly enhance the speed of computers, so the superconductors use semiconductor laser of Gallium Arsenide. ‘ Barcode scanners - Supermarkets use barcode scanners that use lasers to scan the universal barcode to identify products.

• **Heat treatment —** A laser beam's highly focused energy can produce a great amount of heat and thus can be used for cutting, welding and even for drilling holes.

• Holography — It is a method of storing and displaying a 3D image using laser beams usually on a photographic plate or light sensitive material. • Nuclear research — Scientists use laser to produce controlled miniature hydrogen bomb explosions. Lasers are used for concentrating huge amount of energy on hydrogen pellets in bringing them up to the thermo-nuclear temperatures. The laser is already playing a concrete role in speeding up the day when we may control thermo-nuclear fusion.

• Medicine — Lasers are used for blood less surgeries including dissolving kidney and gall stones. Eye surgeons use lasers to 'weld' detached retinas back into place without making incision.

• **Surveying and measurement —** Lasers are used to measure distances. An object's distance can be measured by measuring the time a pulse of laser light takes to reach and reflect back from the object. Laser devices used to measure shorter distances are called Laser Range Finders. Surveyors use laser devices to get information needed to make maps. Laser beams have been used to measure the exact distance between the earth and the moon and to provide information on continental drift. Police use special guns emitting short bursts of infrared laser lights to measure the speed of vehicles. A laser speed gun measures the round trip time for light to reach a vehicle and reflect back. If the gun takes a large number (say 1000) of readings per second, it can compare the change in distance between readings and calculate the speed of vehicles.

Military applications — Missiles may have laser beam detectors which help in seeking reflected beam and accordingly adjust their flight to hit the spot where the beam is aimed. Under advanced military applications, US is developing 'Mobile tactical high energy laser' (MTHEL) which could be used as field deployable weapons system able to track incoming missiles by radar and destroy them with powerful Deuterium Fluoride Laser. Strategic Defence Initiative of US, also called as STAR WARS, involve space based laser system to destroy incoming Intercontinental Ballistic Missiles. In India, DRDO has made a laser range finder to be used in The Main Battle Tank 'Arjun' to improve its accuracy. ISRO has developed LEA\ R (Laser detection and ranging laser) for tracking satellites.

Other Uses - The detection and measuring of pollutants in vehicular exhaust gases is accomplished with lasers. A laser beam is used as a knife to rapidly and accurately cut cloth in garment factories, as a tool for meat inspection, and for finger print detection,

BASICS OF MOTION

When a body changes its position with respect to something else as time goes on, we say the body is in motion. Mechanical motion is of two types —

• Translational (linear)

• Rotational (spin) The motion of a car on a road is translational whereas the motion of a top, spinning on its axis is rotational.

Basic Concepts in Motion Speed The speed of a moving body is the rate at which it covers distance, i.e., the distance it covers per unit of time. Distance Speed Time The SI unit of speed is m/s. Speed is a scalar quantity.

Velocity The distance covered by an object 'in a specified direction' in unit time interval is called velocity. The SI unit of velocity is also m/s. In ordinary conversation, the velocity is often confused with speed. The difference between them is that speed refers only to the distance covered by a moving object whereas velocity takes into account the direction also. For example, a motorcyclist driving his vehicle with a uniform speed of 30 km/h on a circular track is not moving with a uniform velocity since his direction is continuously changing. Velocity is a vector quantity.

Acceleration The velocity of a body changes due to change in its speed or direction or both. The rate of change of the velocity of a body is called its acceleration. Change in Velocity Acceleration Time

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Acceleration The velocity of a body changes due to change in its speed or direction or both. The rate of change of the velocity of a body is called its acceleration. Change in Velocity Accelaration Time Usually the term acceleration is used When the velocity of a body increases. When the velocity decreases the body is said to undergo retardation or deceleration. Acceleration is also a vector quantity and it SI units are m/s2.

Acceleration due to Gravity The most familiar acceleration is due to gravity. When something is dropped it does not fall with uniform velocity. A cricket ball released from the top of a tall building strikes the ground with a much higher velocity than a ball released from the first floor. if we jump off a table, we strike the floor with greater impact than if we jump off a small stool.

The value of the acceleration due to gravity (g) on the surface of the earth is about 9.8 m/s2. This means that when a body falls freely, its velocity increases every second by 9.8 m/s. The value of g is constant at a place but varies slightly with the latitude and therefore changes from place to place.

Equations of Motion Equations of motion are very useful in finding out the basic parameters like velocity, acceleration etc of a body at a given point of time. If an object, travelling with an initially velocity u, accelerates for time t with uniform acceleration a, then the final velocity v is given by $v = u + at$ The distance S travelled by an object moving with uniform acceleration a for a time t from an initial velocity u is given by $S = ut + 1/2$ ate Another equation which relates v, u and S without using time t can be written as - v2 u2 = 2as

Example 1: A train travelling at 72 km/h decelerates uniformly at 2 m/s2. How much time does it take to stop?

Initial velocity Final velocity

u = 72 km/h or 20 m/s v = 0

Acceleration a = - 2 m/s2 (Deceleration or retardation is negative acceleration.) Use v = u + at By putting all values and solving for t, we get, t = 10 seconds. Example 2: A cyclist accelerates at 1 m/s2 from an initial velocity of 3 m/s for 10s. Find the distance covered by the cyclist in 10 seconds. Initial velocity = 3 m/s

Graphical Representation of Motion
Graphs provide a convenient method to present basic information about a variety l». events. To describe the motion of an object, we can use line graphs. ln this case, line graphs show dependence of one physical quantity, such as distance or velocity, on another quantity, such as time. Useful information about motion of an object can also be obtained from graphs.

Displacement-Time Graph The change in the position of an object with time can be represented on the distance- time graph adopting a convenient scale of choice. ln this graph, time is taken along the x axis and distance is taken along the y~axis. Distance-time graphs can be employed under various conditions where objects move with uniform speed, non-uniform speed, remain at rest etc. equal distances in equal intervals of time, graph shows that the distance is increasing at a uniform rate. We can usethe distance- time graph to determine the speed of an object. To do so, consider a small pad AB of the distance-time graph shown in the Fig. Draw a line parallel to the x-axis from point A and another line parallel to the y-axis from point B. These two lines meet each other at point C to form a triangle ABC. Now, on the graph, AC denotes the time interval speed of the body.

To know the distance moved by the car between time t1 and t2 using the Fig, draw perpendiculars fromithe points corresponding to the time t1 and t2 on the graph. The velocity of 40 kmph is represented by the height AC or BD and the time (t2 — t1) is represented by the length AB. So, the distance s moved by the car in time (t2 - t1) can be expressed as
ln the case of non-uniformly accelerated motion, velocity-time graphs can have any shape. E Circular Motion Figur When the velocity of an object changes, we say that the object is accelerating. The change in the velocity could be due to change in its magnitude or the direction of the motion or both. The motion of a body moving along a circular pathgisi therefore,' an example of an accelerated motion. The circumference of a circle of radius r is given by Zrrr. If the athlete takes t seconds to go once around the circular path of radius r, the velocity v is given by When an object moves in a circular path with uniform speed, its motion is called uniform circular motion. There are many examples of objects moving under uniform circular motion, such as the motion of the

moon and the earth, a satellite in a circular orbit around the earth, a cyclist on a circular track at constant speed and so on.

FORCE AND LAWS OF MOTION

The word force generally denotes a push or a pull. ln a hockey match a player hits a stationary ball with his stick and the ball starts moving in a straight line. Another player deflects the moving ball in another direction and yet another player stops the ball. Sometimes a player simply pushes the moving ball to increase its speed without changing its direction. In all the cases the players apply force with their sticks. Thus we can say that force produces (or tends to produce) change in a body's state of rest or of uniform mot/on in a straight line. Consider what happens when more than one force are exerted on a body. lf two persons pull an object in the same direction with equal force, the object will have twice the acceleration than if one pulled alone. lf, however, the two pulled with equal force but in opposite directions, the object will not accelerate because the oppositely directed equal forces cancel one another and the net force in zero.

It should be noted that zero net force, and therefore, zero acceleration does not necessarily imply zero velocity. Zero acceleration means that the object maintains its velocity, neither increasing nor decreasing. If the object is at rest, it remains at rest under the action of zero net force. Even when a single force is applied on an object, the idea of net force must be taken into account because forces other than the applied force may act on the object. Usually these other forces are friction forces. The direction of the friction force is always
opposite to the direction of motion. lf under the action of an applied force, a wooden block slides on a table top with constant velocity (i.e., zero acceleration), we conclude that no net force is acting on the block. Obviously a friction force is acting on the block, equal in magnitude and opposite in direction to the applied force. . _
Centripetal Force .
For a body to move in a circle there must be a force on it directed towards the centre. This is called the centripetal force and is necessary to produce continuous change oi direction in a circular motion. ln case of the moon, gravitational force between the earth and the moon acts as the centripetal force. When a stone tied at one end of a string is whirled in a circle, the pull in the string provides the centripetal torce.
The magnitude of the centripetal force Fe required to cause an object of mass m and speed v to travel in a circular path of radius r is given by the relation-

Centrifugal Force

This force is supposed to be acting on a body revolving in a circle when the motion is analysed with respect to the body's frame of reference. Centrifugal force is equal and opposite to centripetal force, i.e., it acts outwards. lt may be emphasised that centrifugal force is not a real force, however it is invoked to explain various phenomena successfully.

Friction

Friction is the force which opposes the relative motion of two surfaces in contact. Friction plays an important role in our lives. lt is friction between the ground and the soles of out shoes that makes walking possible and it is lack of friction that makes our feet slip on highly polished surfaces.

Types of Friction

Sliding friction - The force of friction that acts when a body is moving (sliding) on a surface is called sliding friction. The amount of sliding friction depends on the nature of the two surfaces and not on the area of contact. However, it also depends on the weight of the moving body. Heavier objects experience more friction.

Q Rolling Friction - When a cylindrical or spherical body rolls over a surface; the force opposing the motion is called rolling friction. For the same pair of materials, rolling friction is much smaller than sliding friction. While friction' is necessary in some circumstances, it becomes a nuisance in others. Friction in machines wastes energy and also causes wear and tear. This friction is reduced by using
(i) lubricants, and
(ii) ball bearings. The presence of a liquid lubricant in a machine prevents metal to metal contact and since the friction between liquid layers (called viscosity) is much less than the friction between solids, the frictional forces in the machine are greatly reduced.

Since rolling friction is much less than sliding friction, theuse of ball bearings in a machine considerably reduces friction. When an object moves through air, frictional forces oppose its motion. However, air friction is much less than liquid friction. This is demonstrated by a hovercraft, which travels smoothly on a cushion of air. A hovercraft experiences much less frictional forces than a boat of the same size which has to push through waters.

Newton's laws of motion

First Law: Every object continues in its state of rest or of uniform motion in a straight line if no net force acts upon it. In other words, all objects resist a change in their state of motion. In a qualitative way, the tendency of undisturbed objects to stay at rest or to keep moving with the same velocity is called inertia. This is why, the first law of motion is also known as the law of inertia.

Applications of the First Law

A passenger in a fast-moving bus tails forward when it stops suddenly. This happens because the feet of the passenger come to rest suddenly whereas his body continues to be in motion.

In a head-on collision between two vehicles, passengers are quite often injured when they hit the windscreen. The collision stops the vehicle suddenly but the passengers continue their straight-line motion in accordance with the first law and hence hit the screen.
A person getting down from a moving bus has to run some distance, in the direction of the bus, before stopping. lf he does not run he is bound to tall because his feet come to rest whereas his body continues to be in motion.

Second Law: This law states that "the rate of change of momentum of a body is proportional to the applied force and takes place in the For travelling the same distance, a car consumes more fuel on a crowded road than on a tree road. This happens because the car has to stop and start quite often on a crowded road. The repeated acceleration requires a force (second law), which ultimately comes from the fuel. On a free road the car runs at almost uniform speed requiring fewer accelerations and hence less fuel consumption.

Third Law: This law states that "to every action there is an equal and opposite reaction." The statement means that if body A exerts a force on body B, then B exerts an equal and opposite force on A along the same line of action. Thus if a person strikes a wall with his fist, the force on the wall (action) is equal and opposite to the force on the fist (reaction) at the moment of impact.

Applications of the Third Law • Recoil of a gun: When a bullet is fired from a gun equal and opposite forces are exerted on the bullet and the gun. Owing to action, the bullet goes in the forward direction and because of an equal and opposite reaction the gun experiences a recoil in the backward direction.

• Rocket Propulsion: A rocket contains solid chemicals which burn to produce a high velocity blast of hot gases. Space rockets have liquid fuel together with a supply of liquid oxygen to enable the fuel to burn. In either case, the large force created by chemical reaction propels out hot gases through the tail nozzle with a very high velocity. The reaction to this force propels the rocket forward. Though the mass of gases escaping per second is very small, their momentum is very large due to their tremendous velocity of escape. An equal and opposite momentum is imparted to the rocket which, despite its large mass, builds up a high velocity. • Jet Engines - The engine in a jet aeroplane works on the same principle as a rocket but there is a difference in the method of obtaining the high velocity gas jet. The fuel used in a jet engine is kerosene (paraffin). While rockets carry their own oxygen supply, jet engines draw air out of the atmosphere. Therefore, jet engines cannot be used to propel vehicles into outer space where there is no atmosphere.

