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1. UNITS AND MEASUREMENT

Measurement involves comparison of the quantity to be measured with a reference standard. The reference standard of measurement is what we call a unit. All quantities in physics which can be measured directly or indirectly are called physical qu antities such as length, mass, time, temperature, speed, force, electric current etc. Physical quantities are divided into two classes, Fundamental and Derived. Length for example, is one of the several properties that are said to be fundamental in systems of measurement for science. Other properties are amount of mass, duration in time, temperature, flow of electrical current, and intensity of light. From these fundamental properties other properties can be derived. For example, the property of density in defined in terms of mass per volume, and volume is define in terms of a length cubed (multiplied by itself, then multiplied by itself again).

System of Units. Several systems of units have been use for describing measurements. The common systems are: the CGS system (Centimeter, Gram, Second); the FPS system (Foot, Pound, Second) which is the British system the MKS system (Meter, Kilogram and Second) and now internationally accepted is the Systems Internationale d'Units, abbreviated SI.

System Internationale (SI) Units. In 1971 the General Conference on Weights and Measure (CGPM) gave office status to a single practical system, the International System Units, abbreviated SI in all languages. The system is a modernise version of the metric system. The SI, as subsequently extended includes seven base units, two supplementary units, and nineteen derived units with special names. These derived units, and others without special names, are derived from the base a supplementary units in a coherent manner. A set of prefixes is used to form decimal multiples and submultiples of the SI unit Certain units which are not part of SI but which are widely used or are useful in specialised fields have been accepted for use with the SI or for temporary use in those fields.

The Seven Basic SI Units

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Amount of substance	mole	mol
Electric current	ampere	A
Luminous intensity	candela	cd

Length

The SI unit of length is the metre [Symbol m]. Metre was originally defined as one ten millionth of the distance from the North Pole to the equator of the Earth. In 1889, the standard metre was defined as the distance between two lines marked on a platinum-iridium rod preserved at constant temperature of 273.16 at 1 bar pressure in the International Bureau of Weights and Measure at Sevres, near Paris, France.

In 1983 the metre was defined again, as the distance light travels through space in 1/299, 792, 458 of second. Accuracy can be measured to one part in 10^{13}.

Large distances such as the distance of stars from the earth are expressed in light years. A light year is a unit of length equal to the distance travelled by light in one year; 1 light year = $9.46x10^{15}$m.

Very small distances are measured in micrometres or microns (ìm), angstroms (A), nanometers (nm) and femtometre (fm).

Several other units based on metre are:

1km = 1000m = 10 3m

1cm = 1/100m = 10^{-2}m

1mm = 1/1000m = 10^{-3}m

1(ìm) = 1/1000000 m = 10-6 m

1 (nm) = 1/10000000000 m = 10-9m

Mass

Mass is the measure of the quantity of matter that an object contains. It is independent of temperature, pressure or location of the object in space.

The SI unit of mass is the kilogram [kg]. The standard kilogram is the mass of a platimum-iridium cylinder stored in a special vault in the International Bureau of Standards in Sevres, France. Other units of mass based on kg are.

1 tonne (t) = 1000kg = 103 kg

1 gram (g) = 1/1000kg = 10-3 kg

1 milligram (mg) = 1/1000000 kg = 10-6 kg.

Time

The SI unit of time is the second [s]. A natural standard for measurement of time can be derived from the rotation of the earth. The average time between successive passages of the sun across a meridian is called the mean solar day, and the second is 1/86, 400 of it.

Derived Units The units of all other physical quantities can be expressed in terms of the seven base units.

F.P.S. System of Units

In this system, the unit of length is foot (ft), the unit of mass is pound (lb) and the unit of time is second (s).

1 foot = 0.3048 m

1 pound = 0.4536 kg

The unit of time is the both the S.I. and the F.P.S system.

2. MOTION

Concept of Motion

In strict terms, if the position of a material system as measured by a particular observer changes with respect to time, that system is said to be in motion with respect to the observer. Absolute motion, then, has no significance, and only relative may be defined. In this context, frame of reference is a crucial concept. For instance, the relative motion of a train will seem different from the ground than from the train. It is important to know where you are.

There are various kinds of motion-one dimensional, two-dimensional and three-dimensional. A train running on a railway track, or a bus on a road, is examples of motion in one dimension. A carom coin or a billiard ball in motion; are examples of motion in two dimensions over a plane. Objects moving on the surface of the earth over distances comparable to the earth's radius are examples of motion in two dimensions, but not over a plane. Finally, the most general motions we can consider are of objects moving in space, involving all the three dimensions.

Rectilinear Motion

If a body moves so that every particle of the body follows a straight-line path, then the motion of the body is said to be rectilinear. Rectilinear motion is an idealised form of motion which rarely, if ever, occurs in actual experience, but it is the simplest imaginable type of motion and thus forms the basis for the analysis of more complicated motions. However, many actual motions are approximately rectilinear and may be treated as such without appreciable error. For example, a ball thrown directly upward may follow for all practical purposes, a straight-line path. The motion of a high-speed rifle bullet fired horizontally may be essentially rectilinear for a short length of path, even though in its larger aspects the ideal path is a parabola. The motion of an automobile travelling over a straight section of roadway is essentially rectilinear if minor variations of path are neglected. The motion of a single wheel of the car is not rectilinear, although the motion of the centre of mass of the wheel may be displayed graphically by plotting position against time.

Distance and Displacement. The distance that an object moves is an important thing to know when describing motion. Displacement is the distance travelled by a body in a particular direction. Distance is simply the magnitude of the displacement.

Speed and Velocity. When the body covers equal distances in equal intervals of time, we say that the motion is uniform.

The speed of a body is the distance covered by it in a unit time interval.

$$\text{Speed} = \frac{\text{total distance moved by a body}}{\text{time taken}}$$

If the distance is measured in metres and time in seconds, the unit of speed will be metre/second (SI unit of speed).

We often use "speed" and "velocity" interchangeably and sometimes we are justified in doing so. However, speed is not always the same thing as velocity. Strictly speaking, *speed* measures the rate at which we travel, while *velocity* involves not only speed but also direction. In rectilinear motion, or motion in a straight line, velocity and speed are practically synonymous, since only one direction is involved. In motion along a curve, however, the direction of the velocity is always different from the actual path along which the moving object travels.

The units of velocity are the same as those of speed. Thus if a body undergoes a displacement s is a time-interval t, then its velocity v is given by $v = s/t$. The velocity of a body at a given instant of time is known as its *instantaneous velocity.* Velocity is not to be confused with speed. It includes the speed and the direction of motion at that same instant of time.

The simplest type of motion is rectilinear motion at constant speed. If the speed of an automobile is constant, and it covers 4 km in four minutes, it will have travelled at the rate of 60 km per hour at each and every moment of the hour. What we really mean is that its average speed is 60 km per hour. The average speed is equivalent to the total distance divided by the elapsed time.

$$\text{Similarly. Average velocity} = \frac{\text{total displacement}}{\text{total time taken}}$$

Acceleration. Changes in speed are described in terms of the rate at which we changes our speed. The velocity of a body changes due to change in its speed or direction or both.

Acceleration is defined as the rate of change of velocity. If the velocity of a body changes from to *u* to *v* in a time interval t, then its acceleration a is given by

$$a = \frac{\text{change in velocity}}{\text{time}}$$

Acceleration is a vector quantity. In general the velocity of a body can change with time. Consider the case in which velocity of the body changes at a uniform rate i.e., the amount of increase of decrease in the velocity in equal intervals of time is always the same. Such a motion is called uniformly accelerated motion. One example of uniformly accelerated motion is the motion of the cycle going down an inclined road when the rider is not pedaling and wind resistance is negligible. The change in velocity in successive equal intervals of time may not be the same and then the body is said to be in non-uniformly accelerated motion.

Acceleration due to Gravity. Freely falling bodies move with constant acceleration. The force bringing this about is the gravitational attraction of the earth. The force of gravitation differs at various locations. It is stronger, for example, at the poles than at the equator.

The gravitational attraction of the earth causes all objects to fall with an acceleration of about 9.8 metres per second per second ($9.8 m/s^2$). The exact rate will depend on the gravitational force at a given part of the earth's surface. Suppose we drop a ball from the top of a skyscraper. At the end of 1 second, the ball will have attained a velocity of 9.8 metres per second. At the end of 2 seconds, the velocity will be 19.6 metres per second, at the end of 3 seconds, 29.4 metres per second, and so on. In this case, of course, we have positive acceleration. Actually, the velocity in each case would not be quite so great as we have indicated, because the air resistance would hold the ball back by a slight amount. If an object is cast straight up in the air, the force of gravity will decelerate it (decrease its velocity) at the rate of 9.8 metres per second per second.

Equations of Motion. There exist some relations between velocity, acceleration and the time intervals during which we study the motion of a body. These relations are called equations of motion.

Let a body be moving with initial velocity, u, under a uniform acceleration, a. Suppose it undergoes a displacement, s, in a time interval, t. At the end of the time interval, let its velocity be v. The relationship between *u, v, a, s* and *t* can be given by the following equations.

$v = u + at$	u = initial velocity (m/s)
$s = ½ (v + u) t$	v = final velocity (m/s)
$s = ut+1/2at^2$	a = acceleration (m/s^2)
$v^2 = u^2 +2as$ t	s = displacement (m)
	t = time taken (s)

If the values of three of the quantities u, v, s, a and t are known, you can calculate the value of fourth quantity by substituting the numbers in appropriate equation.

Motion in two and three dimension

Vectors and Scalars When we want to describe the motion of objects over two-dimensional plane or in three dimensional space, the idea of direction becomes more important than in one dimension. This is because there are many more directions in two and three dimensions than just the two possibilities in one dimension. To deal with position, velocity and acceleration in two and three dimensions, new mathematical quantities called *vectors* have to be used.

- Those quantities that have magnitude and direction are called vector quantities or vectors. Example- displacement, acceleration, force, etc.
- Those quantities that have magnitude only, are called scalar quantities or scalars. Example–distance, area, work, etc.

Vector and Scalar Addition

Scalar quantities A scalar quantity has size but no direction. Examples include mass, volume, temperature, time wavelength and speed. Scalar quantities are added just as any two numbers can be added.

Vector quantities A vector quantity has size and direction. Examples include velocity, force, acceleration, momentum and weight. When several vectors act together from a point, their combined effect is called their resultant. The resultant is a single vector that can replace those several vectors. For example, two forces of 3 N and 4 N can pull in the same direction, oppose one another or work together at a certain angle.

In (a) the resultant is 1 N :

In (b) the result is 7 N

The vectors in (c) cannot be added together in such a simple way. We use the parallelogram low.

Force

The word force generally denotes a push or a pull. Let us see what a force can do. In a hockey match a player hits a stationary ball with his stick and the ball starts moving in 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 player 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 motion in a straight line.

Consider what happens when more than one force are exerted on a body. If two persons pull an object in the same direction with equal force, the object will have twice the acceleration than if one pulled alone. If, 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.

NEWTON'S LAWS OF MOTION

Force and Inertia It is an observable fact that inanimate objects at rest do not start moving of their own accord. Effort is required to move them. When we push or pull a table, for instance, we are exerting a force on the table. It is the force exerted by a bat that makes the ball move.

Inertia is the inherent property of objects to remain at rest unless acted upon by a force. Also the property of a body to keep moving with constant velocity in the absence of any force acting on it is its inertia. Gelileo discovered the law of inertia. Bodies moving with uniform velocity would maintain this state of motion forever in the absence of forces acting upon them. Continuing his investigations on the basis of Galileo's findings, Issace Newton formulated his three laws of motion which form the foundation of mechanics.

Newton's First Law of Motion Newton's first law of motion is a reformulation of Galileo's law of inertia and states: *Every body continues in its state of rest of uniform motion in a straight line unless compelled by some external force to act otherwise.*

The state of rest and that of uniform motion are both examples of zero acceleration. They are, as a matter of fact, the only examples of zero acceleration. The first law tells us therefore that in order to change such a state of motion we need a force. If a body is at rest, we will have to apply a force on it to make it move. If a body is moving with constant speed in a straight line and if we want to change its speed, we will have to apply a force on it to make it move. If body is moving with constant speed we will have to apply a force in the direction of motion. If we just want to change the direction of motion, we still need a force acting normal to this direction.

Momentum The momentum of an object is defined as follows:

momentum = mass X velocity

With mass measured in kg and velocity in m/s, momentum is measured in kg m/s. like force and velocity, momentum is a vector quantity.

Force and momentum There is an important relationship between momentum and force. It emerges if you consider the equation *F=ma* in more detail. Take the case of the spacecraft.

To begin with, the spacecraft has a velocity *u*. its rocket motor is fired briefly, so that a force *F* acts on the spacecraft for a time t. As a result, the velocity is increased to *v*.

