General Knowledge Today

General Science-7: Everyday Physics

Target 2016: Integrated IAS General Studies
Last Updated: February 2, 2016
Published by: GKTODAY.IN

Contents

Model Questions

Prelims MCQ Topics

Fundamental Units and Derived Units, Horizontal Motion basics, Speed, Velocity, Acceleration, Retardation and simple motion graphs, Motion under Gravity, Terminal Velocity, Horizontal Projectile Motion, Circular Motion, Laws of Motion, Inertia, Force, Weight, Conservation of Momentum, Friction, Pushing or pulling an object, Work, Power and Energy, Kinetic and Potential Energies, Work-Energy Theorem, Artificial Satellites, Kepler's Laws. Projectile motion in artificial satellites, Geostationary and Geosynchronous Orbits, Low and Medium Earth Orbits, Polar Orbit, Sun-synchronous Orbit, Elasticity, Elastic Limit, Crazy Balls, Fluids- Pascal's Law, Atmospheric Pressure, Pressure in water, Blood Pressure, Buoyancy-Archimedes Principle, Laws of Floatation, Viscosity, Lubricants, Bernoulli's Theorem, Surface Tension & Capillary Action, Conduction, convection and radiation, Specific Heat Capacity, Thermal Expansion, Change in state of mater, Light-Refraction, Refractive Index, Total Internal Reflection, Optical Fibres and Periscope, Lenses, Real Images and Virtual Images, Twinkling of Stars, Mirage, Optical Illusion, Human Eye-its parts and working, Dispersion of Light, Various Colors, Sound-Pitch, Loudness, Speed of Sound, Echo, Refraction and Resonance of Sound, Doppler Effect, Sonic Boom, Static Electricity and Current Electricity, Common Electric Appliances.

Measurement and Units

Measurement refers to comparison of a physical quantity with its standard unit. The standard unit should be easily reproducible and internationally accepted.

Fundamental Units and Derived Units

The units which are independent of each other are known as Fundamental Units. Derived Units are derived from Fundamental Units. For example, meter is a fundamental unit of length and second is a fundamental unit of time. However, meter per second (ms^{-1}) is a derived unit of velocity. There are seven fundamental units as given in the below table:

No.	Quantity	Fundamental Unit	Symbol
1.	Length	metre	m
2.	Mass	kilogram	kg
3.	Time	second	S
4.	Temperature	Kelvin	kg
5	Electric current	ampere	A
6	Luminous intensity	candela	cd
7	Amount of substance	mole	mol

Apart from the above seven, there are two supplementary fundamental units viz. Radian and Steradian. While Radian (Rad) is used to measure plane angle, Steradian (Sr) is used to measure Solid Angle.

The derived units are derived from fundamental units. Examples of derived units are velocity (meter/second), acceleration (meter /second^2) etc.

Kilogram

At present, a kilogram is defined by a cylindrical piece of platinum-iridium kept at the office of International Committee on Weights and Measures in Paris. However, that lump has lost 50 microgram since 1879 and that is why scientists are looking for ways of expressing a kilogram in terms of the fundamental constants of nature, rather than a man-made object.

Meter

Earlier meter was calibrated as the distance between two "Xs" on a platinum Iridium metal bar kept in Paris at a temperature of 0°C. Later, it was fixed as length of the path travelled by light in vacuum during a time interval of 1/299,792,458 of a second. Currently, one meter contains 1650763.73 wavelength of orange-red light of Kr-86.

Second

Earlier, second was the length of a mean solar day divided by 86,400. Since 1967, a second has been classified time in which caesium atom vibrates 9192631770 times in an atomic clock.

Kelvin

One Kelvin is the 1/273.16 part of the thermodynamics temperature of the triple point of water.

Candela

Candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1⁄683 watt per steradian.

Ampere

1 ampere is the electric current which it maintained in two straight parallel conductor of infinite length and of negligible cross-section area placed one metre apart in vacuum will produce between them a force 2×10^{-7} N per metre length.

Mole

One mole is the amount of substance of a system which contains a many elementary entities (may be atoms, molecules, ions, electrons or group of particles, as this and atoms in 0.012 kg of carbon isotope $_6C^{12}$.

A complete set of units, both fundamental and derived is known as System of Units. There are four commonly used systems of units' viz. CGS, FPS, MKS and SI systems. CGS refers to centimetre, gram and time; FPS refers to foot, pound and second; MKS refers to meter, kilometer and second while SI system uses the seven fundamental units as mentioned above.

Motion

Horizontal Motion

Motion is when an object changes its position with respect to its surroundings with time. If the object does not change its position with respect to its surroundings with time, it is called to be at rest. Being is rest and motion are relative and depend on reference frames. This implies that an object may be in rest in one frame of reference while in motion in another frame of reference. For example, if I am standing on ground, that is my frame of reference. Motion of anything would be compared to reference point of ground. However, if I am in a moving Bus, then moving Bus is my reference point. Any other person in Bus will be in rest for my, while for anyone standing on ground Bus and everything within that will be in motion.

One, Two and Three Dimensional Motions

Motion can be either one dimensional or two dimensional.

- In one dimensional motion, only one out of three coordinates specifying the position of object changes. Example: object falling under gravity.

- In two dimensional motion, only two out of three coordinates specifying the position of the object change. Example: Circular motion.
- In three dimensional motion, all the three coordinates specifying the position of object change with respect to time. Example: A flying bird, kite or aeroplane.

Distance and Displacement

Distance refers to the actual path traversed by an object. Distance is a scalar quantity and it can be never zero or negative. Distance is measured by meter. Displacement is the shortest distance between initial and final positions of any object during motion. Displacement is a vector quantity and can be either positive or negative or zero. Displacement is also measured in meter.

Can displacement be greater than distance?
Kindly note that magnitude of displacement can NEVER be greater than distance. This is because displacement is the shortest route connecting two positions of the particle.

Speed

Speed refers to the rate of change of position of the object in any direction with respect to time.

Speed (v) = Distance travelled (s) / Time taken (t)

The unit of speed is meter / second and it's a scalar quantity. If the object covers equal distance in equal intervals of time, it would be *uniform speed*. If the object covers unequal distances in equal intervals of time, it is called *non-uniform speed*.

Average Speed

Average speed is the total distanced travelled divided by total time taken. When an object moves in a straight line at a steady speed, we can calculate its average speed if you know how far it travels and how long it takes. The below equation shows the relationship between average speed, distance moved and time taken:

$$\text{average speed} = \frac{\text{distance moved}}{\text{time taken}}$$

where **average speed** is measured in metres per second, m/s; **distance moved** is measured in metres, m; and **time taken** is measured in seconds, s

For example, a car travels 300 m in 20 s. Its average speed is: 300 ÷ 20 = **15 m/s**

Velocity

Velocity is the rate of change of displacement of an object in particular direction. Thus, Velocity is Displacement / time taken. The unit of velocity is also meter per second. However, unlike speed, velocity is a vector quantity both in magnitude and direction. Thus, velocity of an object can be positive or negative or zero.

If an object undergoes equal displacements in equal intervals of time, it would be called uniform velocity; while if it undergoes unequal displacements in equal intervals of time, it would be called non-uniform velocity. Relative velocity is the time rate of change of relative position of one object with respect to another object. The average velocity is ratio of total displacement to total time taken.

Acceleration

The rate of change in velocity per unit of time is called acceleration.

$$\text{acceleration (metre per second squared)} = \frac{\text{change in velocity (metre per second)}}{\text{time taken (second, } s)}$$

The units for acceleration are commonly written as m/s/s or m/s^2. The equation for acceleration can also be represented as:

$a=(v-u)/t$

where **a** is acceleration in m/s^2; **v** is final velocity in m/s; **u** is initial velocity in m/s and **t** is time in s

For example, a car accelerates in 5 s from 25 m/s to 3 5m/s. Its velocity changes by 35 – 25 = 10 m/s. Therefore its acceleration is 10 ÷ 5 = 2 m/s^2

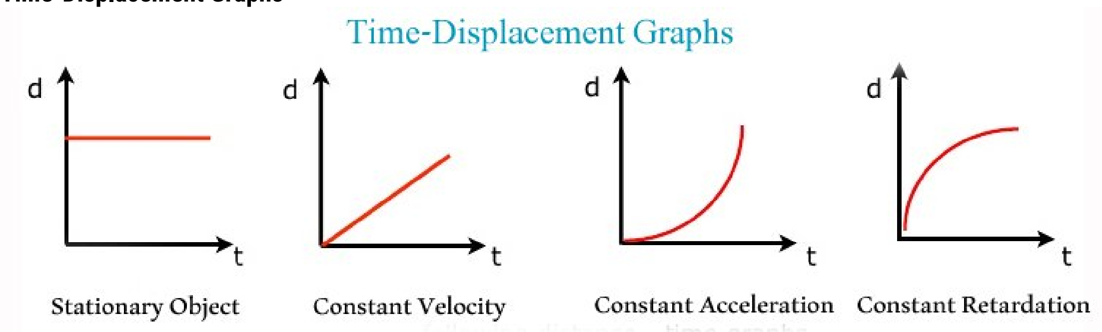
Deceleration / Retardation / Negative Acceleration

Deceleration, or negative acceleration, is observed when an object slows down. The units are the same as for acceleration but the number has a negative symbol before it. For example, the car slowed down at -1 m/s^2. For example, a car decelerates in 5 s from 35 m/s to 25 m/s. Its velocity changes by 25 – 35 = -10 m/s. Therefore its acceleration is -10 ÷ 5 = -2 m/s^2

Acceleration is also a vector quantity and can be positive, negative or zero. Positive acceleration means velocity is increasing with time, zero acceleration means velocity is uniform while negative acceleration means velocity is decreasing with time. Negative acceleration is also known as retardation.

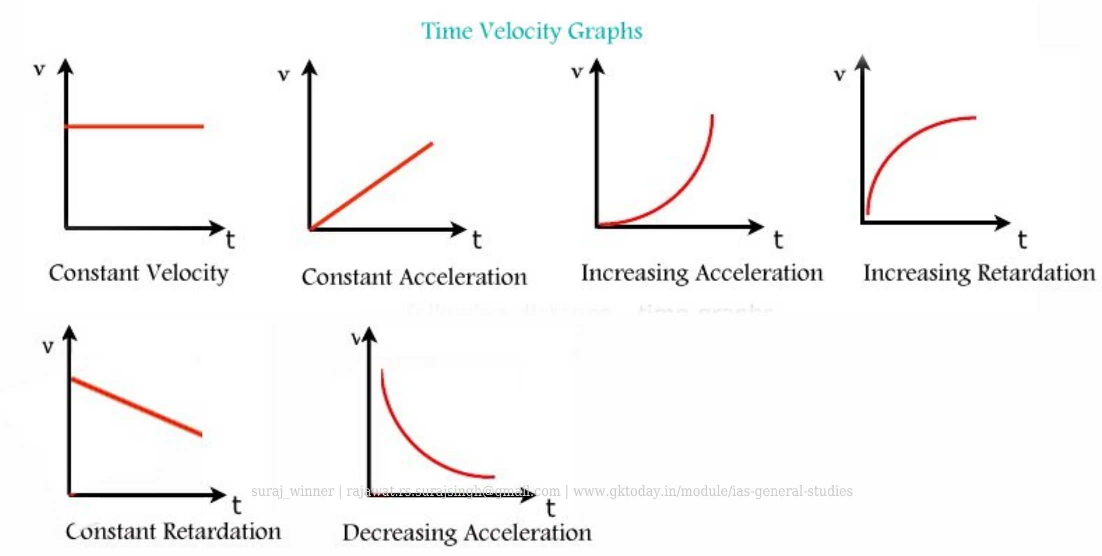
Various Graphs

Time-Displacement Graphs

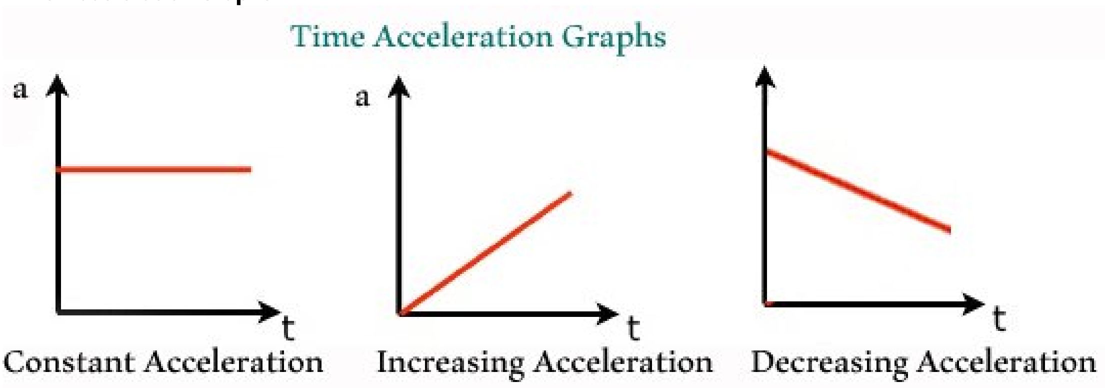


In the above graphics, first graph from left is of a stationary body because there is no change in displacement with time. Second graph denotes constant velocity because equal distance is being covered in equal time intervals. Third graph is of constant acceleration because more distance is being covered as time lapses. Fourth graph is constant retardation because less distance is being covered as time lapses.

Time-Velocity Graphs



Time Acceleration Graphs



Important Basic Equations

If a body starts with velocity (u) and after time t its velocity changes to (v), if the uniform acceleration is a and the distance travelled in time t in s, then following would be the equations of uniformly accelerated motion.

Formula to get final velocity:

$v = u + at$

Formula to get distance covered:

$s = ut + 1/2\ at^2$

Relation between v, u, a and s

$v^2 = u^2 + 2as$

Distance travelled in nth second.

$S_n = u + a / 2(2n – 1)$

If a body moves with uniform acceleration and velocity changes from u to v in a time interval, then the velocity at the midpoint of its path:

$\sqrt{u^2 + v^2 / 2}$

Example:
A is running after a bus. The bus is travelling at an average speed of 5 m/s. The man runs 25 m in 6 s. Does he catch the bus?
Answer: No. The man's average speed is 25 ÷ 6 = **4.2 m/s**. So he will not catch a bus moving at 5 m/s.