Impulse It can be seen from Newton's second law that Force x Time = change in momentum The quantity F x t is called impulse. Thus, when a fast-moving car dashes against a wall, it comes to rest and its momentum becomes zero. This large change of momentum imparts high impulse to the wall. Since the car comes to rest suddenly, i.e., the time of impact is short the force of impact is very large. Applications of Impulse

• In a cricket match, when a fielder has to catch a fast moving ball, he moves his hand along with the ball. In doing so he increases the time of contact thereby reducing the force of impact.

• A boxer confronted with a high momentum punch from his opponent minimizes the force of the punch by withdrawing his face along with the punch, thereby increasing the time of contact.

• A karate expert can break a slab with one blow of his bare hand. He brings his hand down with great speed and hence, great momentum. This momentum is changed to zero when he delivers an impulse to the slab. By making the time of contact of his hand with the slab as short as possible, he makes the force of impact huge.

WORK AND ENERGY

The Concept of Work In ordinary conversation work means any kind of physical or mental activity. In mechanics, the term is usually associated with movement. An engine pulling a train is said to do work. A man pushing hard against a wall may get tired but he is not doing any work since he is not able to move the wall. Thus work is said to be done when a force produces motion and is measured by the product of the force and the distance moved in the direction of the force.

A porter carrying a box on his head applies a force equal to the weight of the box in the vertically upward direction. The work done by the porter in carrying the box from the ground floor to the first tloor ot a building is given by the product of the force (weight of the box) and the vertical height of the first floor, even though he might have used a slanting or spiral staircase to walk up, thereby actually covering a largerdistance than the height through which the box has been lifted. Thus it is the distance in the direction of the force which determines the work and not the distance actually covered.

Power

The definition of work says nothing about the time during which the work is done. A porter does the same amount of work in carrying a load up a flight of stairs whether he runs up or walks up. But he feels more tired when he runs up. To distinguish between such cases, the concept of power is introduced. Power is defined as the rate of doing work.

Power Z Work done

Time Taken Thus, when the porter runs up he develops more power and, therefore, gets tired. A strong boy can climb a hill in less time than a weak boy of the same weight because the former is capable of developing more power. The unit of power is watt (W).

Energy

When work is done in winding the spring of a watch, the spring acquires the capacity to do work and is able to run the clock for more than 24 hours. We say that the spring acquires energy. Thus energy is defined as the capacity to do work. The unit of energy also is joule (J). The mechanical energy can be of two kinds - kinetic and potential. Kinetic Energy The energy possessed by an object due to its motion is called kinetic energy and is described by the expression.

Notice that in the expression for kinetic energy, the velocity is squared, which means that if the velocity of an object is doubled, its kinetic energy becomes four times. A car travelling at 60 kmph has four times as much kinetic energy as the same car travelling at 30 kmph.

Potential Energy The energy possessed by an object by virtue of its position is called potential energy. One of the commonest forms of potential energy is that possessed by an object when it is above the level of the earth's surface. This is called gravitational potential energy and is described by the expression

P.E = mgh where m is the mass of the object, g the acceleration due to gravity and h the height of the object above the earth's surface.

There are many examples of potential energy. A stone held at some height above the ground has potential energy. Water in an elevated reservoir possesses potential energy. A stretched or compressed spring also has potential energy.

The concept of energy is much wider than the simple idea of kinetic and potential energies of a mechanical system. In addition to mechanical energy (kinetic and potential), there are several other forms of energy, e.g., heat energy, light energy, sound energy, nuclear energy, etc.

The Principle of Conservation of Energy The principle states that 'Energy can neither be created nor destroyed; it can only he from one form into another; but the total amount of energy remains

When a stone is held at a certain height, its energy is entirely potential-. When the stone is released it starts falling and gains kinetic energy (KE) due to motion. At the same time since its height is decreasing its potential energy (PE) diminishes. Thus the stone gains KE at the expense of its PE. lf we ignore the energy spent in overcoming air friction, then the loss in PE is exactly equal to the gain in KE. Just before hitting the ground its energy is entirely kinetic. On hitting the ground the mechanical energy of the stone is converted into internal (heat) energy and some sound energy. This is an example of the conservation of energy.

Commercial Unit of Energy

The unit joule is too small and hence is inconvenient to express large quantities of energy. We use a bigger unit of energy called kilowatt hour (kWh). Let us say we have a machine that uses 1000 J of energy every second. lf this machine is used continuously for one hour, it will consume 1 kWh of energy. Thus, 1 kW h is the energy used in one hour at the rate of 1000 J per second (or 1 kW power).

GRAVITATION

Gravitational Force The gravitational force exists between all bodies, even between two apples lying on a table. It is gravitational force that holds the moon in its orbit round the earth and the earth in its orbit round the sun.

Newton's Law of Universal Gravitation — It states that every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. In equation form, the gravitational force Gmini2

F = r2 where r is the distance between two particles of masses rn, and m2 and G the universal gravitational constant. The value of G is 6.67 X 1 0-1 1 Si units.

The Concept of Weight The weight of a body is the force with which the earth attracts the body towards its centre. The weight of a body should not be confused with its mass, which is a measure of the quantity of matter contained in it. When we say that a person weighs 60 kg, we are actually describing his mass and not weight. The mass of a body is a constant quantity whereas its weight varies slightly from place to place on the earth, Some interesting observations about Weight The weight of a body is maximum at the poles and minimum at the equator. This variation in weight is due to the shape of the earth and the rotation of the earth about its axis. The earth is not a perfect sphere but bulges at the equator. The equatorial radius is more than the polar radius by about 21.5 km. Therefore, from Newton's law of gravitation (see the equation above), it can be easily seen that gravitational force, and hence the weight of a body at the poles, should be more than that at the equator.

Due to the rotation of the earth, a body on the surface of the earth revolves in a circular path and, therefore, a centrifugal force acts on it. The centrifugal force is zero exactly at the poles and maximum at the equator. Since the centrifugal force radius as it talls. We thus conclude that the higher the speed of the stone, the greater the radius of the curved path. lt somehow we could throw the stone with such tremendous speed that the radius ot its path became a little greater than the radius of me earth, the stone would never tall on the eanh and would keep revolving around it.This is the principle of an artificial satellite. " .

ln the case ot a satellite, revolving around the earth, the centripetal force is provided by the gravitational pull of the earth We can calculate the speed of a satellite-at a distance from the centre of the earth by equating the centripetal torce with gravitational force. Thus if m is the mass ofthe satellite and g the acceleration due to gravit'y, From both the relations, we see that the speed of the satellite does not depend on" its mass. lt means that at a panicular distance from the earth, all objectswould have thesame speed ot revolution. . The relation v = \/GM/r shows that vis inversely proportional to the square root of r. Thus it a satellite moves from a higher orbit to a lower orbit, its speed increases.
This is approximately equal to 28,500 km/h. It the speed is lower than this, the projected satellite would simply fall to the eanh, while at a higher speed it would have an elliptical rather than a circular orbit. If, however the speed is more than 11.2 km/s or 25,000 miles/hour, the satellite would escape from the earth entirely and would never come back_ This is called escape velocity. The existence of gaseous atmosphere on the earth is due to the high value of its escape velocity. Since the gaseous molecules have velocities much less than 11.2 km/s, they cannot escape from the earth‘s field and hence form the atmosphere around. On the moon the value of the escape velocity is 1.9 km/s (nearly one-sixth of that on earth). It any gases are formed on the moon, the molecules would have velocities greater than 1.9 km/s and would therefore escape, leaving the moon bare.

To give the desired speed to a satellite and overcome the force of gravity, the munching of a satellite requires a tremendous force. This is achieved with the help of rockets.

Since the force of gravity is minimum at the equator, it is easier to launch satellites from equatorial regions. Since the earth rotates from west to east, satellites are launched in the eastward direction to give them additional push. It is still easier to launch satellites from space shuttles orbiting the earth. The USA launched a geostationary satellite from its space shuttle 'Discovery' in 1985.

Geostationary or Synchronous Satellites

A geostationary satellite is one which appears stationary with respect to the earth. The period of rotation of the earth about its axis is 24 hours. Thus if a satellite orbiting the earth over the equator has a 24-hour period of revolution, it appears stationary. The 24-hour period is possible when a satellite is at a height of nearly 35,000 km above the earth. Geostationary satellites are used for communication and weather forecasting.

Kepler's Three Laws of Planetary Motion

In the early 1600s, Johannes Kepler proposed three laws of planetary motion. Keploi was able to summarize the carefully collected data of his mentor - Tycho Brahe – with three statements that described the motion of planets in at sun-centered solar system. Kepler's efforts to explain the underlying reasons for such motions are no |OTlQf'I 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 follows:

The path of the planets about the sun is elliptical in shape, with the center of the sun being located at one focus. (The Law of Ellipses) An imaginary line drawn from the center of the sun to the center of the planet will sweep out equal areas in equal intervals of time. (The Law of Equal Areas). Thus. this law describes the speed at which any given planet will move while orbiting the sun. The speed at which any planet moves through space is constantly changing. A planet moves fastest when it is closest to the sun and slowest when it is furthestfrom the sun. Yet. if an imaginary line were drawn from the center of the planet to the center of the sun, that line would sweep out the same area in equal periods of
time.

The ratio of the squares of the time periods of revolution of any two planets is equal to the ratio of the cubes of their average distances from the sun. (The Law of Harmonies). ln other words, the ratio T2/R3 remains the same for every planet. Thus, this law compares the orbital period and radius of orbit of a planet to those of other planets. Unlike Kepler's first and second laws that describe the motion characteristics of a single planet, the third law makes a comparison between that: motion characteristics of different planets.

SOME MISCELLANEOUS CONCEPTS IN MECHANICS

Moment of a Force/Torque The turning effects of forces are widely utilised in everyday life. When a door is opened, the force on the handle exerts a turning effect about the hinges. lt is a common experience that a large force is needed to open the door if the force is applied near the hinges. Thus the turning effect of a force depends on two factors: (i) the magnitude of the force, and (ii) the distance of the line of the force from the axis or fulcrum about which turning takes place. The turning effect of a force is called its moment and isdefined as follows:

Moment of a force about a point or axis = Force X perpendicular distance of the line of action of the force from the point or axis. lt is obvious that the turning effect of a small force can be increased by applying it at a large distance. Spanners, used for screwing and unscrewing nuts and bolts, work on this principle. While playing on a see-saw, a weak boy can balance a healthy boy by sitting at a funher distance from the fulcrum, thereby increasing his turning effect.

Centre of Gravity

The centre of gravity of a body is the point where the who/e weight of the body can be considered to act. The centre of gravity of a body may even lie outside the actual material of the body. For example, the centre of gravity of a ring lies at its centre, which is outside its material.

Stability and Centre of Gravity: The stability of an object is connected with the position of its centre of gravity (CG). If the vertical through the CG passes through the base of an object, then it is stable, otherwise it is unstable and topples down. Bodies with low CGs and wide bases are more stable. Some of the applications of this concept in real life situations are-

~ Racing cars are built low and with wide wheelbases to reduce the risk of overturning at sharp bends.

~ While crossing a river in a boat, passengers are not allowed to stand. This keeps the CG of the system (boat and passengers) low and ensures stability.

ln a double-deck bus, more passengers are allowed in the lower deck than in the upper deck. Moreover, standing is not allowed in the upper deck. This is done to keep the CG fairly low.

Tall lamp stands have heavy bases so that the CG is low. A potter carrying a load on his back leans forward to keep the vertical line passing through the CG of the system (load plus himself) between his feet. A person has to bend forward while going uphill and backward while coming down. He bends in order to keep the vertical line passing through his CG always between his feet, thereby increasing his stability.

In an advanced stage of pregnancy women develop back pains. The CG of a pregnant woman extends forward, beyond the area bounded by her feet. To maintain her balance she extends her upper body backward to bring her CG above her feet, which unfortunately often causes a back pain.

Machines

A machine is a device by which a small force applied at convenient point can be used to overcome a large force at some other point. Although the force overcome by a machine is many times greater than the input force, the energy or work output can never be greater than the input energy or work. In principle, Work Input = Work Output Efficiency of a Machine: ln a machine, some energy is always wasted in overcoming frictional forces. In practice, therefore, the useful work done by a machine is always less than the input work. The ratio of the useful work done by a machine and the input work is called the efficiency of the machine. Usually, this ratio is expressed as a percentage,

OSCILLATIONS

Periodic and Oscillatory motions A motion that repeats itself at regular intervals of time is called periodic motion. Very often the body undergoing periodic motion has an equilibrium position somewhere inside its path. When the body is at this position no net external force acts on it. Therefore, if it is left there at rest,.it remains there forever. If the body is given a small displacement from the position, .a force comes into play which tries to bring the body back to the equilibrium point, giving rise to oscillations or vibrations. For example, a ball placed in a bowl will be in equilibrium at the bottom. If displaced a little from the point, it will perform oscillations in the bowl. Every oscillatory motion is periodic, but every periodic motion need not be oscillatory. Circular motion is a periodic motion, but it is not oscillatory. There is no significant difference between oscillations and vibrations. It seems that when the frequency is small, we call it oscillation (like the oscillation of a branch of a tree), while when the frequency is high, we call it vibration (like the vibration of a string of a musical instrument). Simple harmonic motion is the simplest form of oscillatory motion. This motion arises when the force on the oscillating body is directly proportional to its displacement from the mean position, which is also the equilibrium position. Further, at any point in its oscillation, this force is directed towards the mean position.