Then, the acceleration a of the spacecraft

$$= \frac{\text{gain in velocity}}{\text{time}}$$

$$= \frac{v-u}{t}$$

So : $F = ma$ can be written $F = m\left(\frac{v-u}{t}\right)$

Multiplying out the brackets : $F = \left(\frac{mv-mu}{t}\right)$

mu is the momentum the spacecraft had originally; *mv* is the momentum it ends up with after the force has acted. The equation above can therefore be expressed in words:

$$\text{force} = \frac{\text{gain in momentum}}{\text{time}}$$

or force = rate of change of momentum

It follows, for example, that a force of 1 N, applied to an object, will make its momentum increase by 1 kg m/s, each second.

Newton's Second Law of Motion Force acting on a body causes changes in its position or state of uniform motion; the acceleration produced is the effect. Newton's second law of motion relates these two quantities–force and acceleration. It states that the force as an object is directly proportional to the product of the mass of the object and its acceleration.

The law is also stated as: The rate of change of momentum of an object is directly proportional to the force acting, and takes place in the direction in which the force acts.

If a constant force is being considered, the law can be written in the following form:

The above proportions show that there are two ways of regarding a force. There are also two ways of defining the newton: 1 newton is the force which gives a mass of 1kg an acceleration of 1 m/s^2 or 1 newton is the force which cause an object to gain momentum at the rate of 1kg m/s per second [1kng m/s^2].

Impulse

As: force =

It follows that : force X time = gain in momentum

In symbols: Ft = mv-mu

When a force acts for a given time, the quantity force X time is called an Impulse. If force is measured in N and time in s, impulse is measured in Ns or kg m/s – both amount to the same thing.

Newton observed that when a given force acted for a given time on any object, a larger mass gained less velocity than a smaller one, but the quantity mass X velocity increased by the same amount in every case. It was this observation that led him to define momentum (though he called it a 'quantity of motion') and to put forward his second law of motion.

Newton's Third Law of Motion Newton's third law of motion states : To every action there is always an equal and opposite reaction. It may be noted that action and reaction which occur in pairs act on different bodies. If they acted on the same body, the resultant force would be zero and there could never be accelerated motion.

When one body exerts a force on a second body, the second body at the same time exerts a force on the first body. It is impossible to have a single isolated force. Furthermore, the above two forces are found to be equal in magnitude and opposite in direction. For example, if we try to push a heavy door the force we exert on it accelerates it as it opens. Simultaneously we feel the force exerted by the door on us impeding our movement.

Conservation of Momentum An important consequence of Newton's third law, in combination with the second, is the law of conservation of momentum which states: When two or more bodies interact with one another, their total momentum remains constant, provided no external forces are acting.

Rocket propulsion One of the spectacular instances in which Newton's third law or the momentum of conservation manifests itself is the flight of a rocket. Here gases produced by the combustion of fuel are ejected and the reaction to this generates the thrust on the rocket. Here is an example in which the mass of the body keeps changing, as the gas escapes from the rocket. The exhaust gases move with an approximately constant velocity with respect to the rocket. If the rate of ejection of gas is constant during firing, then the rate of change of momentum will also be constant. However, as the mass of the rocket keeps decreasing due to the escaping mass of the gases, the acceleration will not remain constant. Both the velocity and the acceleration of the rocket will increase.

Newton's Laws and Circular Motion The third law of Newton always applies to curvilinear motion. When we whirl a stone around by a string, our hand exerts an inner pull–a centripetal force—upon the stone to keep it moving around in a curve. Centripetal force is the inward force required to keep a particle or an object moving in a circular path. It can be shown that a particle moving in a circular path has an acceleration towards the centre of the circle along a radius. This radial acceleration, called the centripetal acceleration, is such that, if a particle has a tangential velocity *v* when moving in a circular path of radius R, the centripetal acceleration is v^2/R. If the particle undergoing the centripetal acceleration has a mass M, then by Newton's second law of motion the centripetal force F_c in the direction of the acceleration is expressed by the equation below,

$$F_c = Mv^2/R = MRù^2$$

Satellites in orbit Gravitational pull provides the centripetal force needed to make a satellite follow a circular path around the Earth. When a satellite is put into a circular orbit, its speed is carefully chosen so that its weight supplies exactly the right amount of centripetal force to keep it in that particular orbit. For a satellite orbiting the Earth just above the atmosphere, the orbital speed required is about 8000m/s (29000 kilometres per hour), and the 'burn time' of the launch vehicle's engines has to be controlled very accurately so that the correct speed is achieved.

FRICTION

Friction is the name given to the force that tries to stop materials sliding across each other. There is friction between your hands when you rub them together, and there is friction between your shoes and the ground when you walk along. Friction is caused in two ways. First, rougher surfaces have ridges and bumps which catch in each other. Second, all materials are made up of tiny particles called molecules, and these have a tendency to stick to each other when materials are pressed together.

Static and Dynamic Friction When a side way force is applied to the block placed on the bench, we see that as the force is increased the friction between the block and the bench rises, reaching its greatest value just as the block is about to slide. This steady speed, the friction is slightly less than before, since the sliding or dynamic friction is less than the static friction. It is easier to slide two surfaces across each other than it is to start them sliding in the first place.

Fluid Friction. Gases and liquids are called fluids. There is friction whenever an object moves through a fluid. Air resistance is an example of fluid friction. When a car is travelling fast on a motorway, air resistance is the largest of all the frictional forces opposing its motion. Nowadays, car bodies are designed so that air resistance is reduced to a minimum.

Rolling Friction The wheel has been considered one of the greatest inventions. It is much easier to cart a heavy load on a trolley with wheels than to push it. Wheels are used extensively in our daily lives for transportation, since they save labour to a great extent. This is because of the reduced friction during rolling as compared to sliding. When a body rolls over a surface the frictional force developed is known as the rolling friction.

Importance of Friction Many everyday activities like walking or gripping objects are carried out through friction, and most people have experienced the problems that arise when there is too little friction and conditions are slippery. However, friction is serious nuisance in devices that move continuously, like electric motors or railroad trains, since it constitutes a dissipation of energy, and a considerable proportion of all the energy generated by humans is wasted in this way. Most of this energy loss appears as heat, while a small proportion induces loss of material from the sliding surfaces, and this eventually leads to further waste, namely, to the wearing out of the whole mechanism.

The Moment of a Force An object is accelerated when acted upon by an unbalanced force and the acceleration is in the direction of the applied force. However, there are situations when a body may be fixed at a point (a door hinged along one side) or along an axis (a wheel free to rotate about a fixed axis). We find that the turning effect of a force increases as the distance of the point of its application from the axis of rotation increases. The turning effect of a force depends upon (i) the perpendicular distance between the point of application of the force and the axis of rotation, called the force-arm or the lever-arm; (ii) the magnitude of the applied force. The turning effect of a force is called moment of the force or torque. The moment of the force is given by the product of the magnitude of the force and the length of the corresponding force-arm. The SI unit of torque is newton- metre. If F be the magnitude of the force and l be the length of the force-arm, than the moment of force is given by $F \times l$. If a force F_1 acting at a distance l_1, from the point of rotation is balanced by a force F_2, acting at a distance l_2 then

$$F_1 \times l_1 = F_2 \times l_2.$$

This principle of moments is utilised in the construction of physical balances. The turning effect of a small force can be increased by applying it at a large distance.

Two equal and opposite forces acting at different points of a body are said to form a couple. The moment of a couple is given by the magnitude of the force and the perpendicular distance between them. The action of a couple tends to rotate the object in one direction. If two equal and opposite couples act simultaneously on an object, they balance each other and no rotation is produced. This is similar to the case in linear motion when two equal and opposite forces acting at a point produce a zero resultant.

3. GRAVITATIONAL FORCE

The Gravitational Force All objects fall because of the gravitational force of attraction exerted on them by the earth. The acceleration due to gravity g is independent of the mass of the object. The force acting is given by F= mg and is the weight of the object. The direction of this acceleration and consequently F is towards the centre of the earth. This direction therefore varies from point to point on the earth, although we may assume it to be constant over a small region. The value of g which is about $9.8 m/s^2$ also shows minor geographical variations. The weight of the body varies accordingly, but its mass remains the same.

It is the gravitational pull of the earth that keeps the moon and the man-made satellites in their orbits. However, gravitation is not just a phenomenon associated with the earth alone. According to Newton's universal law of gravitation there exists a gravitational force of attraction between any two objects. It is a gravitational force of attraction between any two objects. It is this aspect that makes gravitation, a fundamental force in nature.

Newton's law of universal gravitation states: The force between any two particles or masses m_1, and m_2 separated by a distance r, is an attraction acting along the line joining the particles and has the magnitude

$$F=Gm_1m_2/r^2$$

Where G is the universal constant having the same value for all pairs of particles. The value of G is now accepted (in SI units) as

$$6.67 \text{ X } 10^{-11} N.m^2/kg^2$$

The words 'gravity' and 'gravitation' are sometimes used as if they meant the same thing. Strictly speaking, gravitation refers to the acceleration of any two objects in the universe towards each other, while gravity represents the gravitational acceleration towards the centre of the earth. The word "gravity" has also been applied to the gravitational acceleration towards the centre of other celestial bodies. Thus we can speak of the force of gravity on the planet Mars.

Factors affecting g are: (i) Distance from the centre of the earth; the nearer an object is to this point, the greater is the earth's attraction for it and the greater the value of g. (ii) The uneven distribution of the mass on the earth, particularly in the crust.

Weightlessness. Weightlessness is a condition induced by the effective lack of resistance to gravitational force on an object or organism, sometimes known as free fall.

As a body moves from the earth's surface to a location an infinite distance from the earth, the gravitational force approaches zero and the body approaches weightlessness. In the true sense, a body can be weightless only when it is at an infinite distance from all other objects.

Weightlessness is also defined as a condition in which no acceleration, whether of gravity or any other force, can be detected by an object or organism within the system in question. When a gravitational force on a body is opposed by an equal and opposite inertial force, a weightless state is produced. This is based on the fact that the mass that determines the gravitational force of a body is the same as the mass related to the acceleration produced by an inertial force of any kind. These inertial forces have no external physical origin, but are the consequences of an accelerated state of motion. Because of inertia, a moving object always tends to follow a straight line. When a person swings a bucket by the handle in a large circle, he or she feels a pull on his or her hand, because inertial force (also called centrifugal force in this case) tends to keep the bucket moving in a straight line, while the bucket holder exerts a counter force constraining the bucket to move along the circle. A similar situation exists in a spaceship orbiting the earth, 320 km above the earth's surface, where the gravitational field is only slightly weaker than at sea level. The ship, in free fall with negligible atmospheric drag is pulled toward the earth by the earth's gravitational attraction force, while the inertial or centrifugal force of the moving ship is directed radially outward from the earth; consequently, the force of gravity on the orbiting ship is opposed and nullified by the centrifugal force, and apparent weightlessness results.

Artificial Satellites

If we throw a stone with some speed in a horizontal direction, it follows a curved path as it falls to the ground. If the stone is thrown with a higher speed it follows a path of bigger radius as it falls. We thus conclude that the higher the speed of the stone, the greater the radius of the curved path. If somehow we could throw the stone with such tremendous speed that the radius of its path became a little greater than the radius of the earth, the stone would never fall on the earth and would keep revolving around it. This is the principle of an artificial satellite.

In the case of a satellite, the centripetal force is provided by the gravitational pull of the earth. We can calculate the speed of a satellite at a distance r from the centre of the force. Thus if m is the mass of the satellite and g the acceleration due to gravity, we have

V=Org and v=OGM/r

From both the relation, we see that the speed of the satellite does not depend on it mass. It means that at a particular distance from the earth, all objects would have the same speed of revolution.

To see the dependence of *v* on r, we cannot use v = $\sqrt{rg}$ because g also depend on r. However, v = $\sqrt{GM/r}$ shows that v is inversely proportional to the square root of r. Thus if a satellite moves from a higher orbit to a lower orbit, its speed increase.

For an approximate value of v, we can use the radius of the earth, 6.4×10^6 m, and the acceleration due to the gravity, 9.8 m/s^2, which yield

$$v = \sqrt{6.4 \times 10^6 \times 9.8} = 7.9 \times 10^3 \text{ m/s}$$

This is approximately equal to 28,500 km/h. If the speed is lower than this, the projected satellite would simply fall to the earth, 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.

This 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 value of the escape velocity is 1.9 km/s (nearly one-sixth of that on earth). If 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 launching 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 satellite 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 or 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.

CENTRE OF GRAVITY AND STABILITY OF BODIES

Centre of Gravity If the body is in a constant gravitational field, the centre of gravity is the point at which the weight may be considered to act. When a body is suspended from its centre of gravity, it will remain in equilibrium. The centre of gravity of a body may lie even outside it, e.g. in a ring.

In the case of solid bodies with regular geometric shapes, the centre of gravity is always at the geometric centre of the body–that is, if the density is the same throughout. The centre of gravity of a cube or of a sphere is at the exact centre of these solids. For a cone, it is on the axis and at a point a fourth of the way from the base of the cone to its vertex, or tip.