Identify if the below statement is true or false

Two persons sitting face-to-face at the two ends of a railway compartment running at a constant acceleration toss a ball to each other with the same muzzle velocity and at the same inclination to the horizontal. The time intervals for the toss are equal in both directions.

Answer:

This is a false statement. The horizontal component of the velocity of the two balls will be equal but opposite, hence one of the ball will get accelerated while the other retarded with respect to the train, so their times of flight will be different.

Motion under Gravity

Under gravity, acceleration is 9.8 m/s² and is denoted by g. When an object is falling freely under gravity, then the above equations would be adjusted as follows:

- $v = u + gt$
- $h = ut + 1/2\ gt^2$
- $V^2 = u^2 + 2gh$

In the above equation, + is replaced by – if the body is thrown upwards.

Maximum Height attained

Let a body be projected vertically upwards with an initial velocity u. As it moves upwards its acceleration is taken as –g. As the body goes up its velocity decreases and finally becomes zero (v = 0) when it reaches maximum height. Now the above equation (3) becomes:

$-u^2 = -2gh$

From the above, we can derive that: $h = u^2/2g$.

Time of Ascent (t_1)

The time taken by a body thrown up to reach maximum height is called its time of ascent. Let t_1 be the time of ascent. At the maximum height its velocity v = 0. Equation (1) becomes

$0 = u - gt_1$

$t_1 = u/g$

Time of descent (t_2)

After reaching the maximum height, the body begins to travel downwards like a freely falling body. The time taken by a freely falling body to reach the ground is called the time of descent (t_2). In this case $u = 0$ and g is positive. Equation (2) becomes

$$h = 0 + \frac{1}{2} g t_2^2$$

$$t_2^2 = \frac{2h}{g}$$

$$t_2 = \sqrt{\frac{2h}{g}}$$

By Equation (4)

$$h = \frac{u^2}{2g}$$

$$\therefore \ t_2 = \sqrt{\frac{2}{g} \times \frac{u^2}{2g}}$$

$$= \sqrt{\frac{u^2}{g^2}}$$

$$= \frac{u}{g}$$

The above discussion makes it clear that time of ascent is equal to the time of descent in the case of bodies moving under gravity.

Time of Flight

The time of flight is the time taken by a body to remain in air and is given by the sum of the time of ascent ($t1$) and the time of descent ($t2$).

$$t_f = t_1 + t_2$$

$$= \frac{u}{g} + \frac{u}{g}$$

$$t_f = \frac{2u}{g}$$

Velocity of a body dropped from a height

When a body is dropped from a height h its initial velocity u is zero. Let the final velocity on reaching the ground is v.

Equation (3) becomes

$v2 = 2gh$

$$v = \sqrt{2gh}$$

At the same time, from Equation (4) we note that

$$u = \sqrt{2gh}$$

This means that:

Velocity of the body falling from a height h on reaching the ground is equal to the velocity with which it is projected vertically upwards to reach the same height h. Hence the upward velocity at any point in its flight is the same as its downward velocity at that point.

Numerical Example

1. A coin was thrown vertically upwards and it rose to a length of 10 metre. What is the velocity with which the body was thrown upwards?

Answer: In this question: h = 10 m, v = 0, u = ?, g = -9.8 ms^{-2}

Using equations: $v^2 - u^2 = 2gh$

$0 - u^2 = -2 \times 9.8 \times 10$; $u^2 = 196$; u = 14 m/s

2. A coin was thrown vertically upwards and it rose to a length of 10 metre. What was the time taken by the body to reach the highest point?

Answer: From the first question u = 14 m/s, v = 0, t = ?

v= u – gt

0 = 14 – 9.8 x t

t = 1.43 second

Practical Questions

When we drop a coin and a feather simultaneously in a tube fill with air and evacuated tube, which one will reach the bottom first?

When we drop a coin and a feather simultaneously in a tube fill with air and evacuated tube, we get the following observations.

- When the tube has air, coin which is heavier than the feather reaches the bottom of the tube more rapidly while the feather flutters down slowly.
- When there is no air in the tube, coin and the feather to fall together.

From this experiment we understand that air resistance affects the motion of a falling body. The air resistance on a falling body depends on its shape, size and speed.

Is it possible for the acceleration to be decreasing while the velocity increasing during the same interval of time?

Yes, it's possible. If the acceleration acts in the direction of motion, it will always cause increment in the velocity. If the acceleration is decreasing but acting in the same direction, the rate, of increase of velocity will decrease. Consequently the velocity will continue to increase slowly. For example, in case of a sphere falling in a viscous liquid, the net acceleration decreases but the velocity increases till the sphere attains its terminal velocity.

A beaker is left out in the rains. Will the rate at which the beaker is filled be altered if a horizontal wind starts to blow?

Answer: No. Beaker will be filled with the same rate because filling of beaker depends on vertical component of the rain.

Two balls of different masses are thrown vertically upwards with the same speed. They pass through the point of projection in their downward motion with the same speed (neglect air resistance). This statement is true or false?

Answer: True. In absence of air resistance a ball will return to the point of projection with the same speed.

Terminal Velocity

When a body falls, it accelerates due to gravity and the retarding force of air resistance increases with speed. This continues till the force of air resistance equals the weight of the object. Now the object no longer accelerates but falls with a constant speed called the terminal velocity. The terminal velocity is about 200 km/hr for a skydiver with an unopened parachute. While falling, the skydivers use a "spread-eagle" position to increase the air resistance and prolong the time of fall. When the parachute is opened, the fall is slowed by the additional resistive force.

Horizontal Projectile Motion

When an object is thrown from horizontal at an angle θ except 90°, then it will follow a trajectory and the motion is called projectile motion. A horizontally thrown ball and a bullet fired from a rifle held horizontally are the examples of projectiles in the horizontal direction. For this type of projection there is an initial velocity u only in the horizontal or x-direction. But there is no initial velocity in the vertical or y-direction.

However, there is acceleration in the downward direction due to gravity. Since there is no acceleration or force in the *x*-direction after it is projected, the projectile moves in this direction with a constant speed (*u*).

As the object moves horizontally, it also falls in the downward direction due to gravity. In the downward direction, the motion is the same as that of a dropped object.

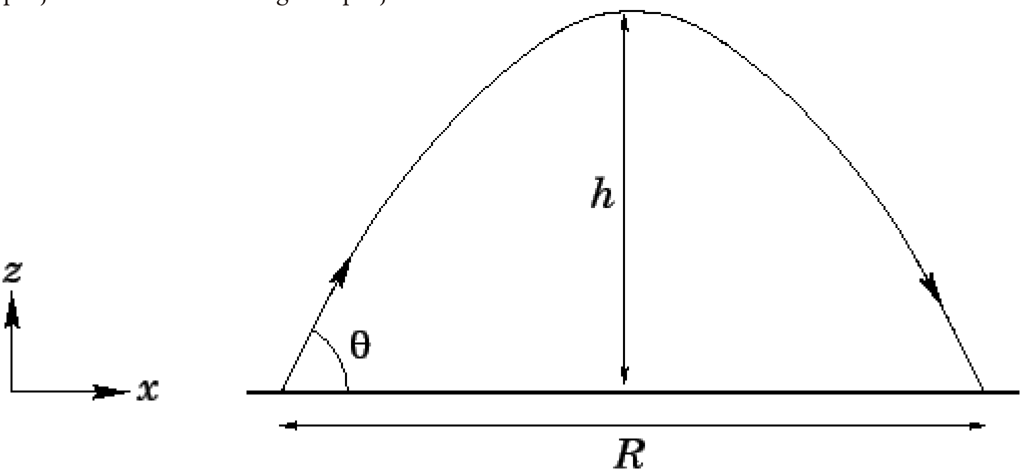
Let us consider a body A which is allowed to fall freely and another body B projected horizontally with a velocity *u* from the same height and at the same time. The body B possesses simultaneously:

- Uniform horizontal velocity *u*
- A non-uniform vertical velocity *v*.

As the body B travels down its vertical velocity (*v*) increases due to acceleration due to gravity. **But the horizontal velocity *u* remains constant.** Hence the body A which is freely falling and the body B projected horizontally from the same height at the same time will strike the ground simultaneously at different points. But the two bodies at any instant will be at the same vertical height above the ground. Thus the motion of a freely falling body is same as that of a horizontally thrown projectile. A stone released from a moving train behaves like the horizontal projectile B. As the path of B is a parabola, a stone released from a moving train also follows a parabolic path.

Oblique projection Motion

Consider a body which is projected at an angle with the horizontal. Let u be the initial velocity of the projectile and θ be the angle of projection.



Initial velocity can be resolved into two components viz. (i) the horizontal component u cos θ and (ii) the vertical component u sin θ. The path of the projectile ACB is a parabola and CD (h) is the maximum height reached by it. The time (t) taken by the projectile to reach the maximum height is given by

$$t = \frac{u \sin \theta}{g} \quad \ldots (1)$$

The maximum height reached is given by

$$h = \frac{u^2 \sin^2 \theta}{2g} \quad \ldots (2)$$

The time of flight (t_f) of a projectile is defined as the time taken by it to reach the horizontal plane after its projection. It s given by

$$t_f = \frac{2u \sin \theta}{g} \quad \ldots (3)$$

The distance between the point of projection A and the point B where the projectile strikes the horizontal plane again is called its range (R). It is given by

$$R = \frac{u^2 \sin 2\theta}{g} \quad \ldots (4)$$

Equation (4) shows that the range is maximum when θ = 45° (because sin 90°= 1). This is a consideration in several sports

Events such as shot-put, javelin and golf where maximum ranges are desired. The player is expected to throw at an angle of 45° to achieve maximum range.

Circular Motion

When an object moves in circular path, it is called circular motion. If the speed of the object in circular motion remains constant, then it is called *uniform circular motion*. If the speed is not constant, then the motion is non-uniform circular motion. In circular motion, an acceleration acts on the body, whose direction is always towards the centre of the path. This acceleration is called centripetal acceleration or radial acceleration. Further, the Centripetal force is the force which makes the body to move in a circular path. Centripetal force is the force that is *directed toward the center of an orbital path*/spinning object which keeps the revolving object in its orbit. This is in opposition to the "centrifugal force" – a kind of fictitious force that appears to try to pull the object away from the center of the orbit (due to inertia).

Important Observations on Circular Motion

Artificial Satellites

An artificial satellite orbiting around the earth does not fall down. This is so because the attraction of earth provides the necessary **acceleration** for its motion. This acceleration is "constant" in magnitude but "changing in direction". By the launch rocket, immediately before the satellite is established in the predetermined orbit, the speed given to it is 30, 000 km/hr. The speed must be great enough so gravity doesn't bring the satellite back to Earth, but not so great that the satellite escapes gravity out into space. This means that the speed, which is provided by the rocket is the source of the centrifugal force, and the attraction of the earth holds it from moving away from this centrifugal force.

Working of Washing Machines

Both Centripetal Force and Centrifugal Force play role in working of a **Washing Machine.**

The spin dryer of a washing machine removes excess water from the clothing by rotating at a high speed. The high speed of rotation creates a high *centrifugal force* for the water in the clothing which causes it to be pulled to the outside of the spinning portion of the washing machine and away from the clothes. However, it is the Centripetal force that keeps the clothes themselves away from the outer portion of the washing machine. This is provided by the walls of the rotating spin dryer. Since

there is insufficient centripetal force affecting the water (only friction & surface tension holding it to the clothes), it flows to the outer walls and is separated from the clothes, which removes the excess water.

Vehicles

Wheel of an automobile spins in mud because the centripetal force is not enough to hold the mud on tyre. When vehicles turn around at a turn, the centripetal force is provided by the friction between tyres and road.

The less desirable case of lack of centripetal force is when the rear wheel of an automobile spins in mud. The adhesion of the mud to the wheel which is the centripetal force in this case is not enough to hold the mud on the tyre. So it comes off tangentially to the tyre's circular motion.

If a vehicle moves at very high speed over a curved path, the *centrifugal force makes it topple.* This is because the centrifugal force overcomes the frictional force between the road and the tyres of the vehicle. To prevent this, the curved tracks are always banked. It means that the outer edge of the road is slightly elevated at an angle. This angle of elevation is given by

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$

Where g is acceleration due to gravity.

Due to banking of curves the centrifugal force balances with frictional force and equilibrium is reached. Thus toppling of vehicles is prevented on curved roads. This is known as banking of tracks. The racing track is designed like a concave disc for the same reason.

In circus there during the cage of death event, a motor cyclist drives a motor cycle at a high speed on the inner walls of a spherical cage of iron. But he does not fall off the motor cycle even when he is upside down. The centrifugal force keeps the motor cyclist glued to his seat while driving his motor cycle inside the cage.

Other Notes

- Total work done by the *centripetal force is always zero* because the centripetal force and displacement are at right angles to each other.
- During orbital motion of the planets, centripetal force is provided by the gravitational force between planet and sun.
- During orbital motion of electron around nucleus in an atom, the centripetal force is provided by *Electrostatic force* between electron and nucleus.
- When we swing a stone tied to a string, the centripetal force is provided by tension in the string.
- Centrifugal force is in opposite direction to Centripetal force. On earth, it is minimum at poles and maximum at equator.
- In centrifuges, heavier particles move away from the centre while lighter particles remain near axis of rotation.
- When a sample of blood is centrifuged, the red blood cells accumulate at the bottom, because red blood cells are heavier than White Blood Cells.
- **Cream from milk** is separated by centrifuges in dairy separators. Ultra centrifuges with speeds of the order of 5×10^5 rpm are used to **concentrate viruses in solution**.
- Centrifuges are used in **Uranium enrichment**.
- **Sugar crystals are separated from molasses** with the help of a centrifuge. **Honey is also separated from bees wax** with the help of a centrifuge.

Laws of Motion

Inertia

The property of an object by virtue of which it cannot change its state of rest or of uniform motion along a straight line its own, is called **inertia.** Inertia is basically a measure of mass of the body. Thus, greater is the mass, greater is its inertia and vice versa.