In practice, oscillating bodies eventually come to rest at their equilibrium positions, because of the damping due to friction and other dissipative causes. However, they can be forced to remain oscillating by means of some external periodic agency. Any material medium can be pictured as a collection of a large number of coupled oscillators. The collective oscillations of the constituents of a medium manifest themselves as waves. Examples of waves include water waves, seismic waves, electro-magnetic waves.

Some Basic Terms Associated with Oscillations —Time Period: We have seen that any motion that repeats itself at regular intervals of time is called periodic motion. The smallest interval of time after which the motion is repeated is called its period. It is denoted the period by the symbol T. Its S.I. unit is second. For periodic motions, which are either too fast or too slow on the scale of seconds, other convenient units of time are used. The period of vibrations of a quartz crystal is expressed in units of microseconds (10 -6 s) abbreviated as ps. On the other hand, the orbital period of the planet Mercury is 88 earth days. The Halley's comet appears after every 76 years.

Frequency: The reciprocal of T gives the number of repetitions that occur per unit time. This quantity is called the frequency of the periodic motion. It is represented by the symbol v. The relation between v and T is v 1/T The unit of v is thus s After the discoverer of radio waves, Heinrich Rudolph Hertz (1857-1894), a special name has been given to the unit of frequency. It is called hertz (abbreviated as Hz). Thus, 1 hertz = 1 Hz = 1 oscillation per second =1s -1. Note, that the frequency, v, is not necessarily an integer.

Displacement: For oscillations, displacement refers to change with time of any physical property under consideration. Generally it is convenient to measure displacement of the body from its equilibrium position. For an oscillating simple pendulum, the angle from the vertical as a function of time may be regarded as a displacement variable as shown in the figure below.

For a block attached to a spring, the other end of which is fixed to a rigid wall, the motion of the block can be described in terms of its displacement x from the wall as shown below. The term displacement is not always be referred in the context of position only. Figure 8.2 There can be many other kinds of displacement variables. The voltage across a capacitor, changing with time in an A.0 circuit, is also -a displacement variable. In the same way, pressure variations in time in the propagation of sound wave, the changing electric and magnetic fields in a light wave are examples of displacement in different contexts. The displacement variable may take both positive and negative values.

Simple Harmonic Motion Consider a particle oscillating back and forth about the origin of an x-axis between the limits +A and —A as shown in the figure ipso, Figure 8.3 This oscillatory motion is said to be simple harmonic if the displacement x of the particle from the origin varies with time as: x (t) A cos (w t + (p)

where A, w and cp are constants. Thus, simple harmonic motion (SHM) is not any periodic motion but one in which displacement is a sinusoidal function of time. The figure below shows what the positions of a particle executing SHM are at discrete value of time, each interval of time being T14 where T is the period of motion.

plots the graph of x versus t for a simple harmonic motion as shown, which gives the values of displacement as a continuous function of time. The quantities A, w and cp which characterize a given SHM have standard names, which are as follows • Amplitude (A): The amplitude A of SHM is the magnitude of maximum displacement of the particle. The speed is maximum for zero displacement (at x = 0) and zero at the extremes of motion.

• Phase (wt (p): While the amplitude A is fixed for a given SHM, the state of motion (position and velocity) of the particle at any time t is determined by the argument (wt + (p) in the cosine function. This time-dependent quantity, (wt + (p) is called the phase of the motion.

• Phase Constant (cp): The value of phase at t = 0 is (4) and is called the phase constant (or phase angle.

The Simple Pendulum Consider simple pendulum - a small bob of mass m tied to an inextensible mass less string of length L. The other end of the string is fixed to a support in the ceiling. The bob oscillates in a plane about the vertical line through the support. By calculations, it can be proved that this periodic motion of the bob of the pendulum is simple harmonic _for small displacements from the mean position. The Time Period T for the oscillations comes out to be T = where g 9 is the acceleration due to gravity.

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Mechanical waves: The most familiar type of waves such as waves on a string, water waves, sound waves, seismic waves, etc. is the so-called mechanical waves. These waves require a medium for propagation, they cannot propagate through vacuum. They involve oscillations of constituent particles and depend on the elastic properties of the medium.

Non Mechanical waves: These waves can travel without a medium. Electromagnetic waves are non mechanical and do not necessarily require a medium - they can travel through vacuum. Light, radio waves, X-rays, are all electromagnetic waves.

Matter Waves: A third kind of wave is the so-called Matter waves. They are associated with constituents of matter: electrons, protons, nee --s, atoms and molecules. They arise in quantum mechanical description of nature. Though conceptually more abstract than mechanical or electro-magnetic waves, they have already found applications in several devices basic to modern technology; matter waves associated with electrons are employed in electron microscopes.

Transverse and Longitudinal Waves Transverse Waves: Waves in which the motion of the particles is perpendicular to the motion of the wave, are called transverse waves. Light waves are transverse waves. Transverse waves can be represented as shown in the Fig below.

Longitudinal Waves: Consider a long spiral spring spread along

L a bench or floor. If one end of the spring, is moved back and Figure 9.2 forth, a wave consisting of compressions and rarefactions moves along the spring to the other end as shown in the figure below. Compressions are regions where the loops of the spring are pressed -together and rarefactions those where loops are stretched apart. In the spring the wave travels due to the vibrations of the loops parallel to the direction of travel of the wave. This type is called a longitudinal wave. Sound waves are longitudinal waves.

Basic Parameters used to describe wave motion

• Crest and Trough: The terms crest and trough refer to the highest and the lowest parts of the wave respectively. • Wavelength: The wavelength of a wave is the distance between adjacent crests (or troughs) in the case of transverse waves, or between adjacent compressions (or rarefactions), in the case of longitudinal waves.

• **Time Period:** It is the time taken to complete one full oscillation by the wave.

• **Frequency:.** The frequency of a wave is the number of waves that pass a given point per second. The unit of frequency is vibrations/second or hertz (Hz).

• **Speed:** The speed (v) of all kinds of waves is given by the relation v = vA. where v is the frequency and the A. wavelength. .

• **Amplitude:** The maximum displacement of the particles of the medium from their equilibrium position is called amplitude. In the above figure, it is represented by A.

When a light or a sound wave of a given frequency travels from one medium to another, say from air to water, its velocity and wavelength change. However, the frequency renlains unaltered.

Sound Waves: All sounds are produced by the vibration of materiat objects. The voice results from the vibration of vocal chords in the larynx. In a sitarthe sound is produced by the vibrating string and in a tabla or a drum by the vibrating stretched skin or membrane. In each of these cases, the frequency of the sound wave is identical to the frequency of the vibrating source. Sound waves are longitudinal and cannot travel in vacuum. The transmission of sound requires a medium: air, liquid or solid. Compared to solids and liquids, air is relatively poor conductor of sound. The sound of a distant train, which cannot be heard through air, Can be heard clearly if the ear is placed against the rail.

Characteristics of Sound 7. Pitch and Frequency: The pitch (shrillness) of a sound depends.on its frequency. A sound of higher frequency as a higher pitch. The pitch of a. woman's voice is higher than that of a man, The uman ear is normally sPnQifive to sounds whose frequencies are between 16 and 20,000 Hz. Sound waves with frequencies below 16 Hz are called infrasonic and those with frequencies above 20,000 Hz are called ultrasonic. Though normal human beings cannot hear sounds of frequencies higher than 20,000 Hz, animals such as cats and dogs can. Dolphins produce high pitched sounds of frequency as high as 100,000 Hz. which enable them to locate each other under water.

2. Loudness The loudness of a sound is related to the energy of the waves and depends on amplitude. The relative loudness of a sound is measured in decibels, (db). Some common sounds and their noise levels are listed in following table. It may Pe mentioned here that exposure to a noise level of 85 db or above can impair or damage hearing.

Source of Sound Noise Level (db) Whisper 20 Ordinary conversation 65 Traffic on a busy road 70 Amplified rock music 120 Jet aeroplane, 30 m away. 140

Sometimes, it is desirable to increase the loudness of a sound. This can be achieved by setting a greater mass of air into vibration. -

All stringed instruments, such as the violin, sitar, guitar, etc. have Sound boxes attached to increase the loudness. When a string of a sitar is plucked, very little air is set in motion due to the small surface area of the string. But the vibration of the string sets the sound box into forced vibrations. When the box vibrates; it moves a large amount of air and in-creases loudness.

A loudspeaker has Vibrating cone with a large surface area Thus a large mass of air in contact with the cone is.set into vibration producing a loud sound.

3. Speed of sound waves The pitch and loudness of sounds have no effect on their speed. In dry air at 0°C, the speed of sound is about 331 metres per second or 750 miles per hour. The speed sound shows the following characteristics - The presence of water vapour in the air slightly increases this speed. Thus; th speed of sound increases with humidity.

• Sound travels faster through warm air than through cold air. Obviously, the speed of sound is higher on a hot day than on a cold day. The speed of sound in air increases by 0.61 metre per second for each degree rise in temperature above 0°C. • The speed of sound depends on the medium. It is more in solids, less in liquids, and the least in gases. In steel the speed of sound is nearly 15 times as great as in air. If one end of a long steel rail is struck, two distinct sounds are heard at the other end. The sound which is heard first is propagated through steel and the second one is propagated through air. • The speed of sound is much less than the speed of light (3 X 10" m/s). Thunder is heard, much after the flash of lighting is seen because of the wide difference in the ° speeds of light and sound. The flash is seen almost instantaneously whereas thunder takes time to reach the earth. In a cricket match, spectators hear the sound of ball'on bat a little after they see the batsman actually striking the ball. The sound of a jet plane does not appear to come from the plane at all, but from a point far behind it, simply because the plane travels so fast that it moves a long distance in the time it takes the sound to reach our cars.

Echo Waves have the property of being reflected when they meet an obstacle. When a sound wave is reflected by a distant obstacle, such as a wall or a cliff, an echo is heard. For an echo to be heard separately from the original sound, it must arrive 0.1 s after the original sound is made. This can happen if the minimum distance of the reflecting surface from the source of sound is 17 m. If the distance is less than 17 m, the echo cannot be distinguished as a separate sound and gives the impression of the original sound being prolonged. This prolonging of sound by reflection is called reverberation. Reverberation is also caused when a series of echoes are heard due to more than one reflecting surface.

Applications of the principle of Echo • An echo can be used for measuring the speed of sound. Exploration of underwalet gas and oil is done by detecting the echoes of shock waves produced by explosions on the water surface.

• Echoes of ultrasonic waves are used for measuring the depth of sea-beds or locating submerged objects. An apparatus called Sonar (Sound Navigation and Ranging) is used for this purpose.

Ultrasonic waves are also used for detecting flaws. in the interiors of solids, destroying microorganisms, and mapping underground structures for oil and mineral deposits. • Bats emit ultrasonic waves of frequencies up- to 80,000 Hz and use the reflection of these waves (echoes) to determine the presence and the distance of objects on their way and from them respectively.

• Ultrasonics is applied widely in medical diagnosis and treatment. In sounding out the abdomen, as an example, the sound waves pass through the different tissues at speeds that depend on the elasticity and density of the tissue. As they collide with different structures, they send back echoes, - which are picked up by sensitive microphones and turned into electrical signals on a television screen. Frcin the pattern of the echoes, tumours, abscesses, lesions and other abnormalities can be picked up within the liver, pancreas, kidneys, heart and other organs. Medical Ultrasonography (commonly called Ultrasound) is ideal for use in human beings.

Refraction of Sound When successive layers of air have different temperatures, the ability of sound to travel faster in warm air than in cold air causes bending of sound. This bending of sound is called refraction.

On a warm day, the air near the ground is warmer than the air above and. so the speed of sound waves near the ground is higher. This causes bending of the sound away from the ground. On a cold day or at night, the reverse happens and the sound waves bend towards the earth. Thus on a cold day sounds can be heard over longer distances. Sounds can be heard at abnormally long distances over water on quiet days. This happens because air next to water is cooler than air above and, therefore, sound waves bend towards the water and can travel long distances.

The Concept of Resonance Any vibrating object has a natural frequency, which depends on factors such as the elasticity and shape of the object. Whenever an object or a system is set in oscillation at its natural frequency, as a result of impulses received from some other system vibrating with the same frequency, resonance is said to have occurred. Resonance can occur in different kinds of systems: acoustical, mechanical, electrical and optical. Resonance results in increased amplitude of vibration.