If a body is in the form of a sheet, the centre of gravity corresponds to the centre of the area. If the sheet is rectangular in shape, the centre of gravity is located at the point where the two diagonals intersect. In the case of a triangle, it is one third of the distance from the middle point of any of the three sides to the opposite point. For a circular sheet it is at the centre of the circle.

The location of a body's centre of gravity will determine how stable it is–that is, to what extent it resists any effort to disturb its equilibrium, or balance. Generally speaking, there are three states of equilibrium. They are known as stable, unstable and neutral.

A body is said to be in stable equilibrium if we raise its centre of gravity when we tip it or lift one end. If we release the body, it will fall back to its former position. A square block of wood resting on the floor is a good example of a body that is in stable equilibrium. If we lift up one end of the block slightly, the weight of the body, concentrated at the centre of gravity, will make it return to its original position. However, if we were to tip the block so that a vertical line from the centre of gravity would fall outside the base of the block, it would tip over. It would be in a state of stable equilibrium in its new position. To keep a body as stable as possible, it is advisable to provide a wide base and a low centre of gravity. This is done in designing automobiles boats, furniture, and the like.

If we lower the centre of gravity of a body when we tip it, the body is in unstable equilibrium. Suppose we set a pointed stick in a vertical position on a horizontal table. Any slight tipping of the stick will lower the centre of gravity and will make it fall over suddenly.

If the centre of gravity of a body is neither raised nor lowered when the body is displaced we say that the body is in a state of neutral equilibrium. A ball on a table is in a state of neutral equilibrium, because any force that moves the ball sideways neither lowers nor raises the centre of gravity. It will continue to remain in equilibrium, no matter how we move it along the table.

4. WORK, ENERGY AND POWER

WORK

In common usage the term 'work' may refer to any kind of physical or mental activity. But according to scientific definition, work is done only when a force produces motion. Thus work is done on a weight that is being lifted, or on a spring that is being stretched or compressed, or on a gas that is undergoing compression in a cylinder.

When the force acting on a moving body is constant in magnitude and direction, the amount of work done is defined as the product of just two factors: the component of the force in the direction of motion, and the distance moved by the point of application of the force.

If the magnitude of the force is F and the distance through which the body moves is d, the work
$W = Fd$.

The SI unit of work is joule (J) which is also newton-metre.

ENERGY

Energy is defined as the capacity to do work. We see energy in many different forms like chemical energy, electrical energy, which are used in a number of ways. For example, we utilise the chemical energy locked up in sources like coal, oil, and gas when it is released in the form of heat. Light and sound also carry energy. One form of energy can be converted into another form. Energy like work is measured in joules (J).

In mechanics, energy is classified into two kinds : kinetic and potential.

Kinetic Energy Moving objects, such as bullets, cars and cricket balls, all have kinetic energy. Kinetic energy is the energy which is possessed by a body by virtue of its motion.

Kinetic energy (KE) = $1/2mv^2$ where m is the mass of the body and v is its speed.

Potential Energy Potential energy is the energy stored in a body or a system by virtue of its position in a field of force or by its configuration. A force acting on a body or a system can alter its potential energy.

There are two common examples of potential energy corresponding to the two situations mentioned above. The first one is the potential energy of a body due to gravity above the surface of the earth. The second example is the potential energy of a spring when it is compressed or elongated by an external force.

Conversion of gravitational PE to KE and then on to some usefull purpose is made use of in many situations. Perhaps the most important instance of this is in hydroelectric power generation. Dams are built at high levels to store large amounts of water which will posses great amounts of gravitational PE. This water is made to rush down pipes; thus its PE is converted in to KE and it gains tremendous speed. It is then made to run the turbines of the electric generators that produce electrical energy. It is this hydroelectrical energy that is used in innumerable ways every day in our lives.

DIFFERENT FORMS OF ENERGY

Thermal energy All materials are made up of tiny particles called molecules. These molecules are constantly in motion. In solids and liquids, the molecules are held close together by strong forces of attraction, and move by vibrating to and fro. In gases, the molecules have become so spaced out that they move about freely at high speed. In some cases they also spin.

Molecules have kinetic energy because they are moving. They also have potential energy because their movements keep them separated, despite the 'spring-like' attractions trying to pull them together. Thermal energy is the name given to the energy an object possesses because of the kinetic energy and potential energy of its molecules. The higher the temperature of an object the faster its molecules move, and the greater is its thermal energy.

Thermal energy is commonly known as heat energy. However, engineers prefer to keep the term heat energy for thermal energy which is the process of being transferred from one object to another.

Chemical Energy A stable chemical compound has less energy than its separated parts, the difference being in the specific arrangement and motion of electrons and nuclei in the compound. This difference is called chemical energy or energy of chemical binding. In a chemical reaction, energy can be absorbed or released, depending on whether the total energy of the reactants is less or more than that of the products (endothermic or exothermic reactions). Examples are respectively, hydrolysis and burning of coal.

Electrical Energy Electric charges and currents attract or repel each other, i.e. they exert forces on each other. Thus work needs to be done in general to move them with respect to one another. The energy associated with this work is called electrical or electromagnetic energy.

Energy Related to Mass While it is commonly known that differnet forms of energy are inter-convertible, it was only recently discovered that matter is equivalent to energy. Albert Einstein showed the energy (E) associated with a mass m (just because of its existence) is given by the formula,

$$E = mc^2$$

Where *c* is the speed of light in vacuum, equal approximately to 3 X 10^5Km/s. Even a minute amount of matter can give rise to an immense quantity of energy if his conversion can be made. A collision between an electron and a positron (oppositely charged version of the electron), two bits of matter, can lead to their total annihilation and to the production of pure energy (electromagnetic radiation) of the amount given in the equation.

Nuclear Energy The mass-energy equation explains nuclear energy. Neutrons and protons attract each other at distances of an order 10^{-15}m, and bind (come together) to form nuclei. The associated energy is called nuclear energy.

CONSERVATON OF ENERGY

Energy cannot be created or destroyed. It may be transformed from one kind to the other. The total energy in a closed system remains constant. Here when we say 'energy' we must include mass also, since mass can be converted into energy.

This is the **law of conservation of energy** which has never been found to be violated. The law cannot be proved mathematically, but is an empirical one. It forms one of the fundamental principles of physics.

POWER

A small engine can do just as much work as a larger engine, but it takes longer to do it. The larger engine can do work at a faster rate.

The rate at which work is done is called the power:

$$\text{Power} = \frac{\text{work done}}{\text{time taken}} \text{ or } \frac{\text{energy transferred}}{\text{time taken}}$$

Power is measured in joules per second (J/s), or watts [W]. If an engine does 1 joule of useful work every second, it has a power output of 1W. If an engine does 4000J of work in 10s, it has a power output of 400W. Larger powers are also given in kilowatts or megawatts.

1 kilowatt [kW] = 1000W [1000J/s]

1 megawatt [MW] = 1000000 [1000,000J/s]

Sometimes, engine powers are given in horsepower [hp], a unit which dates from the time when steam engines first replaced horses as a power source. 1hp equals 746W, or about 3/4kW.

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

Efficient of a Machine In 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, i.e.,

$$Efficency = \frac{Useful\ work\ done\ by\ the\ machine}{Work\ done\ on\ the\ machine} \times 100$$

Thus in practice the efficiency of a machine is always less than 100 per cent.

Simple Machines If we were to take apart a complicated machine, such as a typewriter, we would find it made up a number of simpler elements. There are actually just six of these basic elements, which we call simple machines. These are the lever, the inclined plane, the wedge, the screw, the wheel and axle, and the pulley.

Three Classes of Lever A lever is the simplest and the most commonly used of all machines. A lever is a rigid bar, straight or curved, which is capable of turning freely about a fixed point, called the fulcrum F or pivot. When a force (or effort) E is applied at some convenient point on the lever, a much bigger force L (called load) is exerted at another point. The perpendicular distance between the fulcrum and the point of application of the effort is called the effort arm of the lever and the perpendicular distance between the fulcrum and the point of application of the load is called its load arm.

Levers are divided into three classes depending on the relative positions of the fulcrum F, load L and effort E.

$$V.R. = \frac{distance\ of\ effort\ from\ fulcrum}{distance\ of\ load\ from\ fulcrum}$$

Levers of first class: The levers which have fulcrum F between load L and effort E are said to be levers of first class. Example : crowbar, see-saw, hammer, scissors, handle of a water pump, pliers, handbrake of a bicycle, etc.

Levers of second class: The levers which have the load L between the fulcrum F and effort E are called levers of second class. Examples: wheel-barrow, nut-cracker, lemon squeezer, oar of a boat, a door rotating on its hinge, foot bellows, etc.

Levers of third class: The levers which have effort E between fulcrum F and load L are said to belong to levers of third class. Examples : fire or sugar or ice cube tongs, table knife, forces in a weight box, etc.

The mechanical advantage of every simple machine is found in the same way. We just divide the load by the effort required to move it, or we divide the effort distance by the load distance, which amounts to the same thing. In the case of levers, we can also divide the effort arm by the load arm.

5. MECHANICAL PROPERTIES OF FLUIDS

Density and Relative Density

Density If we hold cubes of equal volume of different solids such as wood, aluminium, lead, etc. we notice immediately that lead has a higher density than wood or aluminium.

$$\text{Density} = \frac{mass}{volume}$$

The SI unit of density is kilogram per metre cubed. Density of water is 1,000 kg/m^3 (or 1 g/cm^3). The densities of some of the common substances are listed in the following table.

Substance	Density in kg/m^3
Alcohol	790
Aluminium	2,700
Copper	8,900
Gold	19,300
Lead	11,300
Mercury	13,600
Platinum	21,500
Steel (varies)	7,800
Turpentine	870
Water	1,000
Wood (varies)	700

Relative Density The relative density (RD) of a substance is the ratio of the density of the substance to the density of water. Relative density has no unit. From the table of densities we find that the RD of mercury is 13.6 and that of turpentine 0.87.

Pressure

Pressure is defined as force acting per unit area.

$$\text{Pressure} = \frac{force}{area}$$

The SI unit of pressure is newton per metre square or **pascal**.

To illustrate the difference between pressure and force, consider two identical bricks of equal weight. One brick stands on its side and the other on its end. Both bricks exert the same force on the ground but the upright brick exerts greater pressure against the ground due to its smaller area of contact.

It is much easier to cut find with a sharp knife than with a blunt one. In the case of sharp knife the blade makes such as small area of contract 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.

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.

$$P = hpg$$

Where g is the acceleration due to gravity.

Since the pressure of water increase 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 place is transmitted equally throughout the liquid. Hydraulic presses, hydraulic brakes, hydraulic door closers, etc. are application of this principle.

Atmosphere Pressure The air surroundings the earth is pressure not only 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 of air which exerts enormous pressure. This pressure is not felt because the blood exerts a slightly higher pressure from inside. At high altitudes where atmospheric pressure is less nose bleedings 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 a syringe when the piston is pulled.

One is able to have cold drink using a straw-pipe due to atmosphere pressure. When the air from the pipe is sucked, the atmosphere pressure pushes the liquid up in the pipe.

In an aircraft flying at high altitude, normal atmospheric pressure is maintained by the use of air pumps, if this were not done, the crew and passengers would experience difficulty in breathing and consequently face dangers.

Atmospheric pressure is measured with an instrument called the **barometer**. Accurate measurement of atmospheric pressure in laboratories is made with a Fortin's barometer which is an improved form of simple mercury barometer. A small portable barometer, called the aneroid barometer does not use any liquid.

Since atmosphere pressure varies with altitudes, a barometer can be used for determining altitudes. An aneroid barometer calibrated for determining altitude 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 possibilities of rain. A gradual increase in the barometric height indicates fair weather.

Surface Tension

A molecule at A is pulled equally in all directions by the cohesion of liquid molecules all around it. A molecule at B is pulled by the liquid molecules around it, but since it is near the surface there are more liquid molecules below it than above it, so the downward force of attraction is greater than the upward force of attraction. The molecule at C, which is at the surface of the liquid, has no liquid molecules above it, and has a strong downward pull, unbalanced by an equal upward pull as in the case of the molecule at A. We see therefore that there is an unbalanced force tending to pull the surface molecules toward the interior of the liquid and to keep the free surface of the liquid as small as possible. The tendency of a liquid surface to contract and occupy the minimum area possible is called surface tension. When a force acts on a liquid surface and distorts it, the force of attraction between the liquid molecules i.e. the cohesion of the liquid molecules exerts a counter balancing force which tends to restore the original surface.

Surface tension accounts for many interesting phenomena. Small droplets of liquid tend to be spherical shape requires the smallest surface area. The pull on the surface of a liquid produces the effect of a thin skin covering it. Small insects are often observed to walk or run on the surface of water. A needle can be made to float on the surface, even though the needle may be nearly ten times as dense as water.