- When a bus or train starts to move suddenly, the passengers sitting in it falls backward. This is due to inertia called *inertia of rest.*
- When a moving train stops suddenly, the passengers sitting in it jerk in forward direction.

This is due to inertia called *inertia of motion*.

- We are able to protect ourselves from rains using an umbrella because rain drops cannot change their direction on their own. This is called *inertia of direction*.

Force

Force refers to a push or pulls which tries to change the state of rest, motion, size or shape of an object. Its SI unit is Newton. 1 Newton is equal to 1 kg m/s^2. There are two types of forces viz. *Contact forces* and *Action at distance forces*. Examples of Contact Forces include Frictional force, Tensional Force, Spring Force etc. The Forces in action at distance include magnetic force, electrostatic force, gravitational force etc.

Further, the forces which act on an object for a short interval of time but change large change in momentum is called impulsive force. Momentum is the total amount of motion present in a body. Change in Momentum is called Impulse.

Newton's First Law of Motion

Newton's first law of motion says that a body continues to be in its state of rest or in uniform motion along a straight line unless an external force is applied on it. This explains:

- Why when a beat a carpet with stick, dust particles separate out of it.

- Why passengers feel sudden jerk forward when a moving Bus or train stops suddenly.

Newton's Second Law of Motion

Newton's second law of motion says that the rate of change of linear momentum is proportional to the applied force and change in momentum takes place in the direction of applied force. This explains:

- Why it is easier to push empty cart than full cart
- Why adult is able to push or pull a cart easily than a child

The second law of motion is called real law of motion because first and third laws of motion can be obtained by it.

Newton's Third Law of Motion

Third law of motion says that "For every action there is an equal and opposite reaction and both acts on two different bodies." Swimming is possible because of this law. This explains why jerk is produced in a boat when bullet is fired from it. *A person is hurt on kicking a stone due to reaction only*.

Law of Conservation of Linear Momentum

This law says that if no external force acts on a system, then its total linear momentum remains conserved. In equation form, Momentum=mass*velocity. To increase the momentum of an object, we need to either increase its mass or velocity or both.

- Rockets work on law of conservation of momentum. As momentum in one direction is given to the rocket's exhaust gases, momentum in the other direction is given to the rocket itself.

Weight (w)

Weight refers to a force with which a body is pulled towards the centre of the earth due to gravity. It has the magnitude mg, where m is the mass of the body and g is the acceleration due to gravity, thus w=mg

- When a lift is either at rest or moving with a constant speed, then apparent weight of a person standing in it is equal to his actual weight. Thus, R = mg
- When a lift is accelerating upward, then apparent weight would be R1=M(g+a). Thus weighing machine would read the apparent weight more than the actual weight.
- When a lift is accelerating downward, then apparent weight would be R2=m(g-a). Thus, the weighing machine would read less than actual weight.
- When the lift is falling freely under gravity then apparent weight R3=m(g-g) =0. In this case, machine will read zero.
- If lift is accelerating downward with an acceleration *greater than g*, then the person will lift from floor to the ceiling of the lift.

Friction

Friction is force acting on the *point of contact of the objects*, and which opposes the relative motion. Friction always works parallel to the contact surfaces. Frictional forces are produced due to intermolecular interactions acting between the molecules of the bodies in contact.

There are three kinds of friction viz. static friction, limiting friction and Kinetic friction.

Static friction is the opposing force which works when one body tends to move over the surface of the other body but actual motion is not taking place. This makes harder for two objects to slide alongside one another. Glass on Glass is an example of static friction. Static friction results from the interlocking irregularities present on the two surfaces in contact. This force will increase in response to an attempt to move the objects until it is overcome at the threshold of motion. The maximum value of static friction when body is at the verge of starting motion is called Limiting Friction. The friction that occurs after the point where motion is achieved is referred to as kinetic friction.

Common examples of Friction:

- We can hold a pen while writing due to the force of friction. Friction is needed in this case for better grip. If there is no friction, it would be really difficult to write.
- If there was no friction, walking on the road would become impossible. It is friction that allows us to walk.
- After a shower, it becomes difficult to drive a car at high speed on the wet road because friction decreases.
- Angle of sliding or angle of repose is the minimum angle of inclination of a plane with the horizontal in such a way that the body placed on it begins to slide down. It depends upon

limiting friction.

- Further, when a body moves on an inclined plane then several forces work on it viz. normal reaction of plane, friction force acting in opposite direction of motion, gravitation force vertically down etc.

Pushing or pulling an object

To pull an object (such as lawn mower) is always easier than to push whenever the *force is applied at an angle to the object.* This is because horizontal component of force will act to move the object. so:

- If we push, then the vertical component of force will press the object downward and the friction will be more.
- If we pull then the Vertical component of force will act upward and the friction will be less.

Work, Power and Energy

Work

Work is said to have been done when a force acts on an object and the object actually moves in the direction of force. Work done is equal to the product of the *force and the displacement* of the object in the direction of force.

Work = Force X Displacement

SI unit of work is Joule (J) which is equivalent to SI base units 1 $kg.m^2/s^2$. Thus, 1 Joule of work is said to have been done when a force of 1 N causes a displacement of 1 m.

Notable Examples regarding work:

- No work is done by a man rowing a boat upstream but is at rest with respect to the bank. This is because when the man is rowing a boat upstream, it is at rest with respect to the bank. So, the displacement of the boat is zero. Hence, no work is done by the boat.
- No work is done if I apply all the force upon a wall and is not able to move it. Similarly, I will do no work if I am a coolie and I just standing with a load on my head but not moving. {work is done in this case if I lift a luggage from ground to place it on my head}
- Work can be positive, zero or negative. Negative work implies that the displacement is in opposite side of the force. Negative Work is done when brakes are applied to a moving vehicle and vehicle stops.
- When a ball is projected vertically upward and it comes back due to force of gravity, work is done by both ball and gravity in opposite directions.

Work done in Circular Path

Work done depends only on the initial and final Positions and not on the actual path followed between initial and final positions. When a body moves in a circular path no work is done. This is because centripetal force acting on the body is always at right angles to the displacement of the body along the circular path. Since cos 90° = 0, so W = F cos 90° × S = 0 × S = Zero.

Similarly, when a satellite revolves around the earth in a circular orbit, the work done by force of gravity is also zero because it acts at right angles to the direction of displacement of the satellite.

Power

Power is the time rate of work done by a body. Thus if work done is divided by time taken, we get power.

Power =Work done / Time taken

The SI unit of power is Watt which is equal to 1 joule per second. 1 Horse power is equal to 746 watt. Power is a scalar quantity.

Energy

Energy of a body refers to its capacity of doing work. Energy is a scalar quantity. SI unit of Energy is erg. 1 erg = 10^{-7} J

There are several types of energies for example, mechanical energy, chemical energy, light energy, heat energy, sound energy, nuclear energy, electric energy etc.

Mechanical Energy

Kinetic Energy and Potential Energy are called Mechanical Energy. The sum of kinetic and potential energies at any point remains constant throughout the motion. It does not depend upon time. This is known as law of conservation of mechanical energy.

Kinetic Energy

The energy possessed by any object by virtue of its motion is called its kinetic energy.

Kinetic energy of an object is given by $\mathbf{k = 1/2\, mv^2}$

where m = mass of the object, and v is its velocity.

So it's obvious that Kinetic energy is zero in stationary objects as v=0.

The above formula shows that the Kinetic Energy is a product of half the Mass and velocity Squared. *When the velocity is doubled, the Kinetic energy would go up four times. If velocity is tripled, kinetic energy would go up nine times*. If velocity is increased by 1.5 times the Kinetic energy would go up by 1.5×1.5=2.25 times.

Further, since kinetic energy is a product of mass and velocity squared, a tennis ball and a football don't have equal kinetic energy if they have equal velocities. To get equal kinetic energy, the tennis ball needs to have few times higher velocity than a football.

Energy in a running horse, Speeding car, fired bullet, oscillating pendulum, flowing water, flying bird are examples of Kinetic energy.

Potential Energy

The energy possessed by any object by virtue of its position or configuration is called its potential energy. There are three important types of potential energies viz. gravitational, elastic and electric.

- If a body of mass m is raised through a height h against gravity, then it has *gravitational potential energy*. It would be equal to E=mgh
- If a spring of spring constant k is stretched through a distance x, then *elastic potential energy* of the spring would be $E=1/2\ kx^2$

Examples of Potential Energy include: a stretched bow and arrow system; a wound up spring of a watch; water stored high up in reservoirs; stone lying on the top of the roof.

Work-Energy Theorem

Work energy theorem says that the work done by a force in displacing a body is equal to change in its kinetic energy. When we move an object (i.e. we do work on it), we increase its *kinetic energy*. When we bring a moving object to rest, we also do work on the object, but in this case we are decreasing its kinetic energy. Regardless of whether we are increasing or decreasing an object's kinetic energy, the *amount of work done is equal to the change in energy*.

Mass-Energy Equivalence

Einstein showed us the way that mass can be transformed into energy. When

Δm is converted into energy, the energy produced is equal to $E = \Delta mc^2$, where c is the speed of light in vacuum.

Principle of Conservation of Energy

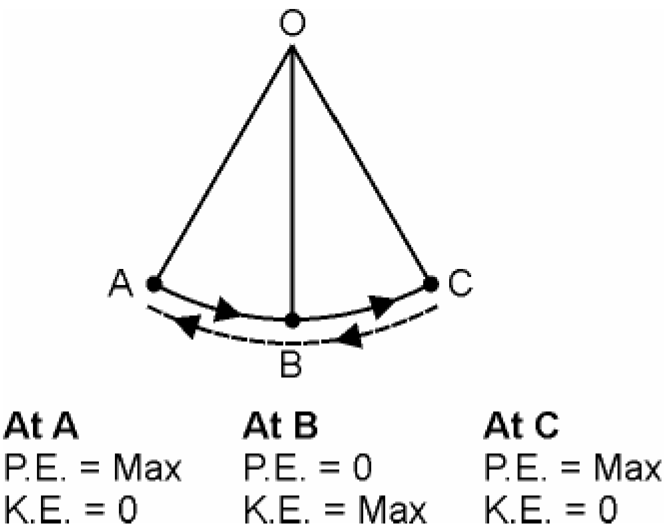
This says that sum of all kinds of energies in an isolated system remains constant at all times.

The law of conservation of mass and energy states that the total energy (Rest mass energy + kinetic energy + potential energy) of a closed system is constant; that is, energy or mass can neither be created nor destroyed.

Principle of Conservation of Mechanical Energy

For conservative forces the sum of kinetic and potential energies of any object remains constant throughout the motion. An object may have both kinetic and potential energy at the same time but total of them would be same. For example, a flying aeroplane, an oscillating pendulum, a stone thrown upwards have both kinetic and potential energy.

A swinging pendulum has maximum kinetic energy and minimum potential energy when it is at the middle of the arc i.e. at its lowest point. However, when it is at highest point on either side, its kinetic energy is zero and all energy is potential energy. Throughout its swing, the total mechanical energy remains same.



Practical examples on Energy

Q-1: A rubber ball dropped from 24 m height and after impact it loses its kinetic energy by 25%. What is the height to which it rebounds?

Answer: In this question, all the potential energy of ball (by virtue of its being at a height of 24 m) is converted into kinetic energy when it reaches to the ground. However, the ball has lost 25% of its kinetic energy (due to inelastic collision). What remains with the ball is 75% of the kinetic energy. So it would rebound only 75% of 24 meters i.e. 18 meters.

Q-2: What kind of Energy is stored in Tides in Oceans?

Tides in the sea have stored in them combination of Hydraulic energy, Kinetic energy as well as Gravitational potential energy.

Q-3: **Which of the following four objects has the least kinetic energy: an object of mass (m) moving with speed (4v), an object of mass (3m) moving with speed (2v), an object with mass (4m) moving with a speed of (v), or an object of mass (2m) moving with speed (3v)?**

Answer:

Let $1/2mv^2$ be X, so:

- Kinetic energy of first mass is 16X
- Second is 12X
- Third is 4X
- and fourth is 18X

Thus, least Kinetic energy is of third one.

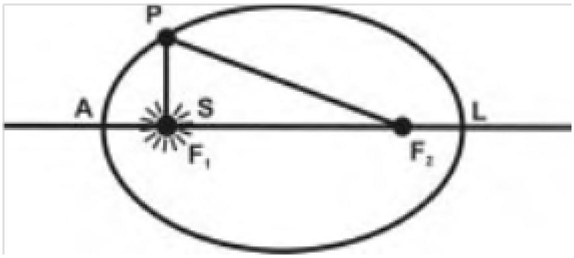
Gravitation and Artificial Satellites

Kepler's Laws

In the early 1600s, Johannes Kepler proposed three laws of planetary motion as follows:

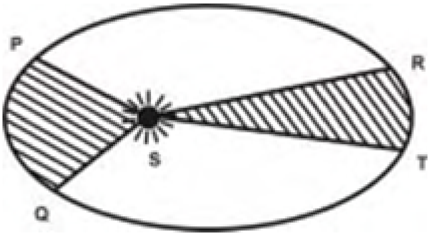
Kepler's First law (Law of orbits)

Each planet moves around the sun in an elliptical orbit with the sun at one of its foci. An ellipse is a closed curve such that the sum of the distances from any point P on the curve to two fixed points (F1 , F2) remains constant.



Second law (Law of areas)

As the planet moves in its orbit, a line drawn from the sun to the planet sweeps out equal areas in equal intervals of time. Let PQS and RST be the areas swept by the line joining the planet and the sun in equal intervals of time. Kepler found that these areas are equal. Hence the speed of the planet around sun must be maximum at the perihelion position and minimum at the aphelion position.



Third law (Law of periods)

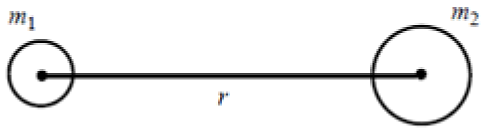
The squares of the periods of revolution of the planets are proportional to the cubes of their mean distances from the sun. If R is the mean distance of the planet from the sun and T is the period of its revolution the third law states that $T^2 \propto R^3$. As per this law, the planets with the mean distances from the sun, their orbital periods and velocities are listed in the table.