Applications of Resonance

• The amplitude of a child's swing can be increased by giving it small pushes in rhythm with the frequency of the swing. This is an example of resonance.
• A diver jumping repeatedly on the edge of a diving-board sets it into resonant vibration and thus gains considerable uplift before diving.
• Sometimes the amplitudes that result from resonance can be disastrous. While crossing a suspension bridge soldiers are ordered to break step as otherwise the resonant vibrations caused by their marching can severely damage the bridge.
• It is a common observation that the rear view mirrors of vehicles vibrate violently only for particular engine speeds. This happens due to resonance. The rear-view mirror vibrates when the frequency of engine vibrations equals its own natural frequency.
• There are oscillations in an electrical circuit too. A radio receiver is tuned to a station only when the oscillating electrical circuit inside the radio is set into resonance by the incoming signals.

The Doppler Effect

The Doppler effect is the change in frequency of a wave (sound or light) due to the motion of the source or observer. The frequency (and hence pitch) of a sound appears to be higher when the source approaches the listener and lower when the source recedes from him. It is due to the Doppler effect that the whistle of a train appears shriller when it approaches a listener than when it moves away from him.

Applications of Doppler Effect

• Speed guns (or radar sets), used by police to measure the speed of vehicles, use Doppler Effect. A radar set sends out a radio pulse and waits for the reflection. Then it measures the Doppler shift in the signal and uses the shift to determine the speed.

• The Doppler effect is very useful in astronomy. It can be used to find out whether a star is approaching us or receding away from us. When a star is receding from us, the light emitted from the star appears more red (red light is of lower frequency than other colours). Thus the fact that the light emitted by the stars of distant galaxies surfer a red shift when observed from the earth means that these galaxies are receding from our galaxy. This is the principle evidence in favour of the hypothesis of expanding universe.

• Doppler Effect can also be used to detect or even measure the rotation of a star, e.g., the sun. • The effect can be used to track a moving object such as a satellite, from a reference point on the earth. The method is remarkably accurate; changes in the position of a satellite 108 m away can be determined to a fraction of a centimetre.

Sonic Boom A supersonic (faster than sound) aircraft produces a cone of sound called a shock wave. When this shock wave reaches a listener, he hears a sort of loud explosion, called the sonic boom. Beats Beats is an interesting phenomenon arising from interference of waves. When two harmonic sound waves of close (but not equal) frequencies are heard at the same time, we hear audibly distinct waxing and waning of the intensity of the sound, with a frequency equal to the difference in the two close frequencies. Artists use this phenomenon often while tuning their instruments with each other. They go on tuning until their sensitive ears do not detect any beats.

Noise Reduction in Recording Media Dolby Laboratories Inc. is .a music recording company, which has developed techniques to reduce noise levels in recorded music. Dolby noise reduction, employed during recording and during playback, works in tandem to improve the signal-to-noise ratio. Dolby A was company's first noise reduction system, intended for use in professional recording studios. It provided about 10 dB of broadband noise reduction.

Dolby B was developed to achieve about 9 dB noise reduction primarily for cassettes. It was much simpler than Dolby A and therefore less expensive to implement in consumer

products. From the mid- 1970s, Dolby B became standard on commercially pre-recorded mus cassettes. Dolby C provides about 15 dB noise reduction. It first appeared on top-end cassette players in the 1980s.

Dolby SR (Spectral Recording) system is a much more aggressive noise reduction ap; c oach than Dolby A. Dolby SR is much more expensive to implement than Dolby B or C, nut, it is capable of providing up to 25 dB noise reduction in the high frequency range. Dolby S is found on some Hi-Fi and semi-professional recording equipment. It is capable of 10 dB of noise reduction at low frequencies and up to 24 dB of noise reduction at high frequencies.

Electromagnetic Spectrum At the time Maxwell predicted the existence of electromagnetic waves, the only familiar electromagnetic waves were the visible light waves. The existence of ultraviolet and infrared waves was barely established. By the end of the nineteenth century, X-rays and gamma rays had also been discovered. We now know that, electromagnetic waves include visible light waves, X-rays, gamma rays, radio waves, microwaves, ultraviolet and infrared waves. The classification of EM waves according to frequency is the electromagnetic spectrum.

Komar

Radio waves Radio waves are produced by the accelerated motion of charges in conducting wires. They are used in radio and television communication systems. They are generally in the frequency range from 500 kHz to about 1000 MHz. The AM (amplitude modulated) band is from 530 kHz to 1710 kHz. Higher frequencies upto 54 MHz are used for short wave bands. TV waves range from 54 MHz to 890 MHz. The FM (frequency modulated) radio band extends from 88 MHz to 108 MHz. Cellular phones use radio waves to transmit voice communication in the ultrahigh frequency (UHF) band.

Microwaves Microwaves (short-wavelength radio waves), with frequencies in the gigahertz (GHz) range, are produced by special vacuum tubes (called klystrons, magnetrons and Gunn diodes). Due to their short wavelengths, they are suitable for the radar systems used in aircraft navigation. Radar also provides the basis for the speed guns used to time fast balls, tennis-serves. and automobiles. Microwave ovens are an interesting domestic application of these waves. In such ovens, the frequency of the microwaves is selected to match the resonant frequency of water molecules so that energy from the waves is transferred efficiently to the kinetic energy of the molecules. This raises the temperature of any food containing water.

The Principle of Microwave ovens The spectrum of electromagnetic radiation contains a part known as microwaves. These waves have frequency and energy smaller than visible light and wavelength larger than it. All food items such as fruit, vegetables, meat, cereals, etc., contain water as a constituent. The frequency of rotation of water molecules is about 300 crore hertz, which is 3 gigahertz (GHz). If water receives microwaves of this frequency, its molecules absorb this radiation, which is equivalent to heating up water. These molecules share this energy with neighbouring food molecules, heating up the food. One should use porcelain vessels and not metal containers in a microwave oven because of the danger of getting a shock from accumulated electric charges. Metals may also melt from heating. The porcelain container remains unaffected and cool, because its large molecules vibrate and rotate with much smaller frequencies, and thus cannot absorb microwaves. Hence, they do not get heated up. Thus, the basic principle of a microwave oven is to generate microwave radiation of appropriate frequency in the working space of the oven where we keep food. This way energy is not wasted in heating up the vessel. In the conventional heating method, the vessel on the burner gets heated first, and then the food inside gets heated because Of transfer of energy from the vessel. In the microwave oven, on the other hand, energy is directly delivered to water molecules which is shared by the entire food.

Infrared waves Infrared waves are produced by hot bodies and molecules. This band lies adjacent to the low frequency or long-wave length end of the visible spectrum. Infrared waves are sometimes referred to as heat waves. This is because water molecules present in most materials readily absorb infrared waves (many other molecules, for example, 002, NH3, also absorb infrared waves). After absorption, their thermal motion increases, that is, they heat up and heat their surroundings.

• Infrared lamps are used in physical therapy.

• Infrared radiation also plays an important role in maintaining the earth's warmth or average temperature through the greenhouse effect.

Incoming visible light (which passes relatively easily through the atmosphere) is absorbed by the earth's surface and re-radiated as infrared (longer wavelength) radiations. This radiation is trapped by greenhouse gases such as carbon dioxide and water vapour.

• Infrared detectors are used in 'Earth satellites, both for military purposes and to observe growth of crops.

• Electronic devices (for example semiconductor light emitting diodes) also emit infrared and are widely used in the remote switches of household electronic systems such as TV sets, video recorders and hi-fi systems.

Visible rays It is the most familiar form of electromagnetic waves. It is the part of the spectrum that is detected by the human eye. It runs from about 4 x 1014 Hz to about 7 x 1014 Hz or a wavelength range of about 700 —400 nm. Visible light emitted or reflected from objects around us provides us information about the world. Our eyes are sensitive to this range of wavelengths. Different animals are sensitive to different range of wavelengths. For example, snakes can detect infrared waves, and the 'visible' range of many insects extends well into the ultraviolet.

Ultraviolet rays It covers wavelengths ranging from about 4 x 10-7 m (400 nm) down to 6 x 10-10 m (0.6 nm). Ultraviolet (UV) radiation is produced by special lamps and very hot bodies. The

142 ;e of sun is an important source of ultraviolet light. But fortunately, most of it is absorbed in the ozone layer in the atmosphere at an altitude of about 40 — 50 km. UV light in large quantities has harmful effects on humans. Exposure to UV radiation induces the production of more melanin, causing tanning of the skin. UV radiation is absorbed by ordinary glass. Hence, one cannot get tanned or sunburn through glass windows. Welders wear special glass goggles or face masks with glass windows to protect their eyes from large amount of UV produced by welding arcs. Due to its shorter wavelengths, UV radiations can be focussed into very narrow beams for high precision applications such as LASIK (Laser-assisted in situ keratomileusis) eye surgery. UV lamps are used to kill germs in water purifiers. Ozone layer in the atmosphere plays a protective role, and hence its depletion by chlorofluorocarbons (CFCs) gas (such as freon) is a matter of international concern.

X-rays Beyond the UV region of the electromagnetic spectrum lies the X-ray region. We are familiar with X-rays because of its medical applications. It covers wavelengths from about 10-8 m (10 nm) down to 10-13 m (10-4 nm). One common way to generate X-rays is to bombard a metal target by high energy electrons. X-rays are used as a diagnostic tool in medicine and as a treatment for certain forms of cancer. Because X-rays damage or destroy living tissues and organisms, care must be taken to avoid unnecessary or over exposure.

Gamma rays They lie in the upper frequency range of the electromagnetic spectrum and have wavelengths of from about 10-10 m to less than 10-14 m. This high frequency radiation is produced in nuclear reactions and also emitted by radioactive nuclei. They are used in medicine to destroy cancer cells.

Basics of Communication Systems Communication is the act of transmission of information. Modern communication has its roots in the 19th and 20th century in the work of scientists like J.C. Bose, F.B. Morse, G. Marconi and Alexander Graham Bell. The pace of development seems to have increased dramatically after the first half of the 20th century.

Elements of a Communication System Irrespective of its nature, every communication system has three essential eler transmitter, medium/channel and receiver. The block diagram shown in the Figure depicts the general form of a communication system. Communication

In a communication system, the transmitter is located at one place, the receiver is located at some other place (far or near) separate from the transmitter and the channel is the physical medium that connects them. Depending upon the type of communication system, a channel may be in the form of wires or cables connecting the transmitter and the receiver or it may be wireless. The purpose of the transmitter is to convert the message signal produced by the source of information into a form suitable for transmission through the channel. If the output of the information source is a non-electrical signal like a voice signal, a transducer converts it to electrical form before giving it as an input to the transmitter. When a transmitted signal propagates along the channel it may get distorted due to channel imperfection. Moreover, noise adds to the transmitted signal and the receiver receives a corrupted version of the transmitted signal. The receiver has the task of operating on the received signal. It reconstructs a recognisable form of the original message signal for delivering it to the user of information. There are two basic modes of communication which are as follows-

• Point-to-point - In point-to-point communication mode, communication takes place over a link between a single transmitter and a receiver. Telephony is an example of such a mode of communication.

• Broadcast mode: In contrast, in the broadcast mode, there are a large number of receivers corresponding to a single transmitter. Radio and television are examples of broadcast mode of communication.

Basic Terminology Used In Electronic Communication Systems • Transducer: Any device that converts one form of energy into another can be termed as a transducer. In electronic communication systems, we usually come

Bandwidth: Bandwidth refers to the frequency range over which an equipment operates or the portion of the spectrum occupied by the signal.Modulation: The original low frequency message/information signal cannot be transmitted to long distances. Therefore, at the transmitter, information contained in the low frequency message signal is superimposed on a high frequency wave, which acts as a carrier of the information. This process is known as modulation. There are several types of modulation abbreviated as AM, FM and PM.

Demodulation: The process of retrieval of information from the carrier wave at the receiver is termed demodulation. This is the reverse process of modulation.

Repeater: A repeater is a combination of a receiver and a transmitter. A repeater picks up the signal from the transmitter, amplifies and retransmits it to the receiver sometimes with a change in carrier frequency. Repeaters are used to extend the range of a communication system. A communication satellite is essentially a repeater station in space.

Modulation and its necessity

As already mentioned, the purpose of a communication system is to transmit information or message signals. Message signals are also called baseband signals, which essentially designate the band of frequencies representing the original signal, as delivered by the source of information. No signal, in general, is a single frequency sinusoid, but it spreads over a range of frequencies called the signal bandwidth.

Suppose we wish to transmit an electronic signal in the audio frequency (AF) range (baseband signal frequency less than 20 kHz) over a long distance directly. Let us find what factors prevent us from doing so and how we overcome these factors. Size of the antenna or aerial: For transmitting a signal, we need an antenna or an aerial. This antenna should have a size comparable to the wavelength of the signal (at least A/4 in dimension) so that the antenna properly senses the time variation of the signal. For an electromagnetic wave of frequency 20 kHz, the wavelength A is 15 km. Obviously, such a long antenna is not possible to construct and operate. Hence direct transmission of such baseband signals is not practical. We can obtain transmission with reasonable antenna lengths if transmission frequency is high (for example, if v is 1 MHz, then A is 300 m). Therefore, there is a need of translating the information contained in our original low frequency baseband signal into high or radio frequencies before transmission.