Surface tension is affected by temperature. It is reduced as the temperature rises. Impurities in solution also bring about a reduction of surface tension. So do modern synthetic detergents. As a result they greatly increase the wetting ability of water. Many materials that are not wet at all by pure water become soaked when a small quantity of detergent is dissolved in the liquid. A duck can swim easily because its feathers are not wet by water. If it tries to swim in water to which detergent has been added, its feathers will becomes soaked and it will drown if not rescued. Antiseptics under for cuts and other punctures of human flesh should have a low surface tension, as well as good germ-killing ability. If the surface tension were high, not all the damaged surface would be wet by the liquid. Alcohol and most other antiseptics have a low surface tension.

Capillarity

A capillary tube is one with a very fine bore, 'capilla' being the Latin word for 'hair'. When such a tube is placed in water, the water will rise up the tube. The thinner the bore of the tube the greater the height to which the water rises. If a capillary tube is placed in mercury, the mercury falls in the tube, and the depression of the mercury is greater in narrow tubes that it is in wider tubes.

The elevation or depression of liquids in narrow tubes, (tubes of very fine bore) is called capillarity.

The rise of water in a capillary tube can be explained in the following way. Since the adhesion of water to glass is greater than the cohesion of water molecules, the water sticks to the glass, and this produces a curved concave surface. Surface tension tends to contract this surface and the water rises as the surface contracts till it loses its curve and is level. Adhesion again results in water sticking to the glass which further curves the surface. The effect of surface tension which contracts the surface again raises the water. Thus the water gradually crawls up the tube due to the effects of both adhesion and surface tension. The water will continue to rise until the combined effect of the forces of adhesion and surface tension is balanced by the force of gravity (i.e. the weight of the water column).

Bearing in mind that in the case of mercury, the force of cohesion between the mercury molecules is greater than the force of adhesion of mercury for glass, explains the depression of mercury in capillary tubes.

Capillarity is of considerable practical importance. Plants grow in soil only because capillarity makes it possible for water to be drawn up through the fine spaces between the grains of the soil to the roots of the plant. Cloth absorbs water by capillary action. Oil is drawn up the wick of a lamp by capillarity, and blotting paper absorbs ink by capillarity.

Osmosis

Certain substances are porous to one material, but not to another. For example, water will diffuse through a thin slice of potato, but sugar molecules will not. A membrane of this sort is called a semipermeable membrane. The selective diffusion through such a membrane is known as osmosis. Osmosis plays an important part in carrying liquids through plants, and in the absorption of food and disposal of waste by cells in plants and animals. It explains how food passes through the walls of intestines, and also explains in part how sap is forced to the top of a tree.

Viscosity

If you stir some water in a glass with a spoon and then stop stirring the water continues to swirl more and more slowly until comes to rest. If you had stirred honey or treacle instead of water, it would have come to rest much more quickly internal friction in treacle or honey is greater than internal friction, or resistance to motion, in water. Treacle is more viscous than water; it has greater viscosity. The viscosity of a fluid is the property it possesses of resisting the movement of its various parts. Viscosity is the internal friction of a fluid.

The viscosity of a gas, however, increases as the temperature increases. The reason is that in the case of a gas the diffusion of gas molecules from one moving layer of gas to another determines the viscosity of that gas. Since the rate of diffusion molecular speed, the viscosity of a gas becomes greater as it temperatures rises.

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' Principles This principle states that when a body is wholly or partially immersed in a fluid, it experience 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. It is due to upthrust that objects apparently weigh less when immersed in fluids.

An angler pulling a fish out of water experiences the sudden increase in the weight of the fish as soon as it is out of water.

It requires relatively less efforts to lift a larger boulder off the bottom of river bed as long as the boulder is under water. Once the same boulder is out of the water, considerably greater effort is required to lift it.

The relative values of the weight and upthrust determine whether an object will sink in a liquid or float in it. If the weight of the immersed object is greater than the upthrust, the object will sink. If the weight is equal to the upthrust, the object remains at any level like a fish. If the upthrust is greater than the weight of the immersed object it will float to the surface.

It can easily be shown that an object will sink in a liquid if its density is more than that of the liquid. If the density of the object is less than that of the liquid, it will float on it.

Law of Floatation When a block of wood is placed in water in sinks until the weight of water displaced is just equal to its own weight. When this happens the block floats. This example illustrates the law of floatation, which states: A floating body displaces its own weight of the fluid in which it floats.

Archimedes' principles and law of floatation can explain several phenomena.

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. It is for this reason that a ship rises a little when it enters a sea from a river.

It is because of the higher density of sea water that it is easier to swim in the sea.

A submarine has large ballast 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 of 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 indefinite altitude. At a certain height, where the density of air is equal to the average density of the balloon, 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.

Hydrometer

A hydrometer is an instrument used for measurement the density or relative density of liquids. It 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.

Bernoulli's Principle–Fluids in Motion. For continuous flow of liquid through a pipeline of non-uniform cross-section, the velocity of the liquid is greater in the narrower parts of the pipe. Bernoulli (1654-1705) observed a very interesting phenomenon. He found that in a liquid flow (this also holds for gas flow), the pressure is lower in the region where the flow is faster. This is called Bernoulli's principle. We may also state it in the following way.

When the speed of fluid (liquid or gas) in a pipeline increases, the pressure decreases and conversely when the speed of a fluid decreases, the pressure increases.

The jet water pump, which is often used to pump water out of basements, works on Bernoulli's principle. Bernoulli's principle also explains why two speedboats moving parallel and close to each other are likely to the pulled together and collide. As the boats move forward, water is funneled into the narrow region between them. The relative speed between the water and the boats is greater in this narrow region than if there were more space between the boats. As a result, there is a decrease in pressure of the water between the boats, and the greater pressure of the water upon the outer sides pushes the boats together.

6. HEAT

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 substances, the hotter it is.

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 increase internal energy.

Water at the bottom of a waterfall is slightly warmer than that at the top. The potential energy possessed by water at the top of the fail 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.

Temperature and Heat The temperature of a body is the quantity that tells how hot or cold it is with respect to some standard body. Heat is the internal energy transferred from one body to another due to temperature difference. Thus heat is the name given to energy only in the process of transfer. After heat has been transferred to a body it becomes the internal energy of the body. Heat always flows from substance at a higher temperature into a substances at a lower temperature, but not necessarily from a substance with more internal energy into a substances with less internal energy. For example, if on dippings a very hot spoon in a bucketful of warm water, heat will flow from the spoon to the water, even thought there is more internal energy in the warm water than in the spoon. It is clear from this example that temperature and heat are different things and should not be confused.

If one places two identical containers, one containing double the quantity of water than in the other, on the same hot plate, one finds that the temperature of the smaller quantity of water rises faster even though equal quantities of heat are being supplied to each container.

Measurement of Temperature Temperature is measured by a **thermometer**. There are several types of thermometer but the most common is the mercury in glass type which measures temperature by means of the expansion and contraction of mercury.

To fix a scale for a thermometer, the number 0 (zero) is assigned to the temperature of pure melting ice and the number 100 to the temperature of steam from water boiling under the standard atmosphere pressure of 760 mm of mercury. The space between is divided into 100 equal parts, called degrees. This is called the Celsius scale and the temperature on this scale are called **degrees Celsius** (ºC)

On the Fahrenheit scale of temperature the number 32 corresponds to 0ºC and the number 212 to 100ºC. To convert temperature from the Fahrenheit to the Celsius scale, the following relation is used.

$$T- c/5=(T_F-32)/9$$

Where t_C is the temperature on the Celsius scale corresponding to t_F on the Fahrenheit scale.

Using the 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 273.16º below zero' on the Celsius scale of temperature. On the Kelvin scale absolute zero is 0 K (it is not written as 0º K). On Kelvin scale 0ºC corresponds to 273.16 K and 100ºC to 373.16 K Degrees on the Kelvin scale are calibrated with the same-sized division as on the Celsius scale. Thus, a 10ºC rise of temperature is equal to a 10 K rise of temperature.

There is an absolute thermodynamic temperature scale. The most recent official temperature scale is the international Temperature Scale of 1990. It extends from 0.65 K (–272.5ºC) to approximately 1358K (1085ºC) .

Types of the Thermometers There are different kinds of thermometers. Some of them are considered here.

Liquid-in-glass Thermometer This thermometer consists of a liquid-filled glass bulb and a connecting partially filled capillary tube. When the temperature of the thermometer increases, the differential expansion between the glass and the liquid causes the liquid to rise in the capillary. A variety of liquids, such as mercury, alcohol, toluene and pentane, and a number of different glasses are used in thermometer construction, so that various designs cover diverse ranges between about-300ºF and + 1200ºF (-184ºC and + 649ºC).

The advantages and disadvantages of mercury and alcohol are as follow:

Mercury Advantage

Doesn't wet sides of tube thread easy to see.

Conducts heat well:

Thermometer responds quickly to temperatures changes

Disadvantages

Freezes at-39ºC: thermometers not suitable for low Arctic temperatures. Poisonous: thermometer hazardous if broken. Expensive.

Alcohol Advantage

Freezes at -115ºC:

Thermometer suitable for low Arctic temperatures.

Expansion greater than mercury: wider tube can be used

Disadvantages

Has to be coloured to be seen easily.Clings to sides of tube. Thread has tendency to break.

The Clinical Thermometer is a special liquid-in-glass thermometer. This thermometer is a specially designed to measure human body temperature. It measures over a very limited range of 35-43ºC. 'Normal' body temperature is 37ºC (98.4ºF). The thermometer contains mercury and the tube has a constriction/(a narrowing) next to the bulb. This stops the mercury thread running back into the bulb, so the temperature reading can be taken after the thermometer has been removed from the patient's mouth. The thermometer has to be shaken to get the mercury back past the constriction.

Thermometers for Industry Many industrial processes depend on the accurate measurement and control of temperature. Liquid-in-glass thermometers aren't really suitable for industrial work. Firstly, their temperature range is often too limited. Secondly, it is usually more convenient for the operator to read the temperature on a meter or digital display placed some distance away from the source of heat. Thirdly, electrical methods of measuring temperature give readings which can be recorded automatically or fed directly to a computer controlling the heating process.

Resistance thermometers are based on the principle that it becomes more and more difficult to pass an electric current through a piece of metal as its temperature rises. These thermometers usually contain a length of this platinum wire connected to a power supply. The higher the temperature, the less the current passing through the wire and the further down the meter scale the needle moves. Resistance thermometers can be used to measure temperatures from about—200ºC to 1200ºC.

Thermistor thermometers work along similar lines. A thermistor is a small device which offers less and less resistance to a flow of electricity as its temperature rises.

Thermocouple thermometer In this two different types of metal wire are joined together at two junctions. A temperature difference between the junctions actually makes the metals produce a small electric current which moves the meter needle across the scale. Thermocouple thermometers are often used to measure oven and furnace temperatures. They can operate over a temperature range from about—200ºC to 1600ºC.

Bimetal thermometer A bimetal thermometer contains a bimetal strip (two thin strips of different metals are bonded together to form a bimetal strip) in the form of a long spiral. The centre of spiral is attached to a pointer; the other end is fixed. When the temperature rises, the bimetal strip coils itself into an even tighter spiral and the pointer moves across the scale. This thermometer is not as accurate as some other types of thermometers but they are robust and easy to read.

Pyrometers These instruments were developed to measure high temperatures using emitted radiation. These instruments are not to be in contact with the hot body. They can measure temperature howsoever high and the lower practical limit for radiation pyrometers is about 900K.

Thermal Expansion

Solids liquids and gases generally expand on heating 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.

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 fixed while the other rests on rollers. Telephone wires sag more in summer than in winter due to expansion.

Thermal expansion of solids has many useful applications too. Iron and steel 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.

Expansivity If we heat a 1-m long iron and through 1ºC (or 1 K), its length increase by 0.0000012 m. We say that the linear expansivity of iron is 0.0000012º/C. Linear expansivities of some solids in per degree Celsius are as follows:

Substance	Linear Expansivity (/ºC)
Brass	0.000019
Invar	0.000001
Glass (ordinary)	0.000009
Glass (pyrex)	0.000003

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 to 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 temperature of electrically-heated rooms, Ovens, toasters, etc. Refrigerators are also equipped with special thermostats.

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

Expansion of Gases – The Gas Laws: The expansion of a gas isn't as simple as the expansion of a liquid or solid. There are more factors to consider because a gas is so much more compressible. Studying the behaviour of a gas is complicated by the fact that you have to consider its pressure as well as its volume and temperature. The pressure, volume and temperature of any fixed mass of gas are all related, so a change in one of these factors always produces a change in at least one of the other two. Sometimes, all three factors may change at once. This happens, for example, when air rises in a thundercloud or gases expand in the cylinders of a car engine.

To find the laws linking pressure, volume and temperature experimentally, each factor is kept constant in turn while the relation between the other two factors is investigated.

The Pressure law and the Kinetic theory : According to the kinetic theory, gas molecules are constantly bombarding the sides of any container they happen to be in. There is an outward force on the container whenever a molecule strikes it and bounces off. Many billions of molecules hit the container every second and this produces a steady outward pressure.