Planet	Time Period (Earth Years	Mean Distance from Earth ($\times 10^9$ m)	Mean Velocity ($\times 10^3$ m/s)	T^2 / R^3 ($\times 10^{-25}$) years² /km³
Mercury	0.241	57.91	47.875	2.991
Venus	0.615	108.21	35.056	2.985

Planet	Time Period (Earth Years	Mean Distance from Earth ($x10^9$ m)	Mean Velocity (x 10^3 m/s)	T^2 / R^3 ($x10^{-25}$) $years^2 /km^3$
Earth	1	149.6	29.806	2.987
Mars	1.881	227.94	24.144	2.988
Jupiter	11.862	778.3	13.072	2.985
Saturn	29.458	1427	9.651	2.986
Uranus	84.015	2869	6.804	2.99
Neptune	164.788	4498	5.438	2.984
Pluto	248.4	5900	4.732	3.004

A century later, Newton demonstrated that Kepler's laws were the consequence of a simple force that exists between any two masses. Newton's law of gravitation and laws of motion, provide the basis for the motion of planets and satellites.

Newton's universal law of gravitation



Everybody in the universe attracts every other body with a force which is directly proportional to the product of the masses of the two bodies and inversely proportional to the square of the distance between them. If m_1 and m_2 are the masses of two bodies separated by a distance r, the force of attraction F between them is given by:

$$F = \frac{G m_1 m_2}{r^2}$$

where G is the universal constant of gravitation. The value of G = 6.67 $x10^{-11}$ N m^2 Kg^{-2}. The force of gravitation is directed along the line joining the two bodies. If m1 = m2 = 1 kg and r = 1 m then F = G. Thus the gravitational constant is equal to the force of attraction between two bodies each of mass 1 kg separated by a distance of 1 metre.

Artificial Satellites

Satellite refers to any project that is orbiting earth, sun or other planetary bodies. Satellites can be artificial or natural. The artificial satellites basically work on principle of projectiles. The only force that works on satellites is gravity. Once launched in an orbit, gravity is the only force governing the motion of the satellite.

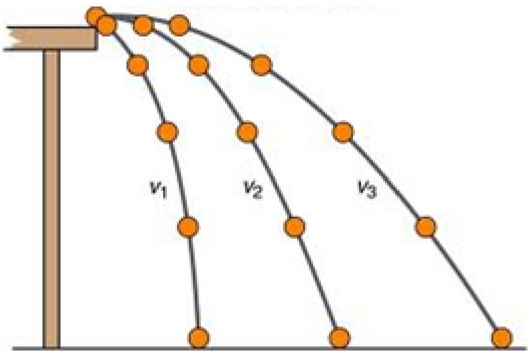
Important Concepts

- Selection of tangential speed is very much important in case of launch artificial satellite launches. They are projected with such a speed that the "radius" of their curved path is "greater" than the radius of earth. However, not such a high speed that the satellite leaves the orbit and gets lost in space.
- The speed of an artificial satellite does NOT depend upon its mass. This implies that at a particular distance from earth, all objects would move at same speed of revolution.
- Higher the orbit is, lower is its speed, so when a satellite moved from higher orbit to lower orbit, its speed increases.
- If we throw the satellite of a speed lesser than 7900 meters per second or 28500 kilometers per hour, it will simply fall on earth. The speed higher than this will produce an elliptical orbit. However if this speed is more than 11.2 kilometers per second, it will escape the earth's gravitation field and will never come back.
- Equator or the places near to equator are found suitable for launching the satellites as it will save efforts.

- Satellites are launched in Eastward direction, it also saves efforts.

Basics

When we throw a stone with some speed in the horizontal direction, it will follow a curved path and fall on the ground. When we throw the stone with a greater speed, it will follow a curved path that is even bigger than the previous one. Thus, greater is the speed, greater is the radius of the curved path as shown below:



Now, if we have such a powerful device to throw this stone with such a tremendous speed that radius of the curved path it follows becomes little bigger than the radius of earth, we cannot expect it to return to earth. Rather, it will keep on revolving around the earth. This is how the artificial satellites work. **They are projected with such a speed that the "radius" of their curved path is**

<u>**"greater" than the radius of earth.**</u>

Gravitational pull of earth would provide the necessary centripetal force that is needed to keep it in its particular orbit. Here, we should note that <u>**speed of the satellite is carefully chosen**</u> so that it provides necessary force to keep it revolving. This implies that:

F (Gravitational) = **F** (centripetal)

So $m\frac{v^2}{r}$ = mg

v^2= rg

V= $\sqrt{rg}$

From the above formula, we first note that there is no place for **m** , which means that the <u>**speed of an artificial satellite does NOT depend upon its mass.**</u> This implies that at a particular distance from earth, all objects would move at same speed of revolution.

But the above formula says that v is dependent upon r. The above formula now we derive again as follows:

F (Gravitational) = **F** (centripetal)

$$\frac{GMm}{r^2} = m\frac{v^2}{r}$$

In the above formula, G is the universal gravitational constant and M is the mass of earth. We arrive at v as follows:

$$m\frac{v^2}{r} = \frac{GMm}{r^2}$$

$$v = \sqrt{\frac{GM}{r}}$$

Here we come to two conclusions:

- v is dependent upon r because **V=** $\sqrt{rg}$
- **v is inversely proportional to r because** $v = \sqrt{GM/r}$

Here we conclude that higher the orbit is, lower is its speed. When we whirl a small string with an small object tied at one of its and also allow to get it rolled around our finger, we find that the smaller the radius of the circle is, higher is its speed.

So, when a satellite moved from higher orbit to lower orbit, its speed increases.

Since, g= 9.8 square meters per second and radius of earth is 6.4 x 10^6 meters, we conclude that

$$V = \sqrt{rg} = \sqrt{6.4 \times 10^6 \times 9.8} = 7.9 \times 10^3 \text{ meters per second} = 7.9 \text{ kilometers per second}$$

Thus, if we throw the satellite of a speed lesser than 7900 meters per second or 28500 kilometers per hour, it will simply fall on earth. But the speed higher than this will produce an elliptical orbit. However if this speed is more than 11.2 kilometers per second, it will escape the earth's gravitation field and will never come back.

This value of 11.2 kilometers per second is known as escape velocity and it explains why we have the gaseous atmosphere which does not go away from earth. On moon the escape velocity is 1.9 kilometers per second and molecules of any gas formed on moon would have velocity more than this value and that is why moon has not gaseous atmosphere.

Launching a satellite needs tremendous forces, because providing it an speed of 28500 kilometers per second is not an easy task.

Launching a satellite on Equator versus Poles

Earth is not round and we all know that its radius on poles is smaller than its radius on equators. The away we move from centre of earth, lower is the gravitational force and this is the reason that the gravitational pull is minimum at Equator. So, **Equator or the places near to equator are found suitable for launching the satellites** as it will save efforts.

Launching a satellite in eastward versus westward direction

We know that Earth rotes from west to east, the satellites are launched in Eastward direction so that the speed of earth's rotation which comes nearly 462 meters per second will provide it additional push. (40000 x 1000 ÷24÷60÷60=462 (though exact speed is 465.1 meters per second))

Geostationary and Geosynchronous Orbits

The core principle of an orbit is that as a satellite or object moved tangentially, it falls toward the earth / other body, but it moved so quickly that earth / body will curve away beneath it. Thus we can understand that gravity pulls this object into a curved path as it attempts to fly off in a straight line. A satellite has enough tangential velocity to miss the orbited object, and will continue falling indefinitely.

In other words, when the satellite is moving in the orbits, it stays in position because the centripetal force on the satellite balances the gravitational attractive force of the earth. This balance depends on the following:

- Distance from the earth
- Tangential speed of the satellite
- Earth's radius

- Gravitational force of the earth.
- But it does not depend upon:
- Mass of the satellite
- Size of the Satellite

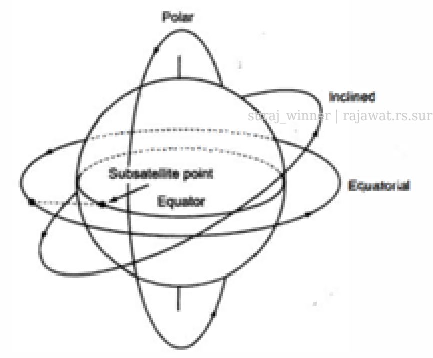
Key Concepts

- An artificial satellite is always falling towards earth, but it has enough tangential velocity to continue fall indefinitely.
- Centripetal force on the satellite balances the gravitational attractive force of the earth. This balance does not depend upon the mass and size of the satellite.

Types of Orbits

There are three major types of orbits viz. **Polar, Inclined and Equatorial**.

The Polar Orbits cover the poles, Equatorial are above the equator and inclined orbits are inclined from the equatorial orbit. They are shown as below:



Geostationary Orbit (GEO)

If we need a satellite for the purpose which needs this satellites to remain at a particular distance from earth at all the time, then we need **circular orbits so all the points on circular orbit are at equal distance from earth's surface**. The **circular equatorial orbit** is exactly in the plane of equator on the earth. If the satellite is moving in the circular-equatorial orbit and its angular velocity is equal to earth's angular velocity, the satellite is said to be moving along with the earth. This satellite would appear stationary from the earth and this orbit would be called **Geostationary Orbit**.

Features of geostationary satellite

- The orbit is circular
- The *orbit is in equatorial plane* i.e. directly above the equator and thus inclination is zero.
- The *angular velocity of the satellite is equal to angular velocity of earth*
- Period of revolution is equal to period of rotation of earth.
- Finish one revolution around the earth in exactly one day i.e. 23 hours, 56 Minutes and 4.1

seconds

- There is ONLY one geostationary orbit.

Geosynchronous Orbit

There is a difference between the geostationary and geosynchronous orbits. We should note that while other orbits may be many, there is ONLY ONE Equatorial orbit, i.e. the orbit which is directly above the earth's equator. Sometimes we send a satellite in the space which though has a period of revolution is equal to period of rotation of earth, but its orbit is **neither equatorial nor Circular**. So, this satellite will finish one revolution around the earth in exactly one day i.e. 23 hours, 56 Minutes and 4.1 seconds, yet it does NOT appear stationary from the earth. **It looks oscillating** but NOT stationary and that is why it is called **Geosynchronous**.

Features of a geosynchronous satellite

- The orbit is **NOT circular**
- The orbit is **NOT in equatorial plane**e. directly above the equator, it's **in inclined orbit**
- The **angular velocity of the satellite is equal to angular velocity** of earth
- **Period of revolution is equal to period of rotation of earth.**
- Finish one revolution around the earth in exactly one day i.e. 23 hours, 56 Minutes and 4.1 seconds
- There are **many geosynchronous orbits**.

Please note that it is practically NOT possible to achieve an absolute geostationary orbit. So, the terms geostationary and geosynchronous are used alternatively.

Advantages of GEO satellites

- Most communications satellites in use today for commercial purposes are placed in the geostationary orbit, because one satellite can cover almost 1/3 of Earth's surface, offering a reach far more extensive than what any terrestrial network can achieve.
- The geosynchronous satellites remain stationary over the same orbital location, users can point their satellite dishes in the right direction, without costly tracking activities, making communications reliable and secure
- GEO satellites are proven, reliable and secure – with a lifespan of 10-15 years.
- GEO systems have significantly greater available bandwidth than the Low Earth Orbit -LEO and Medium Earth Orbit -MEO systems. This permits them to provide two-way data, voice and broadband services that may be unpractical for other types of systems.
- Because of their capacity and configuration, GEOs are often more cost-effective for carrying high-volume traffic, especially over long-term contract arrangements. For example, excess capacity on GEO systems often is reserved in the form of leased circuits for use as a backup to

other communications methods.

Disadvantages of GEO Satellites

- GEO systems, like all other satellite systems, *require line-of-sight communication paths between terrestrial antennae and the satellites*. But, because GEO systems have fewer satellites and these are in a fixed location over the Earth, the opportunities for line of sight communication are fewer than for systems in which the satellites "travel" across the sky. This is a significant disadvantage of GEO systems as compared to LEO and MEO systems, especially for mobile applications and in urban areas where tall buildings and other structures may block line-of-sight communication for hand-held mobile terminals.
- There are concerns with the transmission delays associated with GEO systems, particularly for high-speed data. However, sophisticated echo cancellation and other technologies have permitted GEOs to be used successfully for both voice and high-speed data applications.

Height of Geostationary Satellites

Key Points

- The height of the geostationary orbit is 35786 kilometers above earth
- In Geostationary Orbit, the satellite moves with an orbital speed of 11068 km per hours.

- A minimum of three satellites are needed to cover the entire earth
- Super synchronous orbit is a disposal / storage orbit above GSO. From earth, they would seem drifting in westerly direction.
- Sub synchronous orbit is a orbit close to but below GSO and is used for satellites undergoing station, changes in an eastern direction.

Calculation of Height

For circular motion of a planet, the condition is that:

F (Gravitational) = F (centripetal)

$$\frac{GMm}{r^2} = m\frac{v^2}{r}$$

V is the speed. Now, we know that the speed v of the planet in its orbit is equal to the circumference of the orbit divided by the time required for one revolution T. so v=2πr/T. So, the above formula becomes as follows:

$$\frac{GMm}{r^2} = m\frac{\left(\frac{2\pi r}{T}\right)^2}{r}$$

From the above formula, we can derive the value of T2 as follows

$$T^2 = \left(\frac{4\pi^2}{GM}\right) r^3$$

The above mathematical derivation is suitable for circular as well as elliptical orbits. Now we know that geostationary satellite follows a circular, equatorial, geostationary orbit, without any inclination, so we can apply the Kepler's third law to determine the geostationary orbit. Since, the path is circle, its semi-major axis will be equal to the radius of the orbit.

Now, it has already been calculated that Earth completes one rotation on its polar axis in 23 hr 56 min and 4.09 sec, which comes out to be 86164.09 seconds. So, the period of rotation of the Geostationary satellite should be 86164.09 seconds.