Effective power radiated by an antenna: A theoretical study of radiation from a linear antenna (length I) shows that the power radiated is proportional to (l/A} . This aterl iverl theh-he above arguments suggest that there is a need for translating the original low aI frequency baseband message or information signal into high frequency wave before itransmission such that the translated signal continues to possess the information contained in the original signal. In doing so, we take the help of a high frequency tionsignal, known as the carrier wave, and a process known as modulation which attaches lichHnformation to it implies that for the same antenna length, the power radiated increases with decreasing A, i.e., increasing frequency. Hence, the effective power radiated by a long wavelength baseband signal would be small. For a good transmission, we need high powers and hence this also points out to the need of using high frequency transmission.

• Mixing up of signals from different transmitters: Another important argument against transmitting baseband signals directly is more practical in nature. Suppose many people are talking at the same time or many transmitters are transmitting baseband information signals simultaneously. All these signals will get mixed up and there is no simple way to distinguish between them. This points out towards a possible solution by using communication at high frequencies and allottino a band of frequencies to each message signal for its transmission.

Amplitude Modulation (AM) Frequency Modulation (FM) Origin: AM method of audio transmission was first successfully carried out in the mid 1870s. FM radio was developed in the United states mainly by Edwin Armstrong in the 1930s. Modulating differences: In AM, a radio wave known as the "carrier" or "carrier wave" is modulated in amplitude by the signal that is to be transmitted. In FM, a radio wave known as the "carrier" or "carrier wave" is modulated in frequency by the signal that is to be transmitted. importance: It is used in both analog and digital communication and telemetry. It is used in both analog and digital communication and telemetry. Pros and cons: AM has poorer sound quality compared to FM, FM is less prone to interference than AM.

PROPERTIES OF SOLIDS

All solid bodies can be stretched, compressed and bent. Even the appreciably rigid steel bar can be deformed when a sufficiently large external force is applied on it. This means that solid bodies are not perfectly rigid. A solid has definite shape and size. In order to _'range (or deform) the shape or size of a body, a force is required. If you stretch a helical spring by gently pulling its ends, the length of the spring increases slightly. When you leave the ends of the spring, it regains its original size and shape. The property of a body, by virtue of which it tends to regain its original size and shape when the applied force is removed, is known as elasticity and the deformation caused own as elastic deformation. However, if you apply force to a lump of putty or mud. they have no gross tendency to regain their previous shape, and they get permanently deformed. Such substances are called plastic and this property is called plasticity. Putty and mud are close to ideal plastics.

The elastic behaviour of materials plays an important role in engineering design. For example, while designing a building, knowledge of elastic properties of materials like steel, concrete etc. is essential. The same is true in the design of bridges, automobiles, ropeways etc.

Elastic Behaviour of Solids We know that in a solid, each atom or molecule is surrounded by neighbouring atoms or molecules. These are bonded together by interatomic or intermolecular forces and stay in a stable equilibrium position. When a solid is deformed, the atoms or molecules are displaced from their equilibrium positions causing a change in the interatomic (or intermolecular) distances. When the deforming force is removed, the interatomic forces tend to drive them back to their original positions. Thus the body regains its original shape and size.

Robert Hooke, an English physicist (1635 - 1703 A.D) performed experiments on springs and found that the elongation (change in the length) produced in a body is proportional to the applied force or load. In 1676, he presented his law of elasticity, now called Hooke's law.

Stress And Strain

When forces are applied on a body in such a manner that the body is still in “static equilibrium, it is deformed to a small or large extent depending upon the nature of the material of the body and the magnitude of the deforming force. The deformation may not be noticeable visually in many materials but it is there. When a body is subjected to a deforming force, a restoring force is developed in the body. This restoring force is equal in magnitude but opposite in direction to the applied force. The restoring force per unit area is known as stress.

If F is the force applied and A is the area of cross section of the body, Magnitude of the stress = F/A The SI unit of stress is Nmez or pascal (Pa). There are three ways in which a solid may change its dimensions when ' I an external force acts on it. In the adjoining figure, a cylinder is stretched by two equal forces applied normal to its cross-sectional area. The restoring force per unit area in this case is called tensile stress. If the L I U‘ cylinder is compressed under the action of applied forces, the restoring Ila jl force per unit area is known as compressive stress. Tensile or compressive stress can also be termed as longitudinal stress. In both the 1 F cases, there is a change in the length of the cylinder. The change in the length AL to the original length L of the body (cylinder in this case) is known as longitudinal strain.

Hooke's Law For small deformations the stress and strain are proportional to each other. This is known as Hooke's law. Thus, stress a strain stress = k x strain where k is the proportionality constant and is known as modulus of elasticity. Hooke's law is an empirical law and is found to be valid for most materials. However. there are some materials which do not exhibit this linear relationship.

Stress-Strain Curve The relation between the stress and the mai ini:1 strain for a given material under tensile (`1`istress can be found experimentally. In a • - standard test of tensile properties, a test 1r' 4(cylinder or a wire is stretched by an • - applied force. The fractional change in fi length (the strain) and the applied force f. needed to cause the strain are recorded. f. The applied force is gradually increased in steps and the change in length is noted. A ar'r graph is plotted between the stress (which t4 is equal in magnitude to the applied force per unit area) and the strain produced. A typical Figure 10.3 graph for a metal is shown below. Analogous graphs for compression and shear stress may also be obtained. The stress-strain curves vary from material to material. These curves help us to understand how a given-material deforms with increasing loads.

From the above graph, we can draw the following interpretation-In the region between 0 to A, the curve is linear. In this region, Hooke's law is obeyed. The body regains its original dimensions when the applied force is removed. In this region, the solid behaves as an elastic body.

• In the region from A to B, stress and strain are not proportional. Nevertheless, the body still returns to its original dimension when the load is removed. The point B in the curve is known as yield point (also known as elastic limit) and the corresponding stress is known as yield strength of the material.

• In the region from B to D, if the load is increased further, the stress developed exceeds the yield strength and strain increases rapidly even for a small change in the stress. When the load is removed, say at some point C between B and D, the body does not regain its original dimension. In this case, even when the stress is zero, the strain is not zero. The material is said to have a permanent set. The deformation is said to be plastic deformation. The point D on the graph is the ultimate tensile strength of the matetial.

• Beyond D, additional strain is produced even by a reduced applied force and fracture occurs at point E. If the ultimate strength and fracture points D and E are close, the material is said to be Brittle. If they are far apart, the material is said to be Ductile. As stated earlier, the stress-strain behaviour varies from material to material. For example, rubber can be pulled to several times its original length and still returns to its original shape. Substances like tissue of aorta, rubbers etc. which can be stretched to cause large strains are called Elastomers.

Elastic Moduli The proportional region within the elastic limit of the stress-strain curve (region OA in the above figure) is of great importance for structural and manufacturing engineering designs. The ratio of stress and strain, called modulus of elasticity, is found to be a characteristic of the material. The modus of elasticity are of various kinds which are as follows -Young's Modulus: The ratio of tensile (or compressive) stress (a) to the longitudinal strain (E) is defined as Young's modulus and is denoted by the symbol Y. Tensile (or compressive)stress Y= Longitudinal strain Since strain is a dimensionless quantity, the unit of Young's modulus is the same as that of stress i.e., Nm-2 or Pascal

(Pa). For metals, Young's moduli are large. Therefore, these materials require a large force to produce small change in length. • Shear Modulus: The ratio of shearing stress to the corresponding shearing strain is called the shear modulus of the material and is represented by G. It is also called the modulus of rigidity.

G = Shearing strain Bulk Modulus: The ratio of hydraulic stress (pressure) to the corresponding hydraulic jstrain (change in volume per unit volume) is called bulk modulus. It is denoted by symbol B.

B= AV / / V The negative sign indicates the fact that with an increase in pressure, a decrease in volume occurs. That is, if p is positive, AV is negative. Thus for a system in equilibrium, the value of bulk modulus B is always positive. SI unit of bulk modulus is the same as that of pressure i.e., Nm -2 or Pa. The reciprocal of the bulk modulus is called Compressibility and is denoted by k.

FLUIDS

Liquids and gases can flow and are therefore, called fluids. It is this property that distinguishes liquids and gases from solids in a basic way. How are fluids different from solids? What is common in liquids and gases? Unlike a solid, a fluid has no definite shape of its own. Solids and liquids have a fixed volume, whereas a gas fills the entire volume of its container. The volume of solid, liquid or gas depends on the stress or pressure acting ,on it. When we talk about fixed volume of solid or liquid, we mean its volume under atmospheric pressure. The difference between gases and solids or liquids is that for solids or liquids the change in voluMe due to change of external pressure is rather small. ln° other words solids and liquids have much lower compressibility as compared to gases.

Shear stress can change the shape of a solid keeping its volume fixed. The key property of fluids is that they offer very little resistance to shear stress; their shape changes by application of very small shear stress. The shearing stress of fluids is about million times smaller than that of solids.

Density: If we hold cubes of equal volume of different solids such as wood, aluminium, lead, etc., we notice immediately that lead is heavy but wood and aluminium are light. We express this by saying that lead has a higher density than wood or aluminium. More specifically, the mass per unit volume of a substance is called its density. mass

EMIIMIIIML.

Some everyday applications of the concept of pressure • It is much easier to cut fruit with a sharp knife than with a blunt one. In the case of a sharp knife, the blade makes such a small area of contact with the fruit that the pressure below it is very high and easily cuts the fruit.

• The pin used on a drawing-board has a broad head and a pointed tip. When force is applied on the head, the pressure exerted on the tip, due to its small area, is so large that it pierces the board.

• Broad wooden sleepers are placed below the rails to reduce the pressure exerted by the weight of a train.

Pressure in Liquids: A diver experiences pressure in the water due to the weight of water above him. The pressure at any point in a liquid acts in all directions. The pressure P at a depth h in a liquid of density p is given by the relation

P= pgh where g is the acceleration due to gravity. Since the pressure of water increases with depth, the bottom of a dam is made much thicker than the top. The pressure and hence speed of water obtained from the ground floor tap is much higher than that from the top floor tap.

Transmission of Liquid Pressure The pressure exerted on an enclosed liquid at one throughout the liquid. This is called Pascal's principle. The adjoining figure demonstrates the transmission of pressure. It can be easily seen that pressure exerted on the left side is the same as transmitted on the right side. Hydraulic presses, hydraulic brakes. hydraulic door closers, etc. are applications of this principle. place is transmitted equally

Atmospheric Pressure: The air surrounding the earth is Figure 11.1 called the atmosphere. Air has weight and therefore exerts pressure not only on the earth's surface but on all objects on the earth. In fact, human beings and other animals are living at the bottom of an ocean or air which exerts enormous pressure. This pressure is not felt because the blood exerts a slightly higher pressure from inside.

Some observations linked to atmospheric pressure • At high altitudes where atmospheric pressure is **less**, nose bleeding may occur due to the greater pressure of blood. • It is due to the pressure of the atmosphere that ink rises in the tube of a fountain pen, or liquid rises in a syringe when the piston is pulled. • One is able to have cold drink using a straw-pipe due to atmospheric pressure. When the air from the pipe is sucked, the atmospheric pressure pushes the liquid up in the pipe.

• In an aircraft flying at high altitude, normal atmospheric pressure is maintained by the use of aiLpumps. If this were not done, the crew and passengers would experience difficulty in breathing and consequently face dangers. All the passengers of ill-fated Boeing 'Kanishka' were believed to have died instantaneously after the aircraft got ripped.

Atmospheric pressure is measured with an instrument called the barometer. Accurate measurements of atmospheric pressure in laboratories are made with a Fortin's barometer, which is an improved form of a simple mercury barometer. A small portable barometer, called the aneroid barometer does not use any liquid. Since atmospheric pressure varies with altitude, a barometer can be used for determining altitudes. An aneroid barometer calibrated for determining altitudes is called an altimeter. Barometers are also used for weather forecasting. If the barometric height falls suddenly, it indicates the coming of a storm. A gradual fall in the barometric height indicates the possibility of rain. A gradual increase in the barometric height indicates fair weather.

Upthrust If a block of wood is held below the surface of water and then released, it immediately rises to the surface. The block rises because it experiences an upward force or upthrust (or buoyant force) due to water. Like liquids, gases also exert upthrust on objects inside them.

Archimedes' Principle: This principle states that when a body is wholly or partially immersed in a fluid, it experiences an upthrust equal to the weight of the fluid displaced.

When an object is immersed in a fluid: two forces act on it: (i) the weight of the object acting downward, and (ii) upthrust acting upward. lt is due to upthrust that objects apparently weigh less when immersed in fluids. An angler pulling a fish out of water experiences a sudden increase in the weight of the fish as soon as it is out of water. lt requires relatively less effort to lift a large boulder off the bottom of a river bed as long as the boulder is underwater. Once the same boulder is out of the water, considerably greater effort is required to lift it.