If the temperature rises, the molecules move faster. They strike the container with greater force, and the pressure increases as a result. A fall in temperature produces the opposite effect. The molecules move more slowly and the pressure drops.

If the pressure continued to drop as shown in the graph a gas would exert no pressure at all at absolute zero. It was this feature of a pressure-temperature graph that first suggested to experimenters that there might be an absolute zero of temperature at -273°C. In practice, all gases turn liquid before absolute zero is reached. Oxygen for example liquefies at about 90K.

Charle's Law. This law states that: The volume of a fixed mass of gas is directly proportional to its absolute temperature provided the pressure of the gas is kept constant.

The pressure is inversely proportional to volume.

Boyle's law and the kinetic theory. The kinetic theory explains Boyle's law as follows, If the volume of a gas is reduced to half is value, each cubic metre of a container will hold twice as many molecules as before. Every second, there will therefore be twice as many impacts with each square metre of the container sides. The pressure is doubled as a result.

The Combined Gas Equation. The result of the three laws just described can be expressed in the form of a single equation.

For a fixed mass of gas, $\frac{pV}{T}$ = constant

This is sometimes known as the combined gas equation. The gas laws can all be obtained from his equation:

If V is constant , *p/T* is constant (the pressure law)

If p is constant , *V/T* is constant (Charle's law)

If T is constant ,*pV* is constant (Boyle's law)

A gas which obeys the gas laws exactly is known as an ideal gas. In reality, no gases are ideal though most can be regarded as such at low or medium pressures and medium temperature. If a gas is near its liquefying temperature, attractions between its molecules begin to influence its behaviour and it no longer acts like an ideal gas. If a gas is highly compressed, the size of molecules restricts the space available for movement this to affects the way the gas behaves.

Change of State. An important effect of heat is change of state. This means that as a body is heated, it passes from one another of the three states or phases, in which matter can exist – solid, liquid, and gas.

What happens when a body passes from the solid to the liquid phase? The molecules of a solid are closely packed together and exert considerable attractive force upon one another. That is why the original shape of the solid is maintained. Now, as heat is applied to the solid, the vibratory energy of the molecules is increased, and the individual molecules break loose from the bonds that formerly held them. What was formerly a solid has now become a liquid.

The cooling effect of ice is a consequence of the change of state from solid to liquid. The heat required for the melting of ice is absorbed from the surrounding objects, thus lowering their temperature. When ice cubes are added to a beverage, the cubes gradually melt as they absorb heat from the liquid. This causes the liquid to become cooler.

The temperature at which a solid changes to a liquid is called the melting point of the solid. The name freezing point is applied to the temperature at which a liquid solidifies. For a given crystalline material, these two temperatures are the same. They are not identical in the case of certain substances, such as fats and glasses. Glass is not a true solid, but a supercooled liquid.

The melting points of different materials vary widely. Mercury, for example, melts at –38.87º Celsius; iron, at1535ºC, tungsten at3370ºC. The low melting point of some alloys such as Wood's metal, makes them valuable in fire-control systems. The sprinkler valves in such systems are held shut by plugs of the alloy. If the temperature in the room rises above 70º Celsius, the plug melts, causing the sprinklers to go into action. Wood's metal is often used in making trick spoons. A spoon of this sort will melt when it is used to stir a hot liquid.

The amount of heat required to melt a unit mass of a substance when it reaches the melting point is called the heat of fusion. This varies with different substances. Ice, for example, absorbs 79.71 calories for each gram of ice melted. Aluminum absorbs 94 calories; copper, 49 calories; lead only 5.47. The heat energy absorbed at this stage does not show itself in a rise in temperature. Hence the heat of fusion is sometimes referred to as latent (hidden) heat.

If the temperature of a liquid is lowered, it will become a solid. Here, too, the kinetic molecular theory furnishes an adequate explanation of what takes place. As the temperature of the liquid drops, the molecules of which it consists possess less energy. They move more sluggishly and they undergo, to a greater extent than before, the attraction of adjacent molecules. Finally, they are so strongly attracted by these molecules that they acquire fixed positions.

An increase in pressure can result in a lowering of the melting point for some solids. It happens to those solids. It happens to those solids whose volume decrease on melting e.g. water. If we have a block of ice with a wire carrying weights around it, the wire passes slowly through the ice block, leaving it completely solid. The pressure under the wire is sufficient to lower the melting point; the ice melts and the wire sinks through the melted water which then re-freezes.

Evaporation. When a liquid is heated, a different sort of change takes place. At any specific temperature, a given liquid contains molecules possessing different amounts of energy. Some of the molecules will be energetic enough to pass through the boundary surface of the liquid, but the attraction of the surface molecules will draw the escaping molecules back again. Certain molecules, possessing even more energy, will pass to the outer air and will travel beyond the attractive influence of the molecules at the surface. The escaping molecules will constitute a gas, or vapour. The process of passing from the liquid to the gaseous state is called evaporation.

Evaporation goes on at all temperatures. It continues until the liquid disappears or until the space above the liquid becomes saturated. This condition occurs when as many molecules leave the liquid as return to it from the space above, thus bringing about a condition of equilibrium.

Since evaporation consists of the loss of high-energy molecules from the liquid, it is obvious that the average energy of the remaining molecules will decrease and the temperature will drop. This effect of evaporation has been known since ancient times and is still utilised in various tropical countries in order to cool drinking water.

Water evaporating from the skin helps maintain body temperature. When the weather is warm we perspire. As the perspiration evaporates, the skin is cooled. Evaporation is slowed up in damp weather, since the concentration of water vapour in the air approaches the saturation point. That is why we feel cooler on dry days than on damp days, even though the temperature may be the same.

The rate of evaporation of a liquid can be increased by the following methods:

- Increasing the temperature of the liquid; if the energy of the liquid is increased its molecules move more quickly and more molecules have enough energy to escape.
- Increasing the surface area of the liquid; this increases the chance of a molecule being at the surface.
- Placing the liquid in a draught; the air carries away the molecules that have left the liquid so that they cannot return.

Condensation. Condensation is a change from vapour to liquid. The temperature at which vapour condenses into liquid is dew point. Dew is the water droplets that condense from air onto a cooler surface.

Boiling. As the temperature of a liquid is increased, it will reach a point at which the liquid will begin to boil. Boiling may be considered as evaporation taking place throughout the body of the liquid rather than just at the surface. Bubbles of vapour are formed in the interior of the liquid. They rise and then break through the surface.

Boiling can be brought about more readily either by increasing the temperature or lowering the pressure. An increase in pressure will raise the boiling point. On the other hand, when the pressure is lessened, the boiling point is lowered. At high altitudes, the decrease in atmospheric pressure is such that certain cooking processes are slowed up. Such difficulties can be eliminated through the use of a pressure cooker. This is a closed vessel in which pressure is built up by the steam that forms as water in the vessel is heated.

The reduced boiling point at low pressure finds considerable practical application in the field of vacuum evaporation (evaporation under low pressure). This process is of primary importance in the sugar industry. Boiling off the water from the syrup at normal atmospheric pressure would char the sugar. However, the pressure is kept so low in vacuum evaporation that the water may be removed at comparatively low temperatures.

The amount of heat required to change a unit mass of liquid to its vapour state at its boiling point is called the heat of vaporization of the substance. Each material has its own heat of vaporization. For example, it takes nearly 540 calories to vaporize a gram of water at l00°Celsius. Only 204calories are required in the case of ethyl (grain) alcohol.

The quantity of heat required to completely change 1 kg of a solid to liquid at its melting point, without any change in temperature is known as the latent heat of melting. The latent heat of vaporization is defined as the quantity of heat required to convert 1 kg of water at 100°C into water vapour at the same temperature.

Sublimation. In going from the solid to the gaseous state, most substances pass through the intermediate liquid state. Certain substances, however, go directly from solid to vapour form—a process known as sublimation. Naphthalene moth balls, iodine crystals, and the insecticide paradichlorobenzene are good examples of this phenomenon. Solid carbon dioxide also sublimes under ordinary conditions. It is often called “dry ice” because it is used to keep objects cold. It is excellent for this purpose, since it does not wet the substances it refrigerate.

Greenhouse Effect

Glass is transparent to the light and short wavelength infrared radiation emitted by very hot objects. On the other hand, glass won’t transmit the long wavelength infrared given out by cooler objects. The radiation is either reflected or absorbed. These properties of glass are used in a greenhouse to ‘trap’ heat on a sunny day.

Light and short wavelength infrared radiation from the Sun passes easily through the glass roof of a greenhouse and warms the air and other materials inside. These warmed materials also give off thermal radiation. The wavelengths are longer however, and much of the radiation is reflected back into the green house when it strikes the glass.

Solar Cooker

A simple solar cooker is a box made of insulating materials 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 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. Thus in a thermos flask, the transmission is minimized and, therefore its content remains at nearly the same temperature for a long time.

THERMODYNAMIC PRINCIPLES AND ENTROPY

Laws of Thermodynamics Thermodynamic studies heat and mechanical motion as forms of energy and the conditions under which one may be converted into the other. The fruit of the science of thermodynamics was the development of many processes and devices that perform useful tasks through the conversion of heat into mechanical motion, or through the conversion of mechanical motion into heat. These include refrigeration systems, internal (such as gas turbine and diesel) and external (such as steam turbine) combustion engines, and rocket engines.

Two laws govern the transformation of energy from one form into another. These are known as the first and second laws of thermodynamics.

The first law of thermodynamics, also known as the law of the conservation of energy, states that energy can be neither created nor destroyed, only changed from one form to another. When a hydroelectric plant changes the energy of falling water into electricity, a specific amount of electricity will be created in a certain period of time. Similarly, when an electric motor changes this electricity into the mechanical motion is produced. According to the first law of thermodynamics, the falling water the electricity produced by the water, and the mechanical motion produced by the electricity all have the same amount of energy (ignoring energy lost due to imperfections in the systems). A fixed amount of falling water will never produce more than the equivalent amount of electricity, and this same amount of electricity will never produce more than the equivalent amount of mechanical motion.

In practice, this amount is not quite exact, for a certain amount of energy is converted through friction into heat . The total amount of energy produced, however, including heat energy due to friction, is always the same as the energy that entered into the system.

The first law, in short, says that, ideally, energy transformations are reversible.

Einstein's discovery in 1905 that energy can be created from matter does not affect the first law. It merely means that it must be extended to include the energy in matter (Physicists today regularly refer to subatomic particles not by how much mass they have, but by how much energy their mass represents.) The first law says that although energy may be converted into many forms, the amount of energy in the system is always the same.

The second law of thermodynamics, also known as the law of entropy, places a certain quantification on these energy transactions. Every time energy is converted from one form into another-form the energy of falling water into electricity, or electricity into mechanical motion, for instance-not all of it is completely converted into useful work. A certain percentage of it goes into the creation of heat energy which cannot be applied to do useful work.

This is not a contradiction of the first law. An equal amount of energy is always generated in energy transformations. All that the second law says is that a certain percentage of the energy, however small, must go to generating heat energy. Energy transformations, as it were, always "leak"; more specifically, they leak in the form of heat.

According to the second law, leaking energy as heat is a property of every reversible energy process. One of the pioneers of thermodynamics, the German physicist Rudolf Clausius, coined the word entropy for this property, from the Greek for "humiliation" or "lowering".

While the first law says that the total amount of energy in a system is always constant, the second law says that the percentage of energy in a system available for doing work is always decreasing.

Entropy A scientist thinks of disorder in terms of atoms and molecules. This disorder he calls entropy; i.e., it is the amount of disorder that occurs during a chemical or physical change, or the amount of disorder present in a system. The branch of science that deals with entropy and its changes is called thermodynamics.

In crystalline solids, atoms and molecules are always arranged in an orderly manner. Such an orderly arrangement is typical of matter in a solid state. The molecules do have some freedom of motion, but, because they are so close together and are held in place by very strong forces, their freedom of motion is quite limited. The molecules can rotate about the midpoint of their tiny "cage" within the crystal lattice, but they cannot migrate throughout the bulk of the material. There is, in other words, a great deal of order. Or, to put it another way, there is little entropy in this system.

In liquids and gases, distances between molecules are greater and the forces between them are weaker than in solids. The molecules can migrate throughout the bulk of the material. There is more disorder in liquids and especially in gases than there is in solids. Hence, there is more entropy in these states of matter.

Different substances have different amounts of entropy. Hard substances, such as diamonds, have less entropy than do platinum and lead.

Mechanical Equivalent of Heat The ratio between the energy lost in a mechanical process and the heat produced in the process is a constant, whatever be the nature of the substance or its volume. The ratio, 4185 joule/1Cal is known as the mechanical equivalent of heat and it is represented by J (1 cal= 4.2 joule.). All forms of energy, including heat, are now measured in joule. The heat Q required to raise the temperature of m kg of substance of specific heat C through T°C would be Q=mCT.