This means that

T=86164.09 seconds

Now we use this formula:

$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

$$r^3 = \frac{GM}{4\pi^2}$$

$$r^3 = \frac{6.67x10^{-11}x5.983x10^{24}x86164.09}{4\pi^2}$$

$$r^3 = 7.546x10^{22}$$

$$r = 4.23\ x10^7 \text{ Meters}$$

$$r = 42300\ kilometers$$

The above derivation gives the height of the Geostationary orbit. Now, please note that the above height includes radius of Earth which is 6,384 km. When we deduct it from the calculated height we get 35916 Kilometers. The precise height is altitude of 35,786 km (22,236 mi) above ground.

Orbital speed (how fast the satellite is moving through space) is calculated by multiplying the angular speed by the orbital radius:

$$v = \omega r \approx 3.0746 \text{ km/s} \approx 11068 \text{ km/h} \approx 6877.8 \text{ mph.}$$

Orbiting at the height of 22,282 miles above the equator (35,786 km), the satellite travels in the same direction and at the same speed as the Earth's rotation on its axis, taking 24 hours to complete a full trip around the globe. Thus, as long as a satellite is positioned over the equator in an assigned orbital location, it will appear to be "stationary" with respect to a specific location on the Earth.

Inclined Orbit

An inclined orbit is used to cover the Polar Regions. It's not a very popular orbit and used not very frequently. The height of the inclined orbit is kept such that it covers the required area of the region of interest. The time for which the satellite is visible to the point on the earth is also controlled. Satellite cannot remain in continuous contact with the point on the earth if rotating in inclined orbit.

Sometimes the inclined orbit is also called elliptical inclined orbit.

Clarke Orbit

Please note that a single geostationary satellite can view approximately **one third of the Earth's surface**. If three satellites are placed at the proper longitude, the height of this orbit allows almost the Earth's entire surface to be covered by the satellites. It was first of all conceptualized by world famous science fiction writer Arthur C. Clarke. The arrangement which was suggested by Clarke is shown in the following figure:

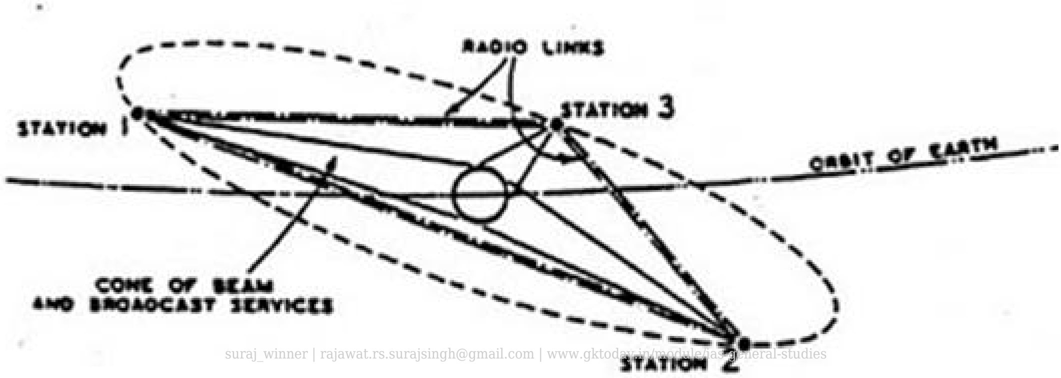


Fig. 3. Three satellite stations would ensure complete coverage of the globe.

The stations would be arranged approximately equidistantly around the earth and the following longitudes appear suitable:

- 30°E – Africa & Europe
- 150°E – China & Oceania
- 90° W- The Americas

The station chain would be linked by radio or optical beams and thus any broadcast service could be provided. The geostationary orbit is now sometimes referred as the Clarke Orbit or the Clarke Belt in his honor.

Low Earth Orbits

A satellite can also be placed in Low Earth Orbits (about 1,000 kilometers above the Earth (between 400 miles and 1,600 miles)). However, satellites in LEO need a higher velocity than Geostationary orbits. For example, a satellite which is placed in an orbit at altitude of 200 kilometers will need an orbital velocity of approximately 29000 kilometer per hour. Similarly, a satellite placed in an orbit at around 1730 kilometers will need a speed of 25,400 kilometers per hour.

Key Features of LEO

Unlike GEOs, the LEO satellites appear travelling across the sky from earth. A typical LEO satellite takes one and half hours to orbit the Earth, which means that a single satellite is "in view" of ground equipment for a only a few minutes. As a consequence, if a transmission takes more than the few minutes that any one satellite is in view, a LEO system must "hand off" between satellites in order to complete the transmission. In general, this can be accomplished by constantly relaying signals between the satellite and various ground stations, or by communicating between the satellites themselves using "inter-satellite links."

International Space Station

The International Space Station is in a LEO that varies from 320 km (199 mi) to 400 km (249 mi) above the Earth's surface

Applications of Low Earth Orbit Satellites

LEO systems are designed to have more than one satellite in view from any spot on Earth at any given time, minimizing the possibility that the network will lose the transmission. Because of the fast-flying satellites, LEO systems must incorporate sophisticated tracking and switching equipment to maintain consistent service coverage. The need for complex tracking schemes is minimized, but not obviated, in LEO systems designed to handle *only short-burst transmissions*.

The advantage of the LEO system is that the satellites' proximity to the ground enables them to

transmit signals with no or very little delay, unlike GEO systems. LEO satellites rotate the earth and currently deliver significant voice quality over the Geosynchronous (GEO) satellite systems. Now days, LEO Satellites are used in constellations such as Globalstar and Iridium constellations. In addition, because the signals to and from the satellites need to travel a relatively short distance, LEOs can operate with much smaller user equipment (e.g., antennae) than can systems using a higher orbit. In addition, a system of LEO satellites is designed to maximize the ability of ground equipment to "see" a satellite at any time, which can overcome the difficulties caused by obstructions such as trees and buildings.

Orbital Decay

The satellites particularly in the LEO are subject to a drag produced by an atmosphere due to frequent collisions between the satellite and surrounding air molecules. The amount of this drag keeps increasing or decreasing depending upon several factors including the solar activity. The more activity heats of the upper atmosphere and can increase the drag. This drag in a long duration causes a reduction in the altitude of a satellite's orbit, which is called orbital decay.

So, the major cause of the orbital decay is Earth's atmosphere. The result of the drag is increased heat and possible reentry of satellite in atmosphere causing it to burn. Lower its altitude drops, and the lower the altitude, the faster the decay. Apart from Atmosphere, the Tides can also cause orbital decay, when the orbiting body is large enough to raise a significant tidal bulge on the body it is orbiting and is either in a retrograde orbit or is below the synchronous orbit. Mars' moon Phobos is one of the best examples of this.

LEO systems Pros and Cons

- It requires less energy to place a satellite into a LEO and the LEO satellite needs less powerful amplifiers for successful transmission, LEO is still used for many communication applications.
- However, since these LEO orbits are not geostationary, a network (or "constellation") of satellites is required to provide continuous coverage.
- The transmission delay associated with LEO systems is the lowest of all of the systems.
- Because of the relatively small size of the satellites deployed and the smaller size of the ground equipment required, the LEO systems are expected to cost less to implement than the other satellite systems.
- The small coverage area of a LEO satellite means that a LEO system must coordinate the flight paths and communications hand-offs a large number of satellites at once, making the LEOs dependent on highly complex and sophisticated control and switching systems.

LEO satellites have a shorter life span than other systems. There are two reasons for this: first, the lower LEO orbit is more subject to the gravitational pull of the Earth and second, the frequent transmission rates necessary in LEO systems mean that LEO satellites generally have a shorter battery life than others.

Medium Earth Orbit

MEO systems operate at about 8,000-20,000 km above the Earth, which is lower than the GEO orbit and higher than most LEO orbits. The MEO orbit is a compromise between the LEO and GEO orbits. Compared to LEOs, the more distant orbit requires fewer satellites to provide coverage than LEOs because each satellite may be in view of any particular location for several hours. Compared to GEOs, MEOs can operate effectively with smaller, mobile equipment and with less latency (signal delay).

These orbits are primarily reserved for communications satellites that cover the North and South Pole. Although MEO satellites are in view longer than LEOs, they may not always be at an optimal elevation. To combat this difficulty, MEO systems often feature significant coverage overlap from satellite to satellite, which in turn requires more sophisticated tracking and switching schemes than GEOs.Typically, MEO constellations have 10 to 17 satellites distributed over two or three orbital planes.Most planned MEO systems will offer phone services similar to the Big LEOs. In fact, before the MEO designation came into wide use, MEO systems were considered Big LEOs. Examples of MEO systems include ICO Global Communications and the proposed Orblink from Orbital Sciences. Unlike the circular orbit of the geostationary satellites, MEO's are placed in an elliptical (ovalshaped) orbit

Polar Orbit

The Polar Orbit is not much suitable for communication purposes because it moves in a different direction than that of direction of earth's rotation. So, the use of Polar satellites depends upon their arrival at a particular point on earth at a particular point. The Polar orbits are used for special applications like navigational satellites.

Key features of Polar Orbits

- Polar orbits are useful in earth mapping
- A satellite in polar orbit would pass over equator on different longitude in successive times.
- No one spot on the Earth's surface can be sensed continuously from a satellite in a polar orbit, however, to make them work on a particular area, they are launched in highly elliptical orbit with its apogee over that area

In a polar orbit, the satellite passes above or nearly above both poles of the earth being orbited on each revolution. So, we can say that the inclination of such orbit is almost 90 degrees to the equator. The Polar orbits are used for earth-mapping, earth observation, and reconnaissance satellites, as well as for some weather satellites. However, Iridium satellite constellation also uses a polar orbit to provide telecommunications services.

Some important notes about Polar orbits

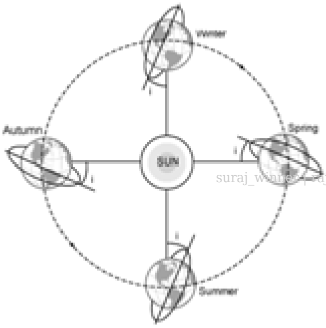
- Except for polar geosynchronous orbit, a satellite in a polar orbit will pass over the equator at a different longitude on each of its orbits.
- No one spot on the Earth's surface can be sensed continuously from a satellite in a polar orbit, this is its biggest drawback.
- The polar orbit can be manipulated also. If we want a satellite in polar orbit to remain

hovering over a certain area for larger time**, it can be placed in a highly elliptical orbit with its apogee over that area.**

Sun-synchronous orbit

Sun-synchronous orbit or a heliosynchronous orbit very important because of its particular importance to satellites intended for remote sensing and military applications. A sun-synchronous orbit is one that lies in a plane that maintains a fixed angle with respect to the Earth-sun direction. In other words, it combines altitude and inclination in such a way that an object on that orbit ascends or descends over any given point of the Earth's surface at the same local mean solar time.

We can say that the orbital plane in such a case has a fixed orientation with respect to the Earth-sun direction and the angle between the orbital plane and the Earth-sun line remains constant throughout the year. It is shown by the below diagram:



Features of Sun Synchronous Orbits

- The satellite passes over a given location on Earth every time at the same local solar time.
- Thus, it guarantees the same illumination condition, which varies only with seasons.
- The orbit is *Quasi-polar in nature and so ensures coverage of the whole surface of the Earth*

Every time a sun-synchronous satellite completes one revolution around earth, it traverses a thin strip on the surface of the Earth. During the next revolution it traverses another strip as shown in the diagram.

Frozen Orbits

We all know that Earth is not perfectly round. This means the gravitation is not exactly same at all the places. Apart from that there is gravitational pull from Sun and Moon too, followed by the solar radiation pressure, air drag and so many other forces. In other words, most satellites experience noticeable variations in orbital eccentricity.

But, fortunately, the distorting impacts of these issues can be induced to cancel each other by expert satellite planners. They choose optimum Orbital altitude, inclination, eccentricity and argument of perigee. The satellites whose orbital parameters are controlled by such techniques is said to be in

Frozen Orbits.

Thus we can say that:

- Frozen orbit is a Sun-synchronous orbit in which the precession of the orbital plane around the polar axis of the Earth caused by the oblateness of the Earth is utilized to the benefit of the mission by choosing correct orbital parameters.
- The Earth observation satellites ERS-1, ERS-2 and Envisat are all operated in Sun-synchronous "frozen" orbits

Other Orbits

- Super synchronous orbit is a disposal / storage orbit above GSO. From earth, they would seem drifting in westerly direction.
- Sub synchronous orbit is a orbit close to but below GSO and is used for satellites undergoing station, changes in an eastern direction.
- Graveyard orbit is a Supersynchronous orbit where spacecraft are intentionally placed at the end of their operational life.

Elasticity

Elasticity refers to that property of an object by virtue of which it regains its original configuration after removal a deforming force. Deforming force is the force which causes a change in configuration of an object when applied to it.

Important Notes on Elasticity

- The upper limit of the deforming force up to which a body regains its original configuration completely is called *Elastic Limit*. Beyond elastic limit, the body will lose its property of elasticity and will deform permanently.
- If a body regains its original configuration immediately and completely after removal of the deforming force, it would be called Perfectly Elastic Body. There is no perfectly elastic body but *quartz fibre and Phosphor bronze are examples of near perfect elastic bodies.*
- If a body does not regain its original configuration at all after the deforming force is removed, it is called perfectly plastic body. Examples of near perfect plastic bodies are wax, putty etc.
- When a ball falls, it is temporarily deformed. Because of elasticity, the ball tends to regain its original shape for which it presses the ground and bounces up.
- The materials which show large plastic range beyond elastic limit are called ductile materials, e.g., copper, silver, iron, aluminum, etc. Ductile materials are used for making springs and sheets. The materials which show very small plastic range beyond elastic limit are called brittle materials, e.g., glass, cast iron, etc.
- The materials for which strain produced is much larger than the stress applied, with in the

limit of elasticity are called elastomers, e.g., rubber, the elastic tissue of aorta, the large vessel carrying blood from heart. etc. Elastomers have no plastic range.

- Elasticity of steel is more than that of copper and so for equal applied force, the elongation of steel spring is less than that of copper for same initial length. This implies that the steel spring can bear a larger tension before the elastic limit is crossed. Further, steel recovers its original state quicker than copper after the deforming force is removed. Due to this reason, steel is preferred in making springs in comparison to steel.
- Glass is more elastic than rubber because for a given applied force per unit area, the strain produced in glass is much smaller than produced in rubber.