The relative values ofthe weight and upthrust determine whether an object will sink in a liquid or float in it. lf the weight ofthe immersed object is greater than the upthrust, the

object will sink. lf the weight is equal to the upthrust, the object_remains at any level like a fish. lf the upthrust is greater than the weight of the immersed object it will float to the surface.
lt can easily be shown that an object will sink in a liquid if its density is more than that of the liquid. lf the density of the object is less than that of the liquid, it will float on it.
Archimedes‘ principle can explain several phenomena which are as follows –

An iron nail sinks in water whereas a ship made of iron and steel floats. This is due to the fact that a ship is-hollow and contains air and, therefore, its density is less than that of water. A ship sinks in water to a level such that the weight of the displaced water equals its own weight. Since the density of sea water is more than that of river water, a ship sinks less in sea water. lt is for this reason that a ship rises a little when it enters a sea from a river.
lt is because of the higher density of sea water that it is easier to swim in the sea. A submarine has large ballast tanks. When these tanks are filled with water the average density of the submarine becomes more than that of water and it can dive easily. When the submarine is ready to surface, compressed air is forced into the ballast tanks forcing the water out, thus reducing the density of the submarine which can then rise.

A solid chunk of iron will sink in the water but float in mercury because the density of iron is more than that of water but less than that ot mercury. A balloon filled with a light gas, such as hydrogen, rises because the average density of the balloon and the gas is less than that of air. The balloon cannot rise indefinitely because the density of the air decreases with increasing altitude. At certain height, where the density of “air is equal to the average density of the it ceases to rise and drifts sideways with the wind.
Ice, being less dense than water, floats in it with one tenth of its volume above the surface. When ice melts it contracts by as much of its volume as was above the surface and, therefore, the level of water remains unchanged.
A hydrometer is an instrument used for measuring the density or relative density of liquids. lt is based on the principle of floatation. A special type of hydrometer is used to measure the density of acid in a car battery. Another special type of a hydrometer called lactometer is used for testing milk by measuring its density.
Some Basic Properties of Fluids

Diffusion:
Diffusion is the mixing up of molecules of different gases. tiquids and even solids. When a bottle of perfume is opened in one comer of a room, its "molecules mix with molecules of air and smell soon spreads even to the far corner of the room. The diffusion in liquids is not as fast as in gases. Sugar crystals placed at the bottom of a bottle containing water will diffuse into water to make a uniform solution in a couple of weeks. Diffusion also occurs in solids though at an extremely slow speed.

Surface Tension:

An insect sailed 'pond skater' can easily walk on the surface of the water. A slight depression of the surface is produced by the legs of the insect, showing that the surface acts like an elastic "skin". lf a needle is placed on small piece of blotting paper, which then placed on the surface of the water. the paper sinks in a few seconds leaving the needle floating on water. A close examination reveals that the needle rests in a slight depression as if lying on an elastic skin.

Thus the surface of a liquid behaves like an elastic membrane and, therefore. has a tendency to contract. This property of a liquid is called surface tension. Surface tension is caused by molecular attractions.

Applications of Surface Tension

When a paint brush is dipped in water all its hair spread out but when it is taken out it is covered with a thin film of water which contracts due to surface tension and pulls the hair together.

Liquid drops, such as raindrops. oil drops, drops of molten metals. dewdrops. etc. are all spherical because their surface tends to contract in order to have minimum surface area. For a given volume, a sphere has the minimum surface area.

Soaps and detergents lower the surface tension of water. This increases the wetting power of water or its ability to detach dirt particles from clothes and utensils.

. Mosquitoes breed on stagnant water. Their larvae keep floating on water due to surface tension. When oil is sprinkled on the stagnant water its surface tension is lowered resulting the drowning and death of the larvae.

Capillarity:

lt a clean glass tube having a small inside diameter (called a capillary tube) is dipped in water, the water risos in the tube. This phenomenon is called capillarity. Water rises in the-capillary tube because water molecules are attracted to glass more than to each other. If the same capillary tube is dipped in mercury, the level ot mercury in the tube is lower than the level outside because mercury molecules are less attracted to glass than to each other. The force of attraction between unlike molecules is called adhesion and that between like molecules cohesion.

Applications of Capillarity

- The melted wax of a candle is drawn up into the wick by capillary action. Oil rises up a lamp wick for the same reason.
- lf one end of a sugar cube is dipped into tea. the entire cube is quickly wet on account ot capillary action.
- The fine pores oi blotting paper act as tiny capillary tubes. The ink rises into the blotting paper through these pores. is opposed by the friction between the two surfaces, the motion of an object moving through a fluid is also opposed by fluid friction or viscosity.

lt is measured in terms of the coefficient of viscosity, n. lts SI unit is pa-s (Pascal-second). Liquids have higher coefficients of viscosity than gases. Some liquids are more viscous than others. For example, honey is more viscous than water.

The viscosity of liquids, in general, falls rapidly with temperature. For water the coefficient of viscosity at 80°C is one-third of its value at 100°C. The coefficient of viscosity of liquids, except water, rises with pressure. For water, it decreases with increasing pressure. The viscous force F acting on an object falling through a fluid of coefficient of viscosity.

As the falling object gains velocity (due to the downward force of gravity acting on it), the opposing viscous force also increases. A stage comes when the viscous force equals the gravitational force and, therefore, the net force on the falling object becomes zero. The object then stops accelerating and falls with constant velocity, known as the terminal velocity. lt is obvious that the terminal velocity is more for heavier objects. Terminal velocity also depends on the size; it is more for smaller objects. lt a metal sphere and a wooden sphere of equal mass (due to much lower density of wood, the wooden sphere will have much bigger radius) are dropped simultaneously from a high altitude, the metal sphere will achieve a higher terminal velocity and will touch the ground before the wooden sphere. While skydiving, even though a group of divers dive from the aeroplane one after another, in mid air the group can hold hands and make beautiful patterns. This is possible because the skydivers can alter their terminal velocities by changing their position in air. A diver falling vertically can reduce his/ he?" terminal velocity by acquiring a horizontal position with arms and legs spread out.

Motion of Fluids — Bernoulli’s Theorem

When a fluid flows from one place to another without friction, its total energy (kinetic + potential + pressure) remains constant. An important corollary of this theorem is: pressure in a fluid decreases with increased velocity of the fluid. When the piston of a sprayer (as shown in the adjoining figure), is pushed, air is forced past the upper end of a tube, whose lower end dips H in the liquid to be sprayed. Due to the increased 0 gt . velocity of air, the pressure near the upper end of the tube is reduced. The atmospheric pressure in the V container, therefore, pushes the liquid to the top, from where it is carried away by the stream of air.

When a bowler spins a ball, it changes its direction (swings) in the air due to unequal pressure acting on it. F'9“'e11'2 Due to spin, the wind velocity is increased above the boll and decreased below it. This creates lower pressure above the ball which, therefore, is lifted upward.

The shape of the wings of an aeroplane is such that the wind velocity above the wings is higher than that below them. Consequently, there is higher pressure below the wings and this lifts the aeroplane, as shown in the I adjoining figure. Figure11.3

HEAT AND THERMODYNAMICS

Temperature and Heat

Temperature is a relative measure. or indication of hotness or coldness. A hot utensil is said to have a high temperature, and ice cube to have a low temperature. An object that has a higher temperature than another object is said to be hotter. Note that hot and cold are relative terms, like tall and short. On the other hand, heat is the form of energy transferred between two (or more) systems or a system and its surroundings by virtue of temperature difference. The S! unit of heat energy transferred is expressed in joule (J) while S1 unit of temperature is kelvin(K), and °C is a commonly used unit of temperature.

Measurement of Temperature

A measure of temperature is obtained using a thermometer. Many physical properties of materials change sufficiently with temperature to be used as the basis for constructing thermometers. The commonly used property is variation of the volume of a liquid with' temperature. For example, a common thermometer (the liquid-in-glass type) with which we are familiar. Mercury and alcohol are the liquids used in most liquid~in-glass thermometers.

Thermometers are calibrated so that a numerical value may be assigned to a given temperature. For the definition of any standard scale. two fixed reference points needed. Since all substances change dimensions with temperature, an absolute reference for expansion is not available. However, the necessary fixed points may be correlated to physical phenomena that always occur at the same temperature. The ice point and the steam point of water are two convenient fixed points and are known as the freezing aqd boiling points. These two points are the temperatures at which pure water freezes and boils under standard pressure. '

The two familiar temperature scales are the Fahrenheit temperature scale and the Celsius temperature scale. The ice and steam point have values 32 °F and 212 °F respectively, on the Fahrenheit scale and O "C and 100 °C on the Celsius scale. On the Fahrenheit scale. there are 180 equal intervals between two reference points, and on the Celsius scale, there are 100. A relationship for conversion between the two scales is -

where F and C are the temperatures in Fahrenheit and Celsius scales respectively. Using this formula, one can easily see that at - 40 degrees both Celsius and Fahrenheit scales will show identical readings. Absolute Zero and Kelvin Scale In principle, there is no upper limit to temperature but there is a definite lower limit, the 'absolute zero'. This limiting temperature is 273.16° below zero on the Celsius scale of temperature. On the Kelvin scale absolute Zero is O K. On Kelvin scale 0°C corresponds to 273.16 K and 100°C to 373.16 K. Degrees on the Kelvin scale are calibrated with the same-sized divisions as on the Celsius scale. Thus, a 10°C rise of temperature is equalto a 10K rise oi temperature.

Types of Thermometer

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A clinical thermometer is also a mercury-in-glass type thermometer, designed for measuring temperature of the human body. Since the temperature ot the human body varies over a short range, the thermometer scale is marked from 95 F to 110 F or 35°C to 43°C. The normal temperature of a healthy person is 98.4 F or 368°C. Another special teature of this thermometer is the constriction in the stem just above the mercury bulb. When the thermometer is placed beneath the tongue of a patient, the mercury expands and pushes through the constriction but when the thermometer is removed from the mouth, the constriction prevents the expanded mercury in the stem from falling back into the bulb. Thus, the correct temperature can be read even after sometime. The thermometer has to be shaken to bring the expanded mercury back to the bulb. A clinical thermometer should not be sterilised in hot water otherwise the mercury will expand too much and break the glass.

Maximum and Minimum Thermometer

Weather reports in newspapers carry the maximum and the minimum temperatures recorded during the last 24 hours. These temperatures are recorded by a special type of thermometer called the Six's maximum and minimum thermometer. Why only mercury is used in thermometers?Mercury is used in thermometers because It is opaque and shining and, therefore, temperature can_be read conveniently.
~ it is a good conductor of heat, and, therefore, records temperatures rapidly
~ lt does not stick to glass and also does not vaporise much and therefore yields correct readings.
Water cannot be used in a thermometer because it freezes at 0°C and also because of its irregular expansion. ln cold countries where winter temperatures of -40 °C are not uncommon, mercury thermometers cannot be used because mercury freezes at -39°C. ln such countries, alcohol thermometers are used, since alcohol freezes at -115°C.

Electronic Thermometer "

lt is now common to measure temperature using electronic thermometers. The resistance of a good conductor depends on its temperature. This property is used for designing an electronic thermometer. The basic component of an electronic thermometer is a thermoresistor or a thermistor, whose resistance changes with temperature. An electronic circuit then measures the resistance and converts it into temperature, which is displayed digitally

Internal Energy

Matter is composed of continually moving molecules. The total kinetic and potential energy of these molecules is termed the ‘internal energy‘ of a substance. The greater the internal energy of a substance, the hotter it is.

Applications -

v When we strike an iron nail with a hammer, the nail becomes warm. The hammer's blow causes the molecules in the nail to move faster and, therefore, increases internal energy. Water at the bottom of a waterfall is slightly warmer than that at the top. The potential energy possessed by water al the top of the fall is transformed into kinetic energy as the water descends. Part of this kinetic energy is transformed into internal energy at the bottom and the temperature rises.
The lower part of the barrel of a bicycle pump becomes quite warm when a tyre is being inflated because the work done in compressing the air is converted into internal energy.

When a ball moving on a surface slows down and then stops, its initial kinetic energy is transformed into the internal energy of the ball, the surface and the air Thermal Expansion Solids, liquids and gases generally expand when heated and contract when cooled. All solids expand on heating and if there is not sufficient space for expansion, large forces may set up within solids resulting in their bending or cracking. The phenomenon of thermal expansion is used is the following real world situations

• Gaps have to be left in railway tracks to make allowance for expansion, otherwise the rails will buckle.

• Allowance is made for the expansion of long steel bridges. One end of such bridge is while the other rests on rollers.

• Telephone wires sag more in summer than in winter due to expansion. • Iron and steel tyres are tightly fitted on cartwheels by first heating them and then slipping them onto the wheel. On cooling, these tyres contract and have a firm grip on the wheels.

• Thermal expansion is made use of in riveting metal plates together. A rivet is heated and pushed through the holes of plates to be riveted till its head holds tightly against one plate. The other end of the rivet is hammered to form a head. On cooling, the rivet contracts and pulls the plates tightly together.

• Since metals expand much more than glass, metal caps of glass bottles and jars can be loosened by heating them under hot water.

• A thick glass tumbler is liable to crack when hot water is poured into it because glass is a poor conductor of heat. When hot water is poured, the interior expands but the exterior remains unaffected and the tumbler cracks. A pyrex tumbler does not crack because pyrex has low expansivity.