7. WAVES

NATURE OF WAVES

There are essentially two ways of sending energy from one place to another. The first involves actual transfer of matter and the second method involves what we call a wave process. Energy may be transferred through matter by mechanical waves such as sound waves or through space by electromagnetic waves–e.g. passage of light from a distant Star through outer space. Waves travel with a finite speed. Each wave has its own wavelength, frequency, amplitude and form. To sum up, a wave may be defined as a form or pattern of disturbances which travels with a finite velocity through the medium as a result of the continuous periodic motion of the particles of the medium.

MECHANICAL WAVES

Transverse and Longitudinal Waves If the motion of the particles is perpendicular to the direction in which the wave moves, it is called a transverse wave. Waves spreading on the surface of water, vibration of a string, are examples. If the motion of the particles is along the direction of motion of the waves, it is then called a longitudinal wave. Sound in air is an example of such waves.

Transverse waves travel in the form of crests and direction of wave troughs while longitudinal wave travels in the form of compressions and rarefactions.

ELECTROMAGNETIC WAVES

Electromagnetic waves are coupled periodic electrical and magnetic disturbances generated by oscillating electric charges.

Electromagnetic waves include an enormous range of frequencies–from radio waves with frequencies less than 10^5 Hz to gamma ray having frequencies greater than 10^{20} Hz. Visible light is simply electromagnetic radiation in the range of frequencies 4.3×10^{14} to 7×10^{14} Hz.

There is no sharp distinction between various sections, which virtually overlap each other. The descriptive names of various sections of the spectrum are merely historical classification, otherwise all waves, from radio waves to gamma rays are same in nature, differing only in frequency, wavelength, and method of production. Radio and micro waves are produced by oscillating electrical circuits. Infrared waves originate in molecular systems. Visible light, ultraviolet radiation, x-rays arise from disturbances in the electronic structure of atoms. Gamma rays originate in atomic nuclei. All electromagnetic waves have the same speed ($c = 3 \times 10^8$ m/s) in vacuum. The relation Speed = frequency x wavelength holds good for all electromagnetic waves.

If the frequency of radio waves sent out by a radio station is known, the wavelength can be calculated by dividing 3 x 108 m/s by the given frequency. For example, the wavelength of radio waves sent out by a radio station at frequency 819 kHz is 366 m.

The energy associated with an electromagnetic radiation is proportional to its frequency. In the visible spectrum (violet, indigo, blue, green, yellow, orange, and red), violet light has maximum frequency and hence maximum energy, whereas red has minimum frequency and hence minimum energy.

Infrared radiation goes through dry air, but not through water vapour. If passed through a sample of a person's breath, transmission is altered if a person has consumed alcohol. It enables a precise and quick means to determine a person's blood alcohol count. Police use breath analyzers to detect and catch people driving under the influence of alcohol.

Photographic film sensitive to infrared rays shows different temperatures as different colours. Anything having a higher or lower temperature than the surroundings can be detected by infrared photography. Devices called thermo-graphic scanners can produce an on-the-spot T.V. like picture of the infrared emission of various bodies. A person having fever can be spotted in a crowd using such thermo-graphic pictures. Currently, people suffering from H1N1 (swine) flu are being detected at airports by the use of this technique.

Radio frequencies for commercial broadcasting range from 550 to 1500 kHz. Radio broadcasting stations use small crystals of quartz that vibrate hundreds of thousands of time each second ensuring a constant radio frequency. In amplitude modulation (AM) an audible signal frequency of several hundred or thousand Hz is impressed upon a carrier radio wave of MHz frequency, modulating (varying) its amplitude but leaving its frequency unaffected. The signal is received at the receiver end amplified and converted to a sound wave. In frequency modulation (FM) only the frequency of the carrier wave is modulated increasing and decreasing at same rate as the impressed audible signal frequency. Since electrical disturbances in the atmosphere affect only the amplitude and not the frequency of the modulated wave, FM transmission is noise free.

Radio and Television Transmission

Radio waves sent only by radio stations are reflected by the ionosphere (a part of the atmosphere which extends from 60 to 500 km above the earth) and can be received anywhere on the earth. Due to slight absorption in the ionosphere, the radio signals received at far-off places are rather weak. At night, the radio reception improves because the layers of the ionoshphere are not as exposed to sunlight and are more settled.

High-frequency waves carrying television signals penetrate the ionosphere and are not received like radio signals. TV transmission was therefore accomplished on a "line-of-sight" basis. The curvature of the earth and mountainous terrains limited the range of TV reception. However, geostationary satellites are being used these days for television (and telephone) links between places anywhere on the earth.

Direct-to-home (DTH) Television

Nowadays, most TV viewers receive programs through a direct broadcast satellite (DBS) provider, such as DISH TV or DTH platform. Unlike earlier programming, the provider's broadcast is completely digital, which means it has high picture and stereo sound quality. There are five major components involved in a DTH satellite system: (i) the programming source, (ii) the broadcast centre, (iii) the satellite, (iv) the satellite dish, and (v) the receiver.

Programming sources are simply the channels that provide programs for broadcast. The provider (the DTH platform) does not create programs itself. It pays other companies (STAR TV, ZEE TV, Doordarshan etc) for the right to broadcast their programs via satellite. At the broadcast centre, the TV provider receives signals from various programming sources, compresses these signals using digital compression, and beams a broadcast signal to the proper satellite. The satellite receives the signal from the broadcast station and rebroadcasts them to the ground. The viewer's dish picks up the signal from the satellite and passes it on to the receiver in the viewer's house. The receiver processes the signal passes it on to a TV set.

Cable TV networks also work on the same principle except that they receive signals from the satellite on large community dish antennas and transmit to TV sets through fixed optical fibers or coaxial cables.

Night Vision

Night vision is the technology that provides us with vision in total darkness and the improvement of vision in low light environment. The most common methods are:

(i) Low-light imaging
(ii) Thermal imaging
(iii) Near infrared illumination.

The most common applications of night vision are: night driving or flying, night security and surveillance, wild life observation, sleep lab monitoring, search and rescue etc.

(i) Low-light imaging: In low-light imaging the objective lens of a special camera focuses available light (photons) on the photo cathode. The light energy causes electrons to be released from the cathode which are accelerated by an electric field to increase their speed (and energy). These electrons after multiple reflections from the specially coated walls of the camera get multiplied and finally hit a phosphorus screen which glows and shows the desired view.

(ii) Thermal imaging: Different from low-light imaging methods, thermal imaging night vision methods do not require any ambient light at all. They operate on the principle that all objects emit infrared energy as a function of their temperature. A thermal imager collects the infrared radiation from objects in the scene and creates an electronic image. A thermal imager is able to penetrate smoke, fog, and haze. Thermal images are normally black and white in nature where black objects are cold and white objects are hot. Some thermal cameras show images in colour. This false colour is an excellent way of distinguishing between objects of different temperatures.

(iii) Near infrared illumination: A popular method for performing night vision is by infrared illumination. In this method, a device that is sensitive to invisible to near infrared radiation is used in conjunction with an infrared illuminator. Near infrared illuminators are LED type and laser type. The most efficient infrared illuminators are based on an infrared laser diode that emits near infrared energy. The near infrared illuminator allows the observer to illuminate only specific areas of interest while eliminating shadows and enhancing image contrast. The technique permits the use of solid state cameras which have the ability to convert near infrared images to visible.

Radar

Radar (Radio detection and ranging) employs high-frequency radio waves for detecting objects like ships and aeroplanes. A rotating aerial sends out pulses which are reflected from the objects on which they fall. The time interval between the transmission and reception of pulses helps determine the distance of the object. A picture of the scanned area is produced on the screen of a special cathode ray tube.

Microwave Oven

As the name suggests, a microwave oven cooks food using microwaves. Microwaves are generated in the oven at a frequency of about 2450 MHz by means of a magnetron. When the waves fall on the food, these are absorbed by water, fats, sugars and certain other molecules whose consequent vibrations produce heat. Since the heating occurs inside the food, without warming the surrounding air, the cooking time is greatly reduced. Most type of glasses, papers etc. do not absorb the microwaves and hence do not heat up. That is why most microwave utencils are made of glass. Foods cannot be cooked in metal vessels because the metal blocks out the microwaves.

Computed Tomography

Computed Tomography (CT) is a medical imaging method employing tomography. It generates a three-dimensional image of the inside of an object from a series of two-dimensional X-ray images taken around a single axis of rotation. The technique is used in diagnostic studies of internal bodily structures, as in the detection of tumours or brain aneurysms.

SOUND

All sounds are produced by the vibration of material objects. The voice results from the vibration of vocal chords in the larynx. In a sitar the sound is produced by the vibrating string and in a table 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.

SPEED OF SOUND

The speed of sound varies considerably depending on material through which the waves are travelling. In general sound travels more rapidly through liquids than through gases and faster of all through solids. Higher speeds result partly from stronger forces between molecules; as in a tightly stretched 'slinky' spring, the oscillations are passed on more rapidly.

Speed of sound in air …………… 330 m/s (dry air, at 0ºC)

Speed of sound in water …………… 1400 m/s (at 0ºC)

Speed of sound in concrete ………………. 5000 m/s

In the case of gases, for example air: The speed of sound does not depend on the pressure; if atmospheric pressure changes for example, there is no change in the speed of sound. Rise in temperature produces an increase in the velocity of approximately 0.6 m/s per degree C. At high altitude, the speed of sound is less than it is at sea level, because the temperature is lower and not because the pressure is less. It is worth noting that the speed of sound in air is only about one three-millionth of the speed of light.

Sound Characteristics

Pitch and Frequency The pitch (shrillness) of a sound depends on its frequency. A sound of higher frequency has a higher pitch. The pitch of a woman's voice is higher than that of a man.

The human ear is normally sensitive to sounds whose frequencies are between 20 and 20,000 Hz. Sound waves with frequencies below 20 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 100,000Hz, which enable them to locate each other under water.

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 Table. It may be 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 increases 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.

Reflection of Sound, 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 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.

An echo can be used for measuring the speed of sound. Exploration of underwater 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 Ranging) is used for this purpose.

Ultrasonic waves is 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. From 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 toward the water and can travel long distances.

Resonance

Resonance is a phenomenon of forced vibrations due to which sound waves can be produced with a large amplitude or intensity. All bodies have their natural frequency of vibration. When we apply a small signal of the same frequency to the body, the signal is greatly amplified and this is called resonance.

For example a singer can shatter a glass by singing a certain note. The frequency of the note is the same as the natural frequency of the glass. The singer sings and the glass resonates. The amplitude of the vibrators increases and the glass shatters.

Soldiers crossing a suspension bridge always break step in case the frequency of vibration of their marching should coincide with that of the bridge. The cumulative effect of a considerable number of impulses applied at exactly the right instants might cause dangerously large oscillations of the bridge.

When we 'tune' a wireless receiver, we are actually adjusting its natural frequency (and therefore wavelength) to that of the incoming wireless carries waves, when it will be excited by resonance.

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 if approaches a listener than when it moves away from him.

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 suffers a red shift when observed from the earth means that the 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.

Musical Scale

A musical scale is a succession of notes, the frequencies of which are in simple rations to one another. Sa, re, ga, ma, pa, dha, ni is one such scale called the diatonic scale. The frequencies of these notes are: sa (256), re (288), ga (320), ma (341.3), pa (384), dha(426.7) and ni (480). The next note denoted by sa has a frequency 512, twice that of sa. The interval sa-sa is called an octave (8).

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 music 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 approach than Dolby A. Dolby SR is much more expensive to implement than Dolby B or C, but, 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 10dB of noise reduction at low frequencies and up to 24 dB of noise reduction at high frequencies.

8. LIGHT

NATURE OF LIGHT

Light is a form of energy. Strictly speaking, light means any radiation whose wavelengths excite a sensation of brightness, or illumination, in the retina of the eye. These wavelengths range from about 0.00004 centimetres to 0.000076 centimetres. Certain types of radiation–ultraviolet light and infrared light–are similar to visible light, though their wavelengths are somewhat shorter or longer than those of the visible range.

Not so many years ego, scientists were quite sure that light and other radiant energy consisted of electromagnetic waves rippling through space. They distinguished sharply between the wave character of radiation and the particle character of matter. Today the picture is not clear. In some respects, atleast, light and other radiations behave like streams of particles. What is even stranger, perhaps, electrons and other very small particles sometimes behave like waves.

The peculiar dual nature of radiation and of material particles is the subject matter of wave mechanics. It would take a great deal of space to explain this theory, even non-mathematically. It is perhaps enough to say here that neither radiation nor material particles ever exhibit both wave and particle characteristics at the same time. In the transit-that is, as it moves from place to place–light behaves like a system of waves. It has a fixed speed in empty space. Its wavelengths can be measured by a variety of methods. In many ways its behaviour is entirely consistent with the theory that it is an electromagnetic wave disturbance. But in its emission from electrons in an atom and in its absorption or other reaction with atoms in its path, light behaves more like a stream of very small particles of energy-photons.