Working of Crazy Balls

Rubber is a common visco-elastic material which means it is both viscous and elastic. Further, Rubber is also characterized by another property called resilience. Resilience is the ability of a material to absorb energy when it is deformed elastically, and release that energy upon unloading. Higher the resilience, higher is the bounce in a rubber ball, which means higher elasticity and lesser viscosity. We note here that the butadiene rubber has highest resilience property, followed by natural rubber.

Fluids and Pressure

Fluids refers to the substances which can flow when an external force is applies to them. Both liquids and gases come under the category of fluids. Fluids don't have a finite shape and take the shape of the vessel containing them. The total normal force exerted by liquid at rest on a given surface is called *thrust of liquid*. Thrust of the liquid is measured in Newton.

Pressure Exerted by the Liquid

Pressure of liquid or its *hydrostatic pressure* refers to the normal force exerted by it per unit area of the surface in its contact. Pressure exerted by a liquid column is given by $p = h\rho g$

Where, h = height of liquid column, ρ = density of liquid

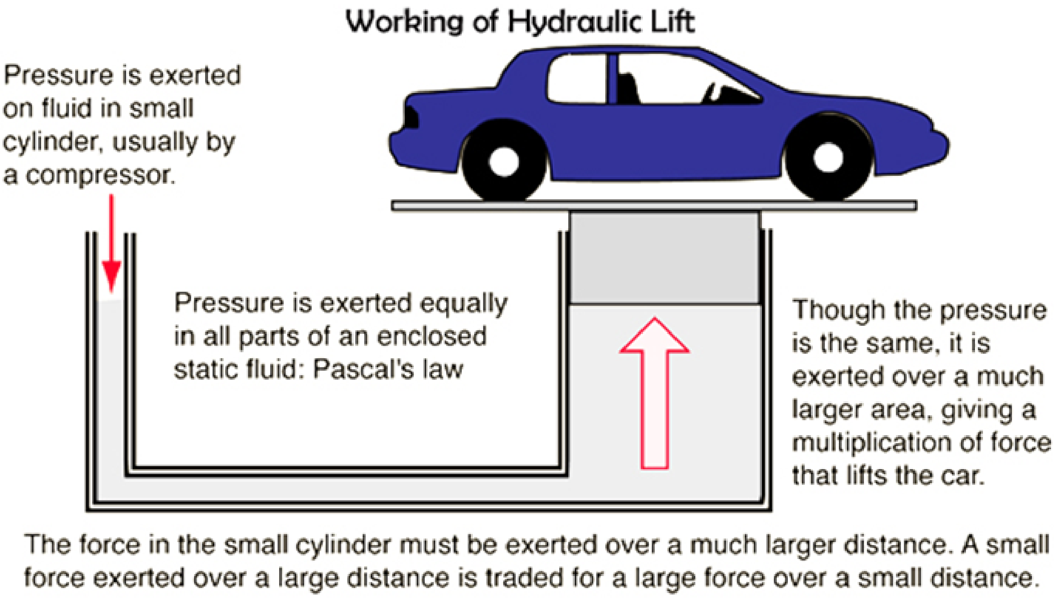
and g = acceleration due to gravity

We note here that mean pressure on the walls of a vessel containing liquid up to height h is $(h\rho g / 2)$.

Pascal's Law

In 1647 the French scientist Blaise Pascal (1623–1662) discovered that water exerts the *same pressure in all directions*. This statement is known as Pascal's Principle.

Pascal's law states that increase in pressure at a point in the enclosed liquid in equilibrium is transmitted equally in all directions in liquid and to the Walls of the container. The working of *hydraulic lift, hydraulic press and hydraulic brakes* are based on Pascal's law.



Atmospheric Pressure

Barometric, or atmospheric, pressure is the force exerted on a surface by the weight of the air above that surface, as measured by an instrument called a barometer.

Pressure is measured in *Pounds Per Square Inch* or *Newton per M²* (also called Pacal). It is also measured in toor and bar. 1 torr is equal to 1 mm of mercury column, while 1 bar = 10^5 Pa.

Pressure is greater at lower levels because the air's molecules are squeezed under the weight of the air above. So while the average air pressure at sea level is 14.7 pounds per square inch {100000 N/m^2}, at 1,000 feet (304 meters) above sea level, the pressure drops to 14.1 pounds per square inch (around about half of the figure at sea level). Changes in air pressure bring weather changes. High pressure areas bring clear skies and fair weather; low pressure areas bring wet or stormy weather. Areas of very low pressure have serious storms, such as hurricanes.

Atmospheric Pressure at sea level is equal to:

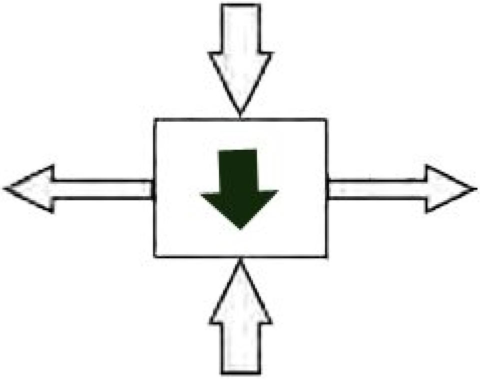
- 76 cm of mercury column
- 980 $dyne/cm^2$
- 100000 N/m^2

Why atmospheric Pressure does not crush over body?

The atmospheric pressure does not crush our body because the pressure of the blood flowing through our circulatory system balances this pressure.

Pressure in water

We can understand this by imagining a small cube of water as shown below:



In the above cube, the middle black arrow shows force of gravity on the cube. This implies that the total downward force of the cube is larger than the upward force. Thus, pressure increases with the depth of the water. This explains why or ears hurt when we dive to the bottom of the swimming pool. It also explains why dams thicker at the bottom than at the top. Also, in Hydro power stations, the generator is placed at the lower part so that the pressure of the water is high enough to drive the turbine.

Blood Pressure

Blood pressure refers to the pressure that our blood exerts on our arteries. The fluid dynamics of blood play a major role in blood pressure. The device used to measure blood pressure is the sphygmomanometer. It is placed around the upper arm (Brachial artery), inflated, and then deflated, while a meter measures the pressure passing through that section of the arm and either a person using a stethoscope or an electronic sensor detects the pulse. The cuff is inflated until no pulse can be heard. It is then slowly lowered. As the pressure falls below the systolic pressure the pulse can be heard. When it's below the diastolic pressure the pulse gets weaker. Also note that the Blood Pressure 120/70 means that the systolic pressure is 120 torr and the diastolic pressure 70 torr.

Why blood Pressure is taken from upper arm?

We have discussed above that pressure of a liquid is dependent on the depth of the fluid. Thus, to get the blood pressure correctly, it should be measured at a height of our heart. It cannot be measured around the heart so brachial artery in the upper arm provides convenient location. *If a person is laying down, the blood pressure can be taken from any artery.*

Where is the water pressure greater, in a lake 20 meters deep or in the ocean at a depth of 10 meters

In the lake, because pressure depends on height.

Where is the water pressure greater, in a lake 10 meters deep or in the ocean at a depth of 10 meters?

At similar depth, Ocean water will exert more pressure because saltwater is denser than freshwater and more pressure should be applied by seawater at same distance.

Buoyancy

When a body is partially or fully immersed in a fluid an upward force acts on it, which is known as buoyant force or simply buoyancy. The buoyant force acts at the *centre of gravity of the liquid displaced* by the immersed part of the body and this point is called the centre of buoyancy.

Archimedes' Principle

The exclamation 'Eureka!' is famously attributed to the ancient Greek scholar Archimedes (c. 287–c. 212 BC), who is known to have devised the way to check purity of a gold crown without breaking it apart. He gave the principle that: When a body is partially or fully immersed in a liquid, it loses some of its weight and that lost weight is equal to the weight of the liquid displaced by the immersed part of the body.

If T is the observed weight of a body of density σ when it is fully immersed in a liquid of density p, then real weight of the body

$w = T / (1 – p / \sigma)$

Laws of Floatation

A body will float in a liquid, if the weight of the body is equal to the weight of the liquid displaced by the immersed part of the body. If W is the weight of the body and w is the buoyant force, then

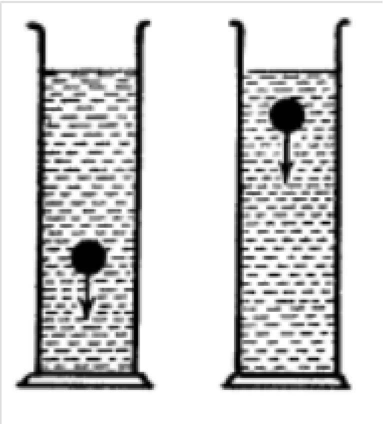
- If W > w, then body will sink to the bottom of the liquid.
- If W < w, then body will float partially submerged in the liquid.
- If W = w, then body will float in liquid if its whole volume is just immersed in the liquid,

Further, the floating body will be in stable equilibrium if meta-centre (centre of buoyancy) lies vertically above the centre of gravity of the body. The floating body will be in unstable equilibrium if meta-centre (centre of buoyancy) lies vertically below the centre of gravity of the body. The floating body will be in neutral equilibrium if meta-centre (centre of buoyancy) coincides with the centre of gravity of the body.

Viscosity & Bernoulli's Theorem

Viscosity

When we move our fingers through any liquid we experience a resistance. This is because liquid offers a frictional force. The resistance offered by fluids (liquids as well as gases) to relative motion between its different layers is called viscous force. This property is called viscosity. The viscous forces are similar to frictional forces which resist relative motion between two bodies in contact. To observe this, we can take two long cylinders, one filled with water while the other filled with glycerine.



We take two identical lead shots and drop one in water and the other in glycerine at the same time. We see that the lead shot dropped in water comes down more quickly and the lead shot in glycerine descends slowly. This implies that the viscous force is more in the case of glycerine than that in the case of water.

Flow of liquid through Pipes

There are two types of flows viz. streamlined flow and turbulent flow.

- If all the particles of the liquid pass across a point with the same velocity, the flow is said to be stream lined. In this flow, a particle follows the same path throughout its motion.
- If the particles pass across a point with different velocities, the flow is turbulent. In this flow, a particle does not follow the same path throughout its motion.

When a liquid flows slowly and steadily through a pipe, the velocity of the layer of the liquid in contact with the walls of the pipe is zero. As we move towards the axis of the tube, the velocity of the layers gradually increases and reaches a maximum value along the axis of the tube. In the case of streamlined flow of a river, the velocity is maximum for water on the upper layer (surface) of river . The velocity is minimum for water in the bottom most layer. When two parallel layers of a liquid are moving with different velocities, they experience tangential forces which tend to retard the faster layer and accelerate the slower layer. These forces are (F) called viscous forces. Newton found that the viscous force is:

- Directly proportional to the common area (A) of the liquid layers in contact.
- Directly proportional to their relative velocity (v1 – v2).
- Inversely proportional to the distance (x) between them.

This can be represented by the following formula:

$$F = \eta A \frac{(v_1 - v_2)}{x}$$

Where η is a constant known as coefficient of viscosity of the liquid and (v1-v2)/x is called the velocity gradient. The unit of coefficient of viscosity is N s m^{-2} or **Poise**. The values of coefficient of viscosity are different for different liquids as shown in the below table:

Fluid	η (poise)
Glycerine	13.4
Castor oil	9.86
Olive oil	0.84
Turpentine	0.015
Water	0.018
Mercury	0.0015
Honey	0.2
Blood	0.0027
Air	0.019×10^{-3}

Applications of Viscosity in Everyday Life

- The motion of falling raindrops is opposed by the viscous force offered by air. Hence the rain drops falls slowly.
- The viscosity of sea water makes the waves subside during a storm.
- The motion of objects in fluids depends upon the viscosity of the fluids.

The viscous force of water or air opposes the motion of ships, cars, aeroplane etc. hence their shapes are streamlined in order to minimise the viscous drag on them.

Working of Lubricants

Friction reduces the efficiency of a machine by converting mechanical energy into heat energy and causes much wear and tear of the moving parts. Friction is reduced by using lubricants. High molecular weight compounds such as hexanol are added as viscosity index improvers. The lubricant forms a thin layer between the two surfaces in contact. It also fills the depressions present in the surfaces of contact and reduces friction considerably. In light machinery, thin oils (e.g., clock oil) with low viscosity are used. In heavy and fast moving machinery solids or thick highly viscous oils (e.g., grease) are used. By adding **long chain polymers with lubricating oil, its coefficient of viscosity is kept constant even at high temperatures**.

Properties of Good Lubricants

A good lubricant should have the following properties:

- It should be able to spread and fill up the minute depressions in the surfaces.
- It should be chemically inert and should not undergo any decomposition at high temperature.
- It should be capable of conducting away the heat produced by friction.

Viscosity of Blood

If the arteries and veins of human body contract and become hard, their diameters decrease. Hence the flow of blood is affected due to the viscosity of blood and the blood pressure increases. This affects the functioning of heart. When the temperature of human body increases during fever, the coefficient of viscosity of blood decreases. This increases the blood circulation and the normal heart functioning is maintained.

Bernoulli's Theorem

When air is blown over the top of a sheet of paper, the paper rises in the air stream. This happens because the pressure falls above the paper where the air is moving faster. We take a table tennis ball and place in a funnel and hold it with the mouth sloping upwards. When we blow it, we can blow the ball out. Similarly, two balls are suspended side by side and air is blown up through the space between them. As the air flows through the narrow space between the balloons, the pressure falls. The atmospheric pressure from the sides brings the balls together.

The above observations lead us to conclude that **there is a relation between pressure and velocity of air**. Bernoulli's equation is a fundamental relation in fluid mechanics. It can be derived from the work-energy theorem. The work-energy theorem says that the work done by the resultant force acting on a system is equal to the change in kinetic energy of the system. Any moving liquid has three kinds of energies:

- Kinetic energy by virtue of its motion
- Potential energy by virtue of its position
- Pressure energy when it is subject to pressure

The work-energy theorem states that the work done by the resultant force acting on a system is equal to the **change in kinetic energy of the system.** Let **m** be mass of the liquid and v be its velocity in motion.