Bimetal Strip A brass bar and an invar bar riveted together form a bimetal strip. When temperature rises, brass expands more than invar and the strip bends with brass on the convex side. When temperature falls, the strip regains its original shape. Thus a bimetal strip can act like a switch. Bimetal strips are used in thermostats which are used for regulating temperatures of electrically-heated rooms, ovens, toasters, etc. Refrigerators are also equipped with special Thermostats.

Anomalous expansion of Water Water shows unusual expansion. it we take a cube of ice at -5°C and heat it, it expands till ice starts melting. During melting its temperature remains 0°C but its volume decreases. If heat is continuously supplied to water at 0°C but it further contracts up to 4°C and then it starts expanding. Thus water has its minimum volume and maximum density at 4°C.

The anomalous expansion of water helps preserve aquatic life during very cold weather. When temperature falls, the top layer of water in a pond contracts, becomes denser and sinks to the bottom. A circulation is thus set up until the entire water in the pond reaches maximum density at 4 cC'. If the temperature falls further, the top layer expands and remains on top till it fredzes. Thus even though the upper layers are frozen, the water near the bottom is at 4 °C and the fishes etc., can survive in it easily.

Transmission of Heat There are three ways of heat transmission which are:

- Conduction
- Convection
- Radiation.

Conduction: If we hold one end of an iron rod in a flame, the other end soon becomes too hot to he held in hand. Heat enters one end of the rod and is transmitted along its whole length. This process of heat transmission is called conduction and takes place mainly in solids. The actual mechanisms of heat transfer differ in metals (iron, silver, etc.) and non-metals (such as wood). Among solids there are good as well as bad conductors of heat. Substances such as wood, cotton, wool and glass are bad conductors (good insulators) of heat. Liquids and gases, in general are bad conductors. Air is a very bad conductor of heat. The good insulating properties of wool, cotton, etc. are mainly due to the air spaces they contain. Woolen clothes do not allow the heat of our body to escape and we feel warm. Sawdust is a bad conductor of heat. Therefore, ice slabs are covered with sawdust to minimise melting.

Some practical applications of Conduction • In air-conditioned rooms, double windows, **consisting** of two panes of glass with a thin layer of air in between, serve as a better insulator of heat than windows with single, thick panes.

• On a cold night two thin blankets are preferred to a single thick blanket because the layer of air between the two blankets serves as a better insulator. Ovens, geysers, etc. have **double** walls with glass wool or straw in between to reduce the loss of heat by conduction. Refrigerators and ice-boxes have similar double walls to minimise heat gain by conduction.

• When we touch an iron hammer lying in the sun, it appears mach hotter than its wooden handle because iron is a good conductor of heat and conducts heat rapidly to the hand. Wood being a poor conductor of heat, conducts heat from the touched surface only.

• In winter, a stone floor feels cold to the bare feet, but a carpet on the same floor feels warm even though both are at the same temperature. Stone, being a good conductor, conveys heat, away from the feet rapidly. Carpet is a poor conductor and conveys little heat. Consequently, the feet feel cold on the stone but not on the carpet.

• A refrigerator has to be switched off for defrosting whenever a thick layer of ice deposits on the outside and inside of the freezer. Ice, being a poor conductor, affects the cooling action of the freezer. Thus defrosting helps in the efficient functioning of a refrigerator.

• During severe winter, Eskimos live in snow huts called igloos. Snow, being a poor conductor shields them from cold. It prevents the heat they generate from escaping and keeps them warm.

Convection: air k In liquids and gases heat is transmitted by convection In this process heat is carried we from one place to another by the actual movement of liquids and gases. If we heat a iith E liquid in a vessel from below, the liquid at the bottom gets heated and expands. The hot liquid rises due to its lower density and its place is taken by cold liquid from above. 'Convection currents' are thus set up and the whole liquid gets heated to a uniform temperature. Convection currents are set up in gases and air in a similar way.

Some Practical Application of Convection • Heating elements in geysers and water heaters are fitted near the bottom so that water can be heated by convection currents. Heating elements in electric ovens are fitted near the bottom to heat the entire enclosed air by convection. An element near the top of an oven would heat only the top layers of air, leaving the cool layers below almost unaffected.

• The cooling unit (freezer) in a refrigerator is fitted near the top to cool the whole of the interior. The air near the top cools and descends due to increased density. Its place near the top is taken by warm air and in this way convection currents are set up, which cool the entire interior.

• Convection currents in the atmosphere result in winds. Sea and land breezes can be explained on the basis of convection. During daytime the seashore (land) warms up much faster than sea water. Air over the shore rises and cooler air from water takes its place resulting in a sea breeze. At night land cools faster than water, resulting in a land breeze.

Radiation: Both conduction and convection require a material medium for conveying heat from one part to another. Radiation, on the other hand, does not require any medium. The earth receives radiant energy from the sun in the form of electromagnetic waves which can pass d ugh vacuum, Ali bodies are continuously emitting and absorbing radiant energy. If a body emits more c; 'ergy than it absorbs, its temperature falls.

Some Practical Application of Convection If we pour hot coffee simultaneously in two metal cups of the same size and shape, but with one having a rough black surface and the other a bright polished surface, the coffee will cool faster in the black cup because the rough black surface is a note(radiator, Thus coffee or tea remains hot in a shining bright cup for longer. When iced water is poured in these empty cups, the water in the black cup will warm up taster since black iq also a better absorber of radiant energy. Is opposed by the friction between the two surfaces, the motion of an object moving through a fluid is also opposed by fluid friction or viscosity. It is measured in terms of the coefficient of viscosity, q. Its SI unit is pa-s (Pascal-second). Liquids have higher coefficients of viscosity than gases. Some liquids are more viscous than others. For example, honey is more viscous than water.

The viscosity of liquids, in general, falls rapidly with temperature. For water the coefficient of viscosity at 80°C is one-third of its value at 100°C. The coefficient of viscosity of liquids, except water, rises with pressure. For water, it decreases with increasing pressure.

The viscous force F acting on an object falling through a fluid of coefficient of viscosity q depends on its size r (in case of a ball r is its radius) and its velocity v.

This is Stokes' law. As the falling object gains velocity (due to the downward force of gravity acting on it), the opposing viscous force also increases. A stage comes when the viscous force equals the gravitational force and, therefore, the net force on the falling object becomes zero. The object then stops accelerating and falls with constant velocity, known as the terminal velocity. It is obvious that the terminal velocity is more for heavier objects. Terminal velocity also depends on the size; it is more for smaller objects. If a metal sphere and a wooden sphere of equal mass (due to much lower density of wood, the wooden sphere will have much bigger radius) are dropped simultaneously from a high altitude, the metal sphere will achieve a higher terminal velocity and will touch the ground before the wooden sphere. While skydiving, even though a group of divers dive from the aeroplane one after another, in mid air the group can hold hands and make beautiful patterns. This is possible because the skydivers can alter their terminal velocities by changing their position in air. A diver falling vertically can reduce his/ her terminal velocity by acquiring a horizontal position with arms and legs spread out.

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HEAT AND THERMODYNAMICS

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• On a cold night two thin blankets are preferred to a single thick blanket because the layer of air between the two blankets serves as a better insulator. Ovens, geysers, etc. have double walls with glass wool or straw in between to reduce the loss of heat by conduction. Refrigerators and ice-boxes have similar double walls to minimise heat gain by conduction.

• When we touch an iron hammer lying in the sun, it appears mach hotter than its wooden handle because iron is a good conductor of heat and conducts heat rapidly to the hand. Wood being a poor conductor of heat, conducts heat from the touched surface only.

• In winter, a stone floor feels cold to the bare feet, but a carpet on the same floor feels warm even though both are at the same temperature. Stone, being a good conductor, conveys heat, away from the feet rapidly. Carpet is a poor conductor and conveys little heat. Consequently, the feet feel cold on the stone but not on the carpet.

• A refrigerator has to be switched off for defrosting whenever a thick layer of ice deposits on the outside and inside of the freezer. Ice, being a poor conductor, affects the cooling action of the freezer. Thus defrosting helps in the efficient functioning of a refrigerator.

• During severe winter, Eskimos live in snow huts called igloos. Snow, being a poor conductor shields them from cold. It prevents the heat they generate from escaping and keeps them warm.

Convection: air k In liquids and gases heat is transmitted by convection In this process heat is carried we from one place to another by the actual movement of liquids and gases. If we heat a iith E liquid in a vessel from below, the liquid at the bottom gets heated and expands. The hot liquid rises due to its lower density and its place is taken by cold liquid from above. 'Convection currents' are thus set up and the whole liquid gets heated to a uniform temperature. Convection currents are set up in gases and air in a similar way.

Some Practical Application of Convection

• Heating elements in geysers and water heaters are fitted near the bottom so that water can be heated by convection currents. Heating elements in electric ovens are fitted near the bottom to heat the entire enclosed air by convection. An element near the top of an oven would heat only the top layers of air, leaving the cool layers below almost unaffected.

• The cooling unit (freezer) in a refrigerator is fitted near the top to cool the whole of the interior. The air near the top cools and descends due to increased density. Its place near the top is taken by warm air and in this way convection currents are set up, which cool the entire interior.

• Convection currents in the atmosphere result in winds. Sea and land breezes can be explained on the basis of convection. During daytime the seashore (land) warms up much faster than sea water. Air over the shore rises and cooler air from water takes its place resulting in a sea breeze. At night land cools faster than water, resulting in a land breeze.

Radiation: Both conduction and convection require a material medium for conveying heat from one part to another. Radiation, on the other hand, does not require any medium. The earth receives radiant energy from the sun in the form of electromagnetic waves which can pass d ugh vacuum, Ali bodies are continuously emitting and absorbing radiant energy. If a body emits more c; 'ergy than it absorbs, its temperature falls. On the other because microscopically a rough surface has more surface area.

Some Practical Application of Convection If we pour hot coffee simultaneously in two metal cups of the same size and shape, but with one having a rough black surface and the other a bright polished surface, the coffee will cool faster in the black cup because the rough black surface is a note(radiator, Thus coffee or tea remains hot in a shining bright cup for longer. When iced water is poured in these empty cups, the water in the black cup will warm up taster since black iq also a better absorber of radiant energy.

The base of an electric iron is highly polished so that it does not lose heat by radiation.

Houses which are white washed or painted in light colours keep cooler in summer, because light surfaces do not absorb much solar radiation.

Newton's Law of Cooling This law states that the rate at which a hot body loses heat is directly proportional to the difference between its temperature and the surrounding temperature. For example, hot water takes much less time in cooling from 90°C to 80°C than in cooling from 40°C to 30 °C.

If hot water and fresh tap-water are kept in a refrigerator, the rate of cooling of hot water will be faster than the tap-water. Suppose, a person is served hot coffee with separate cream (at room temperature), but he wants to drink it after a while. It is then advisable to add cream right in the beginning rather than at the time of taking the coffee because this way, the coffee will remain hotter.

Cooling at Night The earth and other objects on it receive solar radiation during the day and become warm. At night they start emitting radiant energy and become cool: Objects such as stones, metals, etc. which are good conductors of heat, keep receiving heat from the earth by conduction and maintain their temperature. However, bad conductors like grass and wood do not receive the earth's heat by conduction and get colder than the air, resulting in the formation of frost on them.

Cloudy nights are warmer than clear nights because clouds reflect the radiations emitted by the earth at night and keep it warm. Clouds act like a blanket.

Greenhouse Effect A greenhouse acts like a radiation trap.. In a greenhouse, heat radiation from the sun passes through the glass and keeps the plants and the air inside warm. The glass prevents warm air from escaping. Moreover, radiation emitted by objects in the greenhouse cannot escape through glass.

A car parked in the sun with its windows closed gets terribly warm due to the greenhouse effect.

Solar Cooker

A simple solar cooker is a box made of insulating material like wood, card-board etc. The box has a glass cover to retain heat inside by the greenhouse effect The inside of the box is painted dull black to increase heat absorption. The cooking vessel is kept inside the box which is then kept in the sun. Generally, this type of cooker is used only for warming food but can sometimes be used for cooking rice, pulses, etc.

Thermos Flask A thermos flask is double walled with a vacuum between the walls. The two inner glass surfaces facing each other are silvered. It has a plastic or cork stopper. In a thermos flask heat transfer by conduction is almost nil through the vacuum.-The stopper, being a poor conductor, conducts very little heat. The vacuum also prevents heat loss by convection. Silvered surfaces of the walls prevent heat loss by radiation as radiation is reflected back inside by the mirror like surface. Thus in a thermos flask, the transmission of heat by conduction, convection, and radiation is minimised and, therefore, its content remains at nearly the same temperature fur a long time.