The old argument over the nature of light seems to have ended in a draw. Instead of saying that light, or any other kind of radiation, consists of waves or particles, physicists recognize that it behaves like waves in certain respects and like particles in others. The speed of light is nearly 300,000 km per second.

Light is given out or emitted by very hot objects such as the Sun, or the filament of a bulb, or the hot gases in the flame. It may also be emitted from much cooler materials when electrons lose energy. This happens in a fluorescent tube, or a TV screen, or a laser. Any object which produces its own light is said to be self-luminous.

Most of the objects around you do not produce their own light and are said to be non-luminous. They are only visible because they reflect light from some other sources. Some surface are better at reflecting light than others; light which is not reflected is either absorbed, or in the case of the transparent material like glass, transmitted, i.e. it passes right through.

Rectilinear Propagation and Shadows

The formation of shadows with sharp edges demonstrates the rectilinear 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.**

Eclipse

Solar Eclipse : When moon comes between sun and earth then the shadow of moon falls on the earth and from the shadow region sun is not visible and this position is called solar eclipse and this eclipse may be full or partial. Full solar eclipse occurs on the day of full moon.

Lunar Eclipse : When earth comes between sun and moon then the shadow of earth falls on the moon then the shadow region of the moon is not visible and this position is called lunar eclipse and this eclipse may also be full or partial. Full lunar eclipse occurs on the day of new moon.

Reflection of light

When the light ray incidents on the smooth and light polished surface then it is reflected back almost in different direction, such incidence of light ray and its reflection is called reflection of light. The plane mirror is assumed to be the best reflector. The straight line perpendicular to the reflected surface is called normal. The angle between incident ray and normal is called angle of incident and between the normal and reflected ray is called angle of reflection.

Spherical mirror : In any spherical plane the constructed mirror is called spherical mirror, and in the one side of the mirror the layer of mercury or coating of lead oxide is painted and another side is used as reflecting side. The spherical mirror is of two types—

Concave mirror : The spherical mirror whose reflecting surface is inwardly leaned is called concave mirror. It is also called diverging mirror because it diverges the coming rays from infinity.

Convex mirror : The spherical mirror whose reflecting surface is outwardly leaned is called convex mirror. It is also called converging mirror because it converges the coming rays from infinity.

Magnification : The ratio of image distance to object distance or the ratio of the length of image to the length of the object is called the magnification of the mirror and it is represented by *m*.

The image formed by convex mirror : In convex mirror the image of an object is formed behind the mirror between pole and focus and image formed is smaller than object which is erected and virtual.

If the position of the object be increased from the pole then the virtual erected image becomes smaller and shifts towards focus.

The apparent upward bending of the immersed portion of a stick, when dipped in water, can also be explained on the basis of refraction. Another effect of refraction is the apparent shortening of a person's body when he is standing in water and we look at him from the side.

Atmospheric Refraction The density of the atmosphere surrounding the earth decreases with increasing altitude. Thus if light enters the atmosphere from outside, it encounters layers of air of increasing density and, therefore, bends gradually producing a curved path.

It is due to refraction, produced by the earth's atmosphere, that the sun is visible for several minutes after it has set below the horizon. Thus atmospheric refraction tends to lengthen the day.

When the sun (or moon) is near the horizon, it appears elliptical, i.e. with the vertical diameter less than the horizontal diameter. This happens because rays from the lower edge of the sun are bent more than those from the upper edge.

The twinkling of stars can also be partly attributed to atmospheric refraction. The light from a star reaches us after suffering refraction through various layers of air. These layers are not stationary because of convection currents in the air, and hence the light appears shimmering giving the impression of twinkling. Since planets are nearer to us, the light received from them is much greater. Therefore, minor variations in intensity caused by the above effect are not noticeable. Thus planets do not appear to twinkle.

Mirage One of the most interesting effects of atmospheric refraction occurs in the mirage, which 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. On hot summer days, motorists quite often see similar mirages on the roads.

As interesting use of the total internal reflection is in optical fibres, which are fine strands of high quality glass. When light is incident at one end of the fibre, it undergoes repeated total internal reflections and emerges at the other end. Thus an optical fibre pipes light from one point to another. Such optical fibres are used in decorative table lamps. Bundles of tiny optical fibres are used by doctors to see the inside of a patient's stomach. Light is piped down some of the fibres to illuminate the inside of the stomach and is reflected back along some other fibres. This procedure is called endoscopy.

These days optical fibres have largely replaced copper cables for telecommunication and networking. Optical fibres are being used because these are flexible and can be bundled as cables. It is especially advantageous for long-distance communications, because light propagates through the fibre with little attenuation compared to electrical cables. Also, each fibre can carry many independent channels, each using a different wavelength of light.

Although fibres can be made out of transparent plastic, glass, or a combination of the two, the fibres used in long-distance telecommunications applications are always glass, because of the lower optical attenuation.

Fibres have been used in remote sensing. These can be used as sensors to measure temperature, pressure etc. Extrinsic fibre optic sensors use an optical fibre cable. A major benefit of extrinsic sensors is their ability to reach places which are otherwise inaccessible. An example is the measurement of temperature inside aircraft jet engines by using a fibre to transmit radiation into a radiation pyrometer located outside the engine.

In some buildings, optical fibres are used to route sunlight from the roof to other parts of the building. Optical fibre illumination is also used for decorative applications, including signs and art.

Human Eye

The human eye too is a similar optical instrument. Its lens is a transparent structure made of proteins. The focused image falls on a screen behind the lens, called the retina. The retina sends electrical signals to the brain through the optic nerve so that we perceive objects.

The cornea is a transparent spherical structure that refracts light into the eye. The iris is a dark muscular assembly that controls the size of the pupil, the opening that regulates the amount of the light entering the eye. When the light is very bright, the pupil becomes very small, while in a dim light it opens up fully through the relaxing of the iris. The light through the cornea and pupil falls on the lens which focuses it on the retinal screen. The retina has an enormous number of light-sensitive cells. These get activated upon illumination and generate electrical signals that are sent to the brain through the optic nerves. The brain interprets these signals as the sense of light.

There are of course very important different between our eye and a camera. The image on the retina is not permanent but fades away after $1/20^{th}$ of the second and overlaps with the next image. This gives the impression of continuity. There is of course no film in the eye that records the images permanently as a photo film does. More importantly, the focal length of the eye lens is changed when its attached cilial muscles change their tension. When they are relaxed, the lens is thin and you can see distant objects clearly. When you are looking at nearby objects, the muscles compress the lens so as to decrease its focal length. This property of the eye lens of changing its focal length is called its power of accommodation.

However, the focal length of the eye lens cannot be decreased below a certain limit. Try to read this book by holding it close to your eyes. You may find that it strains your eyes. To read the book comfortably you have to hold it at about 25 cm from your eyes. This minimum distance at which one can see objects distinctly is called the distance of distinct vision.

DEFECTS OF VISION AND THEIR CORRECTION

Sometimes the eye loses its power of accommodation. When this happens one cannot see objects clearly, and vision becomes blurred.

Astigmatism This defect is due to the cornea not being spherical. As a result, the rays of light entering the eye in different planes are brought to a focus at varying distances from the retina. So, though the object is a point, the shape of the image may be a line, a circle or any other shape except a point. This defect can be corrected by using a cylindrical lens, instead of a spherical lens.

Dispersion

White light consists of seven colours—violet, indigo, blue, green, yellow, orange, and red. These colours are called the **spectrum** of the white light. Violet has the minimum wavelength (or maximum frequency) and red the maximum wavelength (or minimum frequency). In a vacuum, all these colours travel with the same speed but in a transparent medium they have different speeds. Violet travels the slowest through glass while red travels the fastest. Due to different speeds, the colours are refracted through different angles and, therefore, when a narrow beam of white light passes through a glass prism, it is split up into its constituent colours . This separation of light into colours is called dispersion.

The Rainbow The most spectacular illustration of dispersion is the rainbow. When the sun shines soon after a shower of rain, a rainbow is seen in the sky opposite the sun. The beautiful colours of the rainbow are due to the dispersion of sunlight by water droplets suspended in the air after rain. The droplets act like prisms. In each droplet there is dispersion as well as total internal reflection. A similar effect is produced by droplets of water from a fountain in sunlight.

PRIMARYAND SECONDARY COLOURS: COLOUR ADDITION

Red, green and blue are known as the primary colours because it isn't possible to produce them by mixing light of any other colours together. Artists use different 'primary' colours, which will be explained later. When any two primary colours are combined, they give a secondary colour.

Producing new colours by mixing light of other colours together is known as colour mixing by addition. To the human eye:

Red + green = yellow
Green + blue = peacock blue (turquoise or cyan)
Red + blue = magenta

This secondary colours aren't really single colours at all; they only appear as such to the human eye. The eye cannot for example distinguish between pure yellow in the spectrum and secondary or compound, yellow which is really a mixture of red and green light. Both yellows stimulate the same colour-sensitive cells in the retina.

It is important to note that mixing coloured paints produces entirely different results from mixing coloured lights.

Scattering

Scattering of electromagnetic radiation is the process in which energy is removed from a beam of electromagnetic radiation and re-emitted with a change in direction, phase, or wavelength. All electromagnetic radiation is subject to scattering by the medium (gas, liquid, or solid) through which it passes. Light in the visible, infrared, or ultraviolet region interacts primarily with the electrons in gases, liquids, and solids, not the nuclei. The scattering process in these wavelength regions consists of acceleration from the acceleration changes. Scattering of light is a diffraction effect.

Dust particles and even the molecules of atmospheric gases interrupt the wave fronts of sunlight advancing into the atmosphere. The light that was advancing in a straight line from the sun to the earth is dispersed. A given obstacle "longer bigger" to a short wave of violet light than it does to the longer red. Therefore, the effect of the obstacle on the violet wave will be more drastic. Consequently, violet light is scattered most, blue somewhat less, and green, yellow, and orange still less, in that order. Red is affected least of all.

The sky generally looks blue because the short blue waves are scattered more than the longer waves of red light. It is true that the violet waves are dispersed even more than the blue. However, the sky does not appear violet because the sun is relatively weak in violet light. Deep water appears blue for the same reason. However, impurities in the water often absorb the blue and green, becomes the predominant tint. The sky looks red near the horizon because, at that angle, the path through the atmosphere is long and traverses much low-flying dust. As a result the bluer light is effectively scattered out of the direct beam before it can be observed by the viewer. Twilight is also the result of the light scattered by particles and molecules in the atmosphere.

9. MAGNETISM

MAGNETISM

Ordinary magnets are familiar to everybody. The simple magnet consists of a magnetised bar of iron. A magnet attracts and holds pieces of iron but does not attract pieces of copper. Substances attracted by a magnet are described as magnetic and those not attracted are called as non-magnetic. Iron, cobalt, nickel and certain alloys are strongly magnetic whereas copper, wood, glass, etc. are non-magnetic. However, even non-magnetic substances show feeble magnetism in the presence of very strong magnets. Some are attracted while most are very strong magnets.

When a bar magnet is suspended with a thread tied exactly in its middle, the magnet oscillates for a little while and then comes to rest pointing approximately in the north-south direction. The end pointing towards the north is called the north-seeking or simply north pole of the magnet and that pointing towards the south is called the south-seeking or south pole of the magnet. Thus every magnet has two poles, which are the places near the ends where the resultant attractive force of the magnet appears to be concentrated.

It two bar magnets are brought near each other so that their north poles are close, the magnets repel. If the north pole of one magnet is brought near the south pole of the other; the two attract. Like poles repel and unlike poles attract.

Earth's Magnetism

As stated earlier, a bar magnet always points roughly in a north-south direction when freely suspended. This is due to the earth's magnetism. The origin of the earth's magnetism is still not very clear to scientists. It is, however, believed that the motion of charges (causing currents) in the molten outer core creates the magnetic field. Some geologists think that these currents are caused by the earth's motion. Another likely source of earth's magnetism may be heat arising from the earth's inner core. This heat may be the cause of convection currents in the molten outer core

The motion of ions and electrons in this molten material would produce a magnetic field. It is probably such convection currents in combinations with the rotational effects of the earth that produce the earth's magnetic field.

The earth behaves as if it contained a short bar magnet inclined at a small angle to its axis of rotation, with the south pole of the magnet in the northern hemisphere. At a particular place on the earth, the magnetic north is not usually in the directions is called the **declination.** Mariners and others who use compasses must allow for declination in determining the true north. The angle, which a freely suspended bar magnet makes with the horizontal, is called the dip of the place. Thus, on the equator, the value of the dip is zero and that on the poles is 90°.

Magnetic Resonance Imaging (MRI)

MRI is a non-invasive medical test that helps physicians diagnose and treat diseases that may not be assessed adequately with other imaging methods such as x-ray, ultrasound or CT scanning. MR imaging uses a powerful magnetic field, radio frequency pulses and a computer to produce detailed pictures of organs (heart, liver, kidney, spleen, pancreas etc.), soft tissues, bones and virtually all other internal body structures. The images can then be examined on a computer monitor, printed or copied on a compact disc. MRI does not use x-rays.