Then its kinetic energy will be

$$= \frac{1}{2} mv^2$$

The kinetic energy per unit mass will be:

$$= \frac{1}{2}v^2$$

Similarly, Let h be the height of the liquid above the earth's surface.

Then its potential energy = **mgh**

Potential energy per unit mass = gh

Similarly, Let P be the hydrostatic pressure exerted by a liquid, r be its density and V be its volume.

Then its pressure energy = PV

$$= P\left(\frac{m}{\rho}\right)$$

$$\text{Pressure energy per unit mass} = \frac{P}{\rho}$$

These three types of energies possessed by a liquid under flow are mutually convertible one into another. Bernoulli's theorem says that the *sum of the energies possessed by a flowing, non-viscous, incompressible liquid at any point throughout its flow is constant* ***when the flow is streamlined***.

This implies that:

Pressure Energy + Kinetic Energy + Potential Energy = Constant.

For a unit mass of liquid:

$$\frac{p}{\rho} + \frac{1}{2}v^2 + gh = \text{constant}$$

If the pipe is horizontal, then h also is constant so:

$$\therefore \frac{P}{\rho} + \frac{v^2}{2} = \text{constant.}$$

The above equation makes it clear that when the velocity of the fluid increases, the pressure of the fluid decreases and vice versa. This principle can be illustrated by numerous demonstrations.

Everyday applications of Bernoulli's Theorem

Venturimeter, atomiser and filter pump

Bernoulli's principle is used in venturimeter to find the rate of flow of a liquid.

It is used in a carburettor to mix air and petrol vapour in an internal combustion engine. Bernoulli's principle is used in an atomiser and filter pump.

Wings of Aeroplane

Wings of an aeroplane are made tapering. The upper surface is made convex and the lower surface is made concave. Due to this shape of the wing, the **air currents at the top have a large velocity than at the bottom**. Consequently the pressure above the surface of the wing is less as compared to the lower surface of the wing. This difference of pressure is helpful in giving a vertical lift to the plane.

How storms blow off the roofs?

Due to strong wind, storm or cyclone, the roofs are blown off. When a strong wind blows over the roof, there is lowering of pressure on the roof. As the pressure on the bottom side of the roof is higher, roofs are easily blown off without damaging the walls of the building.

How a moving train attracts a person standing nearby on a platform?

A suction effect is experienced by a person standing close to the platform at railway station when a fast train passes the person. This is because the fast moving air between the person and train produces a decrease in pressure and the excess air pressure on the other side pushes the person towards the train.

Surface Tension & Capillary Action

Surface tension of a liquid is defined as the tangential force per unit length acting at right angles on an imaginary line drawn on the surface of the liquid. Its unit is Newton per Metre.

Understanding Surface Tension

Insects like ants, water-spider are able to walk on the surface of water. Mosquitoes sit and move freely on the surface of stagnant water. When we sprinkle water at the roots of trees and shrubs, the

sprinkled water gradually rises to their branches upwards. All these observations can be explained on the basis of a property of liquids called surface tension. When we take a clean glass plate and place a very small amount of mercury on the plane surface, we observe that the mercury assumes the form of a spherical drop. However, when we place large amount of mercury on the plane surface, we observe that now mercury assumes ellipsoidal shape. Similarly, when we place a greased sewing needle carefully on a water surface, the sewing needle makes a small depression in the surface and keeps floating even though the density of the needle is very much greater than that of water. A tumbler is filled to the brim with water. Some nails are put inside the water so that water is displaced upwards. A few more nails are added carefully. It is found that water surface rises well above the edge of the tumbler but water does not overflow. This is because the water surface stretches as water is displaced upwards. If a brush is dipped in water its bristles spread out. If it is taken out the bristles come closer and cling together.

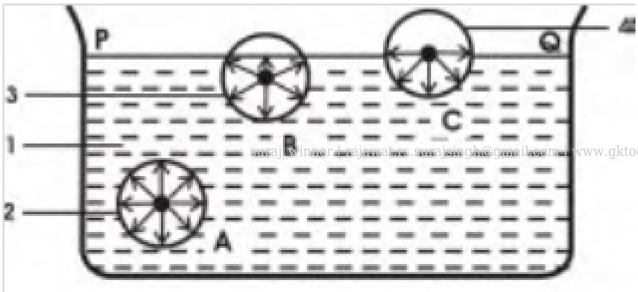
The conclusion from the above observations is that there exists a tension on the surface of a liquid which tends to contract the surface to a minimum area. This property of the liquids is known as surface tension.

Adhesive and Cohesive Forces

Surface Tension is essentially a molecular phenomenon. There are two types of molecular forces of attraction viz. adhesive force and cohesive force. Forces between molecules of different substances are called **adhesive forces.** The adhesive force is different for different pairs of substances. Gum or glue is an adhesive. The force of attraction between gum and paper is an adhesive force. Forces between molecules of the same substances are called **cohesive forces.** *The cohesive forces are short range forces and therefore they are effective only up to a very small distance*. The adhesion of water to glass is stronger than the cohesion of water. On the other hand, the cohesion of mercury is greater than its adhesion to glass. The maximum distance at which the molecules can attract each other is called molecular range. The molecular range is of the order of 10^{-8} cm.

How Surface Tension works?

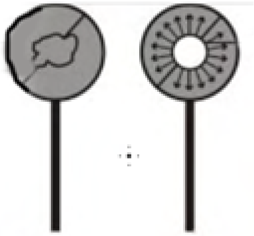
A sphere drawn with the molecule as centre and radius equal to the molecular range is called the sphere of molecular influence. The molecular forces are effective within this sphere of molecular influence. Therefore all the molecules lying within this sphere of molecular influence exert a force of attraction on the molecule at the centre. These molecular forces are responsible for surface tension. On the basis of this, Laplace gave an explanation of the surface tension.



In the above diagram, PQ represents the free surface of a liquid in a container. Let A, B and C represents molecules with their spheres of influence drawn around them. The sphere of influence around the molecule A is well within the free surface PQ. Hence it is equally attracted in all directions by the molecules in the sphere of influence. Therefore the resultant force acting on the molecule A is zero.

In the case of molecule B the sphere of influence is partly outside the liquid surface PQ. The number of molecules in the upper half is less than that in the lower half. Thus the resultant force on B acts in the downward direction.

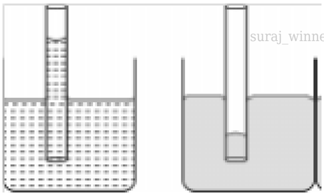
The molecule C is exactly on the free surface PQ. The sphere of influence around the molecule C is exactly half outside and half inside the liquid. **Hence this molecule C is attracted in the downward direction with maximum force.** Thus we conclude that the **molecules in the surface PQ are pulled downwards due to the resultant cohesive force**. This makes the free of the liquid at rest behave like a stretched elastic membrane. This force gives rise to the surface tension of the liquid.



To understand this, we can make a circular wire ring in which a loop of thread is attached as shown in the adjacent diagram. The wire and thread are dipped in a soap solution and taken out gently. We see that a film of the soap solution is formed across the ring. The zig-zag loop of the thread lies on the film. If the film inside the loop of thread is punctured with a needle, then the loop takes the shape of a circle due to surface tension. The surface of the liquid film pulls the thread radially outward as shown by the arrows.

Capillary Action

A glass tube with a very fine uniform bore is called a capillary tube. When a capillary tube is dipped vertically into a liquid contained in beaker, the liquid immediately rises or falls in the tube.



The rise or fall of a liquid in a very narrow capillary tube is given by

$$h = \frac{2T\cos\theta}{r\rho g}$$

Where:

T is the surface tension of the given liquid.

- r is the radius of the capillary tube
- ρ is the density of the liquid
- g is acceleration due to gravity
- θ is the angle of contact for the given pair of solid and liquid

The angle of contact is defined as the angle between the tangent to the liquid surface at the point of contact and the solid surface inside the liquid. The angle can be acute or obtuse. If the angle of contact is acute, the level of liquid inside the capillary tube is higher than that in the beaker. This capillary rise is observed in the case of water. If the angle of contact is obtuse, the level of liquid inside the tube is lower than that in the beaker.

This capillary fall is observed in mercury (θ =140°).

For water in silver tube, θ =90° and h = 0. The level of liquid remains the same.

For pure water and clear glass θ = 0°

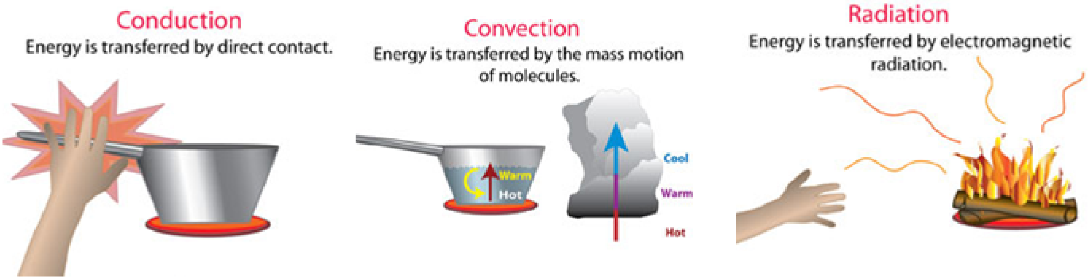
Applications of Capillary Action in daily life

- The rise of sap in trees and plants: The Xylem or Bark has such structure that the water rises to reach from roots to leaves via capillary action, although some other theories also persist to explain this. *When the bark of a tree (Xylem) is removed in a circular fashion all around near its base, it gradually dries up and dies because water from soil cannot rise to aerial parts.*
- The rise of kerosene or oil in the wick of an oil lamp or stove.
- The absorption of ink in a blotting paper.
- Sandy soil is gets drier earlier than clay: *The interspaces between the particles of the clay form finer capillaries and water rises to the surface quickly.*
- *The purpose of applying soap to clothes is to spread it over large area. When soap is dissolved in water the surface tension of water is lowered. Surface tension always opposes the spreading of a liquid. By reducing surface tension we facilitate the liquid to spread over larger surfaces. This is why soap is used for washing.*

- *For the same reason the paste spreads more freely in the mouth and facilitates cleaning of the mouth.*
- *When we pour oil on the surface of water it lowers the surface tension of water. Hence the mosquito breed sinks down and perishes.*
- *In voyage at the high seas, when there are violent waves the sailors pour tins of oil around their boats or ships. Due to oil the surface tension of sea water is reduced thereby the height of water waves is also reduced.*
- *A pen nib is split at the tip to provide the narrow capillary and the ink is drawn upto the tip continuously.*
- *When molten lead is allowed to fall through the end of a narrow tube, lead drops assume spherical shape due to surface tension. In factories lead shots are manufactured in this way.*
- *Rain drops assume spherical shape due to surface tension of water.*

Heat Related Concepts

Heat is the most common form of energy. Heat can be transferred from one place to another by means of **conduction, convection and radiation**. It can be converted into other forms of energy.



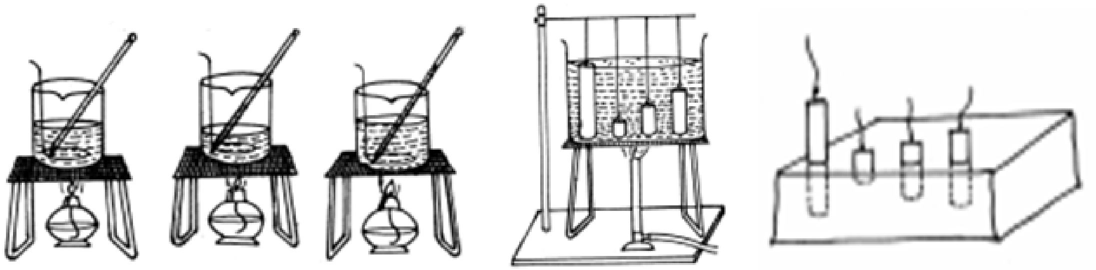
Sun is the main source of heat energy for Earth. Fuels such as wood, petrol, coal and gas are other sources of heat energy. For the survival of all living things, heat energy is essential.

The temperature of a body is a measure of its hotness or coldness. It is a measure of the kinetic energy of the particles of the body.

Change in temperature, change of state and thermal expansion in a body, are some of the main observable physical effects of heat energy. Heat energy plays a major role in determining the climatic and weather conditions.

Specific Heat Capacity

We take three identical glass beakers and fill them with equal mass of water, kerosene and coconut oil. We first note down their initial temperatures and then heat them one by one by same lamp for 5 minutes each; we find that the rise in temperature of each of them is different.



We take four cylindrical blocks of aluminium, lead, copper and iron of equal mass having the same area of cross section. Now, we suspend the cylindrical blocks fully inside boiling water. After few minutes, take out the blocks simultaneously and place them on a thick paraffin cake side by side. What we observe is that depths of sink are different for different materials.

We take a stone and water of same mass. Place them in the hot sun for about half an hour. Now touch the stone with one hand and water with the other hand. What we observe is that the stone is hotter than water.

When a substance is heated, it absorbs heat energy and its temperature rises. The **amount of heat energy absorbed** by the substance (Q) is directly proportional to mass of the substance (m) and the change in temperature (Δt)

$Q = m s \Delta t$

Here s is a constant called Specific Heat Capacity. The value of the specific heat capacity depends on the nature of the substance. In the above equation, If m = 1 kg and Δt = 1 K then Q = s. This implies that:

The specific heat capacity of a substance is the amount of heat energy required to raise the temperature of 1 kg mass of the substance by 1 K. Its unit is J kg^{-1} K^{-1}. **It is a measure of thermal inertia of a substance.**

The heat capacity of a substance is defined as the amount of heat required to raise the temperature of the substance through 1 K.

Thus:

Heat capacity = mass x specific heat capacity.

Its unit is J/K.

The following table shows the specific Heat Capacity of some common materials.