Measurement of Heat Earlier, the unit of quantity of heat was calorie, which is defined as the quantity of heat required to raise the temperature off g of water through 1 °C. The SI unit for the quantity of heat is joule (J). 1 calorie = 4.2 J. AnotHer common unit of heat is the Kilocalorie, which is equal to 1000 calories. The C.7-ek)rie, used in rating the energy of foods, is equal to one kilocalorie. at Lo i.iisicity an SpecificH at Uapaci heaA ,T,apacitv of a body is defined as the heat required to raise the , mperature of K. Its SI unit is specific heat capacity of a substance is the heat required to raisee temperature of a unit mass of the substance by 1 K. Its SI unit is J/kg K. \-Wile explaining sea and and breezes, it was stated that land warms up and cools faster than water, This happens because soil and sand have much lower specific heat ce,oacities as compared to water.

Engine coolant: it is bccause of as high specific heat capacity that water is used as liquid in car engines. As compared to other liquids water absorbs a lot more heat for each degree rise of its temperature. However, water alone is not sufficient for cooling a car engine. One needs to add a coolant such as ethylene glycol, potassium dichromate, tri-sodium phosphate, and sodium nitrate.

A coolant plays the following roles in a car engine

• accentuates the process of cooling by raising the boiling point of water, thus allowing the water to carry extra heat from the engine, resulting in more efficient cooling system

• serves to, reduce harmful effects (corrosion, rusting) that water has on the metallic parts of enaine

• acts as a lubricant for the water pump

• lowers the freezing point or water to prevent freezing at temperatures below 0`C in cold countries.

Change of State When a block of ice at -10°C is heated steadily, at first its temperature rises to 0°C. Then the ice starts changing into water, but although heat continues to be supplied, the temperature remains constant at 0°C until all the ice has changed into water. This heat, which is absorbed by ice without changing its temperature, is the energy needed to convert ice into water, i.e., from the solid to liquid state. The experiment shows that 336000 J of heal is required to convert 1 kg of ice at 0°C into water at the same temperature. This is known as the specific latent heat of fusion of ice. The specific latent heat of fusion of a substance is defined as the heat required to convert a unit mass of the substance from the solid to the liquid state Without change c4:), temperature.

Similarly, when water boils at 100°C, its temperature remains constant at 100°C until of it is converted into steam. The specific latent heat of vaporization of a substance is the heat required to change a unit mass of the substance from liquid to the vapour state without change of temperature. The specific latent heat of steam is 2260000 J/kg oT 2260 J/g

Some practical situations involving the concept of Latent Heat • Bottled drinks are cooled more effectively when surrounded with lumps of ice than with iced water because ice absorbs more heat than does the same amount of iced water. Each gram of ice that melts absorbs 336 J of heat.

• Scalding (burning) with steam is more severe than that caused by boiling water because steam contains more energy than boiling water at the same temperature. Each gram of steam that condenses releases 2260 J of heat.

Evaporation Water can change into the vapour state either by boiling or by evaporation at lower temperatures. Small pools of water, formed on roads after rain, soon disappear due to evaporation. Whether water changes into the vapour state by boiling or by evaporation, at least 2200 joules of heat is needed to convert each gram of water into vapour. Therefore, when evaporation takes place at room temperature, the energy required for evaporation is taken from the liquid itself, which cools as a consequence. Thus evaporation produces cooling.

Application of Evaporation in practiCal situations

• When sweat evaporates from the skin it draws much heat from the body and produces a cooling sensation. In summer, water is stored in pitchers for cooling. Water oozes out of the pores of the pitchers and cools on evaporation.

A little ether spilt on the hand produces a cooling sensation. The evaporation of ether at room temperature results in cooling. The effect increases when we blow over the ether because blowing increases the rate of evaporation and hence cooling.

The use of strips or wet cloth on the forehead of a patient having high fever has a specific purpose. Water evaporating from the wet cloth- produces cooling and brings the temperature down.

• A desert cooler produces cooling by evaporation. The evaporation of water from the straw pads produces cooling in the cooler. The cool air is then circulated in the room by the exhaust fan, which also helps in increasing the rate of evaporation, and hence cooling, by removing vapour from inside the cooler.

For a given liquid, the rate of evaporation depends on the following factors: Temperature of the liquid: It is well known that wet clothes dry more rapidly on a warm day. Thus the rate of evaporation increases with temperature.

Area of evaporating surface: A wet sheet dries more rapidly when spread on a line than when left folded. Thus the evaporation increases with the increased

surface area.

A person who wants to drink hot tea quickly pours it in the saucer in which evaporation increases due to the increased surface area and the tea cools faster.

• Rate of removal of vapour: Evaporation increases if vapour is continuously removed from above the evaporating surface. For example, wet clothes dry quicker on a windy day.

Principle of a Refrigerator

In a refrigerator, cooling is produced by the evaporation of a volatile liquid, freon, inside a copper coil (evaporator), which surrounds the freezer. The vapour is removed and condensed to the liquid form in the condenser coil, fitted at the back of the cabinet, by a. compression pump. The condenser coil becomes warm owing to the conversion of vapour into liquid inside it. From the condenser coil the liquid is sent back into the evaporator coil and the cycle goes on. A thermostat switch regulates the temperature inside the refrigerator by switching the pump on and off at intervals.

In ordinary refrigerators, frost forms around the freezer coils. This frost not only decreases the inner capacity of the freezer, it also affects the cooling. In frost-fw refrigerators, the freezer has three basic parts; a timer, a heating coil around the freezer coil and a temperature sensor. Periodically, the timer turns on the heating coil, whd-, melts off the frost/ice. When the temperature rises to zero degree Celsius and all the is gone the temperature sensor turns off the heater coil.

Relative Humidity The air always contains some water vapour.

When we keep ice cubes in a turri: water vapour in the atmospheric air condenses as water droplets on the outside of tumbler. At a given temperature, there is a limit to the amount of vapour the air

support. When this limit is reached, the air is said to be saturated. At temperatures more water vapour is required to saturate the air. Relative humidity is defined as the ratio of the mass of water vapour in a give:- volume of air to the mass required for saturating the same volume of air at the same temperature. The weather report in newspapers expresses relative humidity as percentage. Thus, if the relative humidity is 50 percent, the air contains half the amen it would contain when saturated at the same temperature. Relative humidity is measitrec-:: with an instrument called the hygrometer. On a chilly night when a bespectacled person enters a warm room. moisture deposited on his spectacle lenses, Due to higher temperature inside the room, contains more water vapour. When the cold lenses cool the air in the vicinity, the cooled air cannot hold the excess moisture which is then deposited on the lenses.

Perspiration: In summer, body temperature is regulated by the evaporation of sweat. But when the air is humid, the rate of evaporation from the body slows down and sweat starts rolling off in streams. Sitting under a fan then increases the rate of evaporation by setting the air in motion. The increased evaporation produces cooling.

Air Conditioning Bodily comfort depends on temperature as well as humidity. The comfortable conditions for an average person are (i) temperature between 23°C and 25°C, and (Ft) relative humidity between 60 and 65 percent. An air conditioner provides these conditions by regulating temperature and humidity. The cooling capacity of an A.C. is expressed in tons, e.g., I ton, 2 ton etc. A 1 ton A.C. transfers 12000 BTU (British thermal unit) of heat from the room in an hour. (1 BTU = 1055 joule). Ton in this case has nothing to do with mass.

The principle of a pressure cooker The boiling point of a liquid depends on external pressure. When the atmospheric pressure is 76 cm of mercury, water boils at 100 CC. But when the pressure is increased, the boiling point of water is raised. For example, at a pressure of two atmospheres, water boils at 120°C. In a pressure cooker, water boils at temperatures higher than 100°C due to increased pressure. The increased boiling temperature allows water to hold more heat which cooks food faster.

At higher altitudes, atmospheric pressure is reduced. This lowers the boiling point of water and food takes much longer to cook. Thus a pressure cooker becomes rn re essential for cooking on hill stations.

ELECTRICITY AND MAGNETISM

Electricity by Friction The electrical effects produced by friction are well known. A hard rubber comb can attract small bits of paper after it has been used on a dry hair. This happens because the comb, after rubbing with hair, becomes charged with electricity. The same phenomenon is noticed when a plastic pen is rubbed on a coat sleeve. The friction of textiles can also produce electrification. If after a dry day, one takes off terylene clothes in a dark room, one can see electric sparks and even hear their crackling sound.

Electricity produced by friction between two dissimilar objects is known as static electricity. Depending on the nature of the objects, one acquires a positive charge and the other an equal negative charge. For example, if a glass rod is rubbed with silk, the rod acquires positive charge and the silk an equal negative charge. On the other hand, when an ebonite rod is rubbed with flannel, the rod acquires negative charge and the flannel an equal positive charge. It is found that like charges repel and unlike charges attract.

Electrification by friction can be explained on the basis of transfer of electrons (negatively charged particles of an atom). When a glass rod is rubbed with silk, some electrons from the rod attach themselves to the silk. Thus by losing electrons, glass becomes positively charged and by gaining the some number of electrons silk acquires an equal negative charge.

When a hollow metallic conductor is charged with static electricity it is found experimentally that the charge resides entirely on the outside of the conductor; the inner surface remains uncharged.

If a car is struck by lightning, persons sitting inside are shielded from the electricity and not harmed at all since the charge remains on the outer surface and may arc to the ground through the lowest metallic part of the car. If a pear-shaped conductor is charged, it is found that concentration of charge on and near the pointed end is much greater. If the charge on the conductor is increased, the pointed end starts losing charge. It can be shown that a pointed end not only enables a conductor to lose charge, it can also act as a collector of charge. The lightning conductor is based on this principle.

Lightning Conductor: Lightning is a gigantic electric discharge occurring between two charged clouds or between a charged cloud and the earth. Lightning conductors are used to protect tall buildings from lightning damage. A lightning conductor is a thick copper strip fixed to an outside wall of the building. The upper end of the strip is in the form of several sharp spikes reaching above the highest part of the building and the lower end is connected to a copper plate buried in the earth. When charged clouds pass overhead, the lightning conductor accepts any discharge which may occur and conducts it harmlessly to earth.

Insulators, Conductors, Superconductors and Semiconductors When a brass rod is held in the hand and rubbed with fur, it also gets charged like an ebonite rod, but the charge cannot be detected because it is conducted through brass and hand to earth. The charge on ebonite can be detected because it cannot flow through ebonite and then to earth. Thus brass is a conductor of electricity whereas ebonite is an insulator of electricity. In fact all substances can be arranged in order of their ability to conduct electrical charges. Nearly all metals are good conductors and most non-metals are poor conductors or insulators. Metals conduct electricity because they have a large number of conduction or free electrons. Insulators have no free electrons.

The resistance of metals to flow of electricity reduces with decreasing temperature. At temperatures near absolute zero, metals have almost zero resistance and become superconductors. Scientists have recently discovered that certain ceramics can he made to behave us superconductors at relatively high temperatures of above 100 K Currently, a lot of research is going on in the field of high temperature superconductivity and scientists are hoping to achieve it at room temperatures. Lf this is achieved there will be a great technological revolution.

Certain materials, such as silicon and germanium, have electrical resistivity intermediate between those of conductors and insulators. These materials are termed as semiconductors. They are good insulators in their pure crystalline form but them-conductivity increases when small amounts of impurities are added to them. After the addition of impurities, they become either n-type or p-type semiconductors.

Transistors: Transistors used in radios, televisions, computers and other devices are composed of both n-type and p-type semiconductors. They require very little power and in normal use last almost indefinitely.

Integrated Circuits (IC): An integrated circuit can be defined generally as an arrangement of multifunction semiconductor devices. It consists of a single-crystal chip of silicon, nearly 1.5 me in cross-section, containing both active and passive elements and their interconnections.

Electric Current: Electric current is simply the flow of electric charge. In solid conductors the flow of electrons and in fluids the flow of ions as well as electrons constitutes the current. An electromotive force (emf), provided by a cell or a generator, is essential to maintain a continuous flow of current in a circuit.

Electrical Resistance: When electric current flows through a conductor, e.g., a metallic wire, it offers some obstruction to the current. This obstruction offered by the wire is called its electrical resistance. The resistance (R) of a wire of a given material depend-3 on its length (I) and area of cross-section (a) 1 R = p —a If the wire has a circular cross-section of radius r. then a = Trt2. p is a constant called the resistivity of the material of the wire. Resistivity of a good conductor (e.g., copper, silver, etc.) increases with temperature. Whereas, resistivity of a semiconductor (e.g., carbon) decreases with increasing temperature.

Electric Cell In a cell, chemical energy is converted into electrical energy. There are two types of cells, primary and secondary. Dry cells used in torches, radios, etc., are primary cells. A dry cell consists of a negative electrode, a positive electrode and an electrolyte. The negative electrode is made of zinc, as is the outer shell of the cell. The positive electrode is a carbon rod surrounded by a mixture of carbon and manganese dioxide. The electrolyte consists of a mixture of ammonium chloride and zinc chloride, made into a I paste. It produces about 1.5 volt. AA and AAA batteries are probably the most common battery sizes. There are many kinds of AA and AAA batteries, nickel metal hydride batteries, lithium batteries, lithium ion batteries, alkaline batteries etc. The alkaline AA and AAA batteries are available in non-rechargeable and chargeable types. Lead cells, used for ignition and lighting on motor cars, are secondary cells. Secondary cells are known as storage cells or accumulators. Because of their low internal resistance, secondary cells are capable of giving large currents. Moreover, they

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