10. ELECTRICITY

Static Electricity

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. When a glass rod is rubbed with silk, some electrons from the rod attach themselves to the silk. Thus by losing, electrons, glass become positively charged and by gaining the same 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 change 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 in the earth. When charged clouds pass overhead, the lightning conductor accepts any discharge which may occur and conducts it harmlessly to earth.

CONDUCTORS, INSULATORS, INDUCTION

When electrons are deposited on certain materials, they can make their way freely in and out among the atoms. In certain other substances they cannot move freely. They remain more or less at the same point on the material at which they were deposited. Substances that allow electrons to pass freely through them are called conductors. They include such metals as silver and copper. We give the name of insulator to a substance that does not allow electrons to move through it freely. Hard rubber, mica, glass, and porcelain are all good insulators.

Dielectrics are insulating substances through which electrical attraction is maintained. Examples are glass, wax, water, oil, wood, rubber, stone, plastics, etc. In these substances, an applied electric field causes a displacement of charge but not a flow of charge.

Induction takes place when an electrical charge of one kind produces a charges of another kind on a nearby body when there is no direct contact. The principle of induction is used in a condenser, a device for storing electricity.

CURRENT ELECTRICITY

Current electricity exists when electrons flow between two charged objects. An electric current, to put it simply, is the flow of electrons along a conductor. There are two types of currents. Direct current (DC), usually obtained from a battery, flows in one directions only; from the negative terminal of the power sources, through conductors, to the positive terminal. Alternating current (AC), on the other hand, flows first in one direction and then in the opposite direction. It always flows from negative to positive terminals, but the polarity (charge) of each terminal alternates from negative to positive. Each set of two reversals is called a cycle.

Alternating current is used more widely than DC. Its main advantage is that its driving force (voltage) can be readily increased or decreased by transformers. Also, AC machinery is generally simpler to design and build than DC machinery. DC, however, is needed in certain electronic devices and for such processes as charging storage batteries, and electroplating. Also, DC can be produced by batteries, which can be carried about.

A path along which the current travels is called a circuit. A current will only flow if there is a complete circuit to flow around.

The magnitude of current (I) is the charge (Q) flowing in the circuit in one second

$I = Q/t = \frac{\text{charge}}{\text{time}}$

Current is measured in amperes (A). One ampere of current flows around a circuit if one coulomb of charge passes around the circuit in one second.

The charge on an individual electrons is -1.6×10^{-19} C, so a current of one ampere means something like 6.2×10^{18} electrons are moving through the conductor in one second.

POTENTIAL DIFFERENCE (P.D)

A current will only flow it there is a complete circuit to flow around. The current can only get through a conductor in the circuit if there is a potential difference across the conductor. As a current moves through the conductor, it gives up some of its energy to the conductor. The greater the potential difference, the greater is the amount of energy given up. The electrostatic potential at any point is defined as the work done in bring a single positive charge from infinity to that point. The unit of potential is volt and has the symbol V.

$$\text{p.d (V)} = \frac{\text{work done}}{\text{charge moved}} = \frac{w}{Q}$$

$$= \frac{\text{Joule}}{\text{coulomb}}$$

Thus, W = V.Q = V.I.t. A potential difference of one volt means that one joule of energy is given up by each coulomb of charge passing through the conductor.

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 depends on its length (l) and area of cross-section (a).

$$R = p\frac{l}{a}$$

If the wire has a circular cross-section of radius r, then a = ðr2. Thus

$$R = p\frac{l}{\pi r2}$$

p is a constant called the resistivity of the material of the wire. Resistivity of good conductor (e.g. copper, silver, etc.) increases with temperature. Whereas, resistivity of a semiconductor (e.g. carbon) decreases with increasing temperature.

ELECTRICAL POWER

Power is the rate at which work is done. In an electric circuit, the work done in a time t is

W = V.I.t

Therefore,

$$\text{Power } P = \frac{W}{t} = VI$$

If potential difference is measured in volts, and current in ampere, the unit of power is a volt ampere, also called a watt. Thus a unit of electric power is watt. Electric power is the rate at which energy is consumed by the circuit. A convenient unit to measure electric power is the kilowatt hour or kWh. This is often simply called a unit.

1kWh = 1000 watt x 3600 seconds.

Effects of Electric Current

(i) Magnetic Effect A current-carrying wire has a magnetic field around it. If the current-carrying wire is wound on a bar of soft iron, it becomes strongly magnetised. When the current is stopped, the iron loses magnetism. Electromagnets, produced in this way, are extremely useful. Strong electromagnets are used in industry for lifting and transporting steel plates, girders, scrap iron etc. These are also used in electric bells, telephone receivers, etc.

(ii) Chemical Effect, Electrolysis An electric current passed through a solution results in the decomposition of the solution into negative and positive ions. Negative ions collect at the positive electrode (anode) and the positive ions collect at the negative electrode (cathode). This phenomenon is known as electrolysis.

Electrolysis is widely used in **electroplating**, i.e. coating of a base metal with a layer of more expensive metal. Electroplating with gold and silver is quite common. Contacts of electronic components used in computers, etc. are gold plated to avoid atmospheric corrosion. Electrolysis plays an important role in metallurgy.

(iii) Heating Effect When a charge moves in a conductor it does work, which results in heating the conductor. Thus electric energy in the form of electric current is converted into heat energy. If the resistance of a wire is R ohms and the current flowing through it is I amperes, the heat produced per second in the wire is I^2R joules. Heat produced, H, in time t is given by $H = I^2Rt$

The heating effect of electric current is made use of in a variety of appliances, such as a geyser, iron, toaster, oven, room heater, and so on. These appliances have coils of nichrome (an alloy of nickel and chromium), which are heated when current is passed. Whenever electricity is used for heating water or other liquids, the heating element is well insulated and enclosed in a tube. Otherwise the liquids will become live and therefore dangerous. In an electric iron, the heating element is sandwiched between two thin sheets of mica, which is highly insulating and can withstand high temperatures.

(iv) Motor Effect When a current-carrying conductor is placed at right angles to a magnetic field, a force acts on the conductor. If a current-carrying rectangular coil is placed in a magnetic field, a couple acts on the coil and it starts rotating. This is the principle of an **electric motor.** Thus in an electric motor, electrical energy is converted into mechanical energy. Electric fans, mixers, washing machines, etc., work on electric motors.

A running motor also acts as a generator producing emf and a current in the reverse direction. This reverse current increases with the speed of the motor. Thus the starting or initial current of an electric motor is much greater than the current flowing after the motor reaches its running speed. If for any reason, the motor armature is brought to rest while the current is still on, the motor may burn out. To avoid damage, a **starter** (a variable resistance) is used in large motors.

The moving coil loudspeaker used in radio receivers etc., works by the force exerted on a current-carrying coil situated in a magnetic field. In a **loudspeaker**, energy is transferred from electric current into mechanical energy of vibration in a cone and then to sound energy.

Though out of place, it would be interesting to note that in a moving coil **microphone**, sound energy is converted into mechanical energy of a vibrating diaphragm and then into electrical energy.

(v) Electric Generator (Dynamo) The construction of a generator is in principle identical to that of a motor. In a generator the armature is rotated in the magnetic field and an emf is induced in it due to electromagnetic induction. Thus a generator converts mechanical energy into electrical energy.

With a minor difference in construction, a generator can produce alternating emf or direct emf the corresponding currents produced are called alternating current (ac) and direct current (dc).

(vi) Inverter An inverter is a device which converts DC to AC. The inverters used in homes and offices are specially designed to

(i) Convert DC from a battery to AC, and

(ii) Charge the battery.

An inverter is fitted in the main power line. When there is a power failure, the inverter automatically switches on the AC, converted from the battery's DC, for lighting and running electrical gadgets. When the mains supply is restored, the inverter automatically switches to a mode where it starts charging the battery depleted due to use during the period of power break-down.

POWER GENERATION AND TRANSMISSION

Electric power stations are, generally, situated in remote areas where it is cheaper to produce electric power. This power has to be transmitted to the cities and areas where it is needed. This is done by transmission lines which consist of two parallel wires for carrying current from and to the power station.

To avoid the loss of power in the line wire, the output voltage of the generator is first transformed to a much higher value by a step-up transformed. It converts the electric power at low voltage and high current to the same power at higher voltage and lower current. Due to reduction in the value of current, the losses in the lines are reduced.

A typical power generator gives an output of 1000 KW at 6.6 kilo-volts. In practice this voltage is stepped up to 132 kilo-volts before transmission. The cables used for transmitting power over long distances are suspended by large porcelain insulators from large steel structures (pylons). The main transmission lines from power stations form part of a common system called the 'grid' which covers a large region of the country. Power from all the power stations in the region is fed into the grid which forms a common pool from which power can be drawn where needed. This allows an efficient power distribution and acts as a safeguard for ensuring a minimum power supply to consumers in the event of failure of power generation at some station. From the grid, the power is fed to the cities at 33KV; the stepping down is done outside the city. Then again at a sub-station, the supply is stepped down to 6.6 KV. Power is supplied to the big consumers like factories at this voltage which they can further step-down according to their needs. For ordinary domestic consumers the voltage is again reduced to 220 V. Since the voltage is alternating, 220 is actually the effective value of the voltage. The peak value of the voltage is 311V.

Domestic Electric Installation

From the local substation, electricity is supplied to a house by two cable, the "live" cable and the "neutral" cable. The neutral cable is earthed at the substation so that it is at earth potential. In domestic supplies, a third cable is introduced for safety. This is called the "earth" and is connected to the earth terminal provided in the building.

Inside the house, the supply is through a meter, which measures the electrical energy consumption in kilowatt hour. From the meter, connections are made to the distribution board through a main fuse and a main switch. There are fuses is each distribution line.

Fuse A fuse is a short piece of wire made of a tin-lead alloy, which has a low melting point. When current in a circuit exceeds the specified value due to short circuiting, overloading, voltage fluctuation, etc., the fuse melts and breaks, thereby protecting expensive electrical appliances and also preventing fire accidents. Fuses are always connected in the live wire.

Nowadays, fuses have been replaced with miniature circuit breakers (MCBs). A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Unlike a fuse, which operates once and then has to be replaced, a circuit breaker can be reset manually to resume normal operation.

The tin-lead alloy is also used as **soldering material** for joining metals in electronic circuits.

Earth The earth wire is used for earthing the metal casings of electrical appliances and is a safeguard against shocks

Flexible Cables All electrical appliances are provided with three-core flexible cables. The insulations on the three wires are coloured red or brown (for live connection), black or light blue (for neutral connection), and green or yellow (for earth connection).

Plugs, Sockets and Switches A three-pin plug has one pin which is longer and thicker than the other two identical pins. It is for earthing and is connected to the green (or yellow) wire of the appliance. The other two are connected to the red (or brown) and the black (or blue) wires. The earth pin is longer so that an appliance is earthed before it is connected to the live circuit. It is thicker so that it cannot be inserted in the live hole of the socket even by mistake.

In a socket, the top bigger hole is for the earth, the lower right hole is for the live connection and the left hole is for the neutral connection.

All switches in a house are put in the live wires. If they were in the neutral wire, the sockets would remain live even when the switches were in the off position. In such a situation one would get a shock from the element of a heater or a stove even when it was cold.

Electric Light

Incandescent Lamp or Filament Lamp An electric lamp produces light energy electrical energy. It has a tungsten filament connected between two lead-in wires. When current is passed, the tungsten filament is heated and emits light. Tungsten is used because it has a high melting point of 3,400ºC. The lamp contains a small quantity of argon (an inert gas) to prevent evaporation of tungsten. Air could not be used as this would oxidise the tungsten. The lead-in wires of the lamp are not heated much because they have very low resistance.

Fluorescent Tubes A fluorescent tube contains mercury vapours at low pressure. When the tube is switched on, the mercury vapours emit invisible ultraviolet rays. These ultraviolet rays fall on the fluorescent coating on the inside of the tube and emit visible light. Since very little heat is produced in a tube, almost the whole of the electrical energy is converted to light energy. Thus these tubes are more efficient and cheaper.

Compact Fluorescent Lamps The problem with incandescent light bulb is that they waste lot of electricity in the form of heat. On the other hand, no electric energy is wasted as heat in a fluorescent tube. A CFL (compact fluorescent lamp) is a miniature fluorescent tube and works on the same principle. A CFL is 4 to 6 times more efficient than an incandescent bulb. That's why one can buy a 15W fluorescent bulb that produces the same amount of light as a 60W incandescent bulb. Although the initial cost of CFL is more, it more than compensates by saving enormous amount of energy and lasting nearly 15 times longer.

Fluorescent lamps contain mercury which is a hazardous substance. Most light sources including fluorescent bulbs emit a small amount of UV, but the UV produced by fluorescent bulbs is far less than the amount produced by natural daylight.

In terms of light emission: 40W incandescent bulb = 10W CFL, 60W incandescent bulb = 15W CFL, and 100W incandescent bulb = 26- 29W CFL