Sr. No.	Substance	Specific Heat Capacity (J kg^{-1} K^{-1})
1.	Lead	128
2.	Mercury	138
3.	Copper	386
4.	Aluminium	899
5.	Wood	1755
6.	Kerosene	2090
7.	Ice	2130
8.	Water	4180
9.	Paraffin Wax	2900

Among the liquids, the specific heat capacity is maximum for water, hence water is used as a coolant in radiators of automobile engines and mercury is used as a thermometric liquid.

Thermal Expansion

Thermal expansion takes place in all states of matter. The gases expand more than liquids and liquids expand more than solids for the same amount of heat. Thermal expansion plays an important role in many engineering applications.

When an object is heated its **molecules vibrate more violently because they have more kinetic energy**. They also need more space around them. This causes the material to expand.

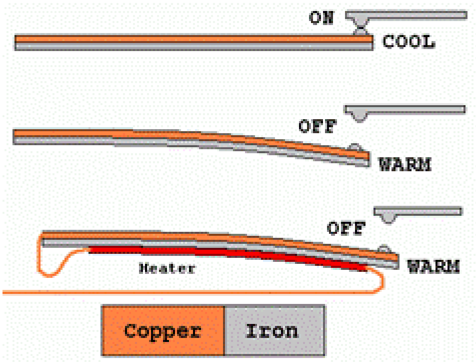
Increase in length due to heating is called **linear expansion**. Increase in area as **superficial expansion** and that of volume as **volume expansion or cubical expansion**. The thermal expansion is **different for different substances.**

Every day applications of thermal expansion of solids

- If we find difficult to remove the stopper from a glass bottle, we can heat the neck of the bottle. Now the neck of the bottle expands and the stopper comes out easily.
- The principle of thermal expansion is used in fixing iron rim with the wooden wheel firmly.
- Rivets are used to hold steel plates together very tightly. A very hot rivet is pushed through the two plates and its end is hammered over. When the rivets cools down it pulls the two plates together very tightly.
- To avoid bursting of soft drink bottles containing gas, due to thermal expansion, their walls are made very thick.

Bimetallic Strip

A bimetallic **strip** consists of two different metals such as brass and iron joined together.



At normal temperature the bimetallic strip is straight. As it is heated the brass expands more than the iron. So the brass forms the outside of a curve with the iron on the inside. Such a bimetallic strip can be used in a thermostat to break an electrical circuit. A thermostat is used to maintain a steady temperature in a system. As the temperature increases the strip bends and breaks electrical contact in the heater circuit. When the temperature decreases, the bimetallic strip returns to its original position and shape. Thus contact is restored.

Some of the problems created by thermal expansion is the changing of shape and dimensions of objects such as doors, Wall collapsing due to bulging, cracking of glass tumbler due to heating and bursting of metal pipes carrying hot water or steam.

Thermal Expansion and Railway Lines

Rails are made of steel which expands on heating and contracts on cooling. A gap is left between two ends of the rails at the joint. If no gaps are left, due to expansion in summer the rails get distorted causing derailment. For the same reason, gaps are left in the concrete slabs of bridges and Highways.

Clock Pendulums

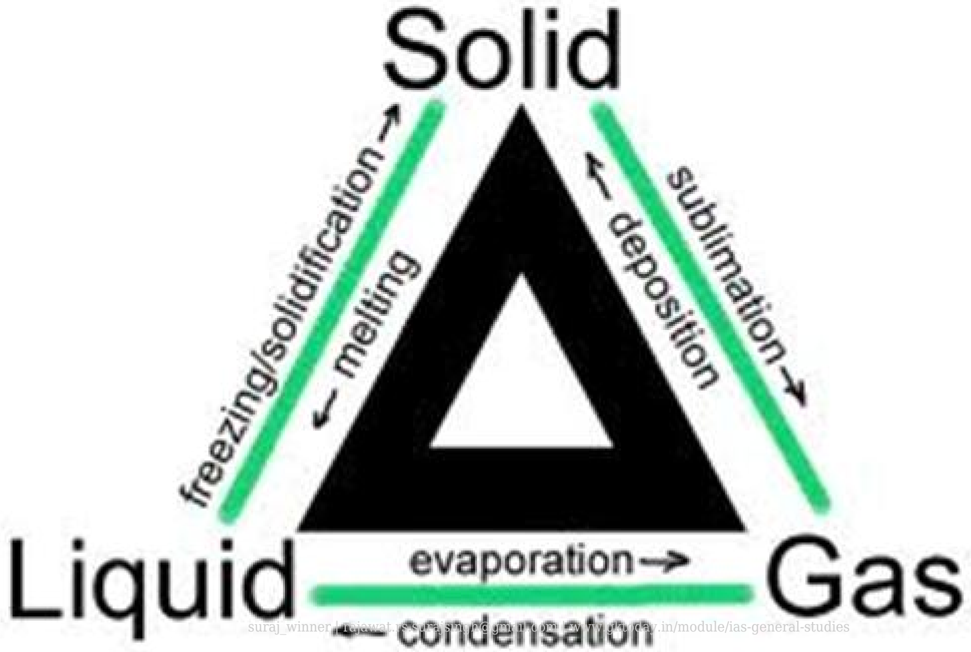
The period of oscillation of a pendulum in a clock depends on its length. When the temperature changes, the length also changes. Hence the clock loses time in summer and gains it in winter. This can be compensated by using a bimetallic pendulum against the effect of thermal expansion.

Change in state of mater

Matter exists in three states viz., solid, liquid and gas. The change from one state to another can be brought about by the application or withdrawal of heat.

Change in State of Matter

The water can be in the form of solid ice or liquid water or gaseous steam. The process in which a solid changes into liquid on heating is called melting. For example, ice changes into water. The change of a liquid into a solid on cooling is known as freezing. The process in which a liquid changes into vapour on heating is called vaporisation. e.g., water changes into water vapour or steam. Some materials may change directly from a solid to a gas. This is called sublimation. Solid carbon dioxide changes to carbon dioxide gas as it warms up. Another substance which sublimes is Iodine. When vapour condenses to form a liquid the change of state is called condensation. Steam changes to water as it condenses.



Latent Heat

The latent heat of a substance is defined as the amount of heat absorbed by a unit mass of the substance to change its state without change of temperature. The heat absorbed during the change of state of a substance is used to overcome the force of attraction between the molecules of a substance. The kinetic energy of the molecules does not increase and hence there is no raise in temperature during the change of state of the substance. Two of the more common forms of latent heat (or enthalpies or energies) encountered are latent heat of fusion (melting or freezing) and latent heat of vaporization (boiling or condensing). These names describe the direction of energy flow when changing from one phase to the next: from solid to liquid, and to gas.

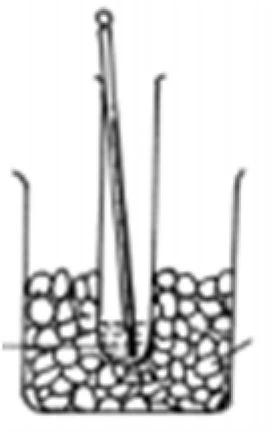
Cooling due to evaporation

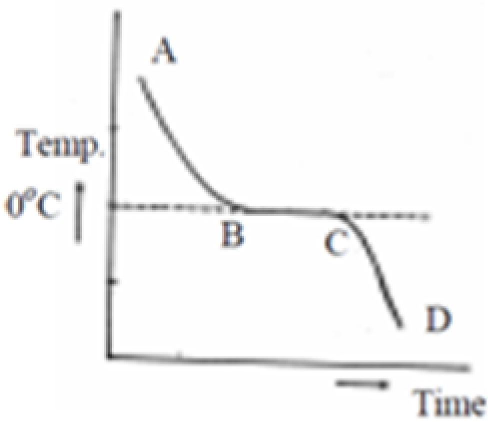
- When we put a little ether or petrol at the back of our hand and wave it around, we observe that the spirit evaporates rapidly and our hand feels very cold. The sprit takes the heat of vaporization from our hand. The hand loses heat and gets cooled. Similarly, water vaporizing from the leaves of the trees cools the surrounding air.
- A liquid evaporates when it changes into gas. Evaporation occurs at the surface of a liquid. During evaporation, only high energy molecules overcome the attraction of their neighbouring molecules and leave the liquid. In this way, the liquid loses its most energetic molecules, while the less energetic molecules are left behind.

- The average kinetic energy of the remaining molecules is therefore, reduced. This results in a fall of temperature of the liquid which gets cooled. The rate of evaporation of a liquid depends on its surface area, temperature and the amount of vapour already present in the surrounding air.
- On a rainy day, wet clothes take longer time to dry, because large amount of vapour already present in the air, slows down the evaporation. Similarly, during high fever, a cloth soaked in cold water is kept on the forehead the water evaporates rapidly and takes heat from the head and the body.
- Dogs keep their tongue usually out in summer. Water evaporates from the tongue and keeps it cool. Water in an earthen pot remains cool in summer. Water comes out of the pores of the vessel and evaporates. Therefore water remains cool in an earthen vessel by evaporation. After sometimes, when the pores get blocked by the dissolved material in water, the earthen pot becomes useless.
- Evaporation of sweat or perspiration from our skin causes a cooling effect.

Fusion of Ice Experiment

We take a test tube with clean water and a thermometer is placed in the test tube. The test tube is placed in a freezing mixture bath. The water level in the test tube is well below the level of the freezing mixture. While stirring water slightly and carefully, the thermometer readings for every 30 seconds are recorded till the temperature falls a few degrees below 0 °C. A graph is drawn by taking time along the X-axis and temperature long the Y axis. The portion AB represents the liquid state. At B the change of state takes place from liquid to ice at 0 °C. At C entire liquid is changed to ice. Here during the change of state the temperature remains constant. Below C it is in the solid state (ice). The flat portion of the graph represents the time during which the water solidifies. Here both solid and liquid states exist together. This is the melting or freezing point. During this time heat continues to be lost from the substance as it changes from liquid to solid but there is no fall in temperature.





When water changes into solid; its volume increases. When a substance melts, heat is gained. When it freezes, heat is lost

Working of Refrigerators

When a liquid evaporates it takes in heat energy and cools its surroundings. When the gas condenses back to a liquid, the latent heat is released. This is used to take heat from inside a fridge, and release it outside. A liquid which evaporates easily is called volatile liquid. Freon is a volatile liquid used in most fridges. The liquid evaporates in the coils around the ice box or cold plate inside the fridge. This causes cooling. The Freon gas formed is pumped away and pressurised in the condenser on the back of the fridge. Here the Freon gas condenses back into liquid. As it condenses it releases the heat energy it has taken in. So heat energy has been taken from food and other things inside the fridge and released outside it.

If we leave the fridge door open, the pump has to work hard and more heat will be released into the kitchen which will eventually become hotter.

Freezing Mixtures

A mixture of compounds that produces a low temperature is called freezing mixture. A freezing mixture consists of powdered ice, common salt and ammonium nitrate. Temperatures lower than 0° C can be produced by mixing certain salts such as Sodium Chloride, Ammonium Chloride, Magnesium Sulphate etc. with ice. When salt is mixed with ice, some ice melts taking heat from the salt. The temperature of the mixture decreases. Now salt gets dissolved in the water formed. The necessary heat for this is extracted from the mixture itself and consequently the temperature of mixture falls below zero. With the freezing mixture of salt and ice in the ratio 1 : 3, temperatures as low as -13°C can be obtained

Latent heat of fusion

The latent heat of fusion of a substance is the quantity of heat required to convert unit mass of the solid at its melting point to the liquid state at the same temperature. The S.I unit of Latent heat is J kg-1.

Ice at 0°C is more effective in cooling a substance than water at 0°C. This is due to the fact that for melting at 0°C each kilogram of ice takes its latent heat of 3.34×10^5 J from the substance and hence cools the substance more effectively. On the other hand water at 0°C cannot take latent heat from the substance. This concept is valid for most of the liquids and their solids.

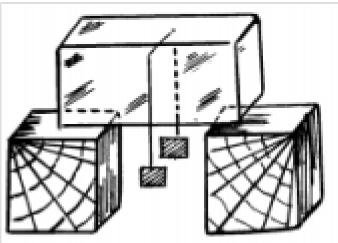
Latent heat of vaporization

Latent heat of vaporization of a liquid is the amount of heat required to convert unit mass of a liquid at its normal boiling point into vapour at the same temperature.

The burns caused by steam are much more severe than those caused by boiling water though both of them are at the same temperature of 100°C. This is due to the fact that steam contains more heat in the form of latent heat (2.26×10^6 J/kg) than boiling water. Here we note that the latent heats of fusion is maximum for ice and latent heat is maximum for steam. Hence steam and ice can be considered to be the best source and sink of heat respectively in a heat engine.

Impact of pressure Melting Points

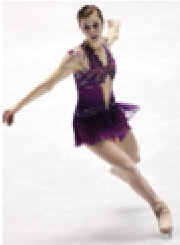
When we take two pieces of ice and apply pressure and release them; we observe that the two pieces freeze together. This implies that melting point of a substance can be lowered by applying pressure. We take a slab of ice is and a put a metal wire over it. Two equal weights (5 kg) are fixed to its ends. The wire passes through ice slab due to the load applied to it. Just below the wire, ice melts at a lower temperature due to increase in pressure. When the wire has passed, the water above the wire freezes again. Thus the wire passes through the slab and the slab does not split. This phenomenon of refreezing is called **regelation**.



Here, we have to note down that if a substance contracts on melting, as in the case of Ice, its melting point is lowered by an increase of pressure. If a substance expands on melting, as in the case of a paraffin wax, its melting point is raised by an increase of pressure.

Skates, Sledges and Snowballs

Since the edges of the skates are fine, the pressure applied on ice is sufficient to melt it. Water thus formed due to melting acts as a lubricant and enables the skates to move freely over ice. Due to regelation the water formed is again converted into ice. Thus free motion of skates with good grip is achieved. The same explanation holds good for sledges and snow balls.



Impact of impurities on Melting Points

We put some salt or other impurity into a beaker of water and heat it until it boils. Measure the boiling point and observe that it is above 100°C. It shows that the boiling point of liquid is raised by adding impurities. Again, we take some pieces of ice in a beaker and sprinkle some salt on the ice. Stir until the ice melts and measure its temperature. We observe that it is less than 0°C. The presence of impurity lowers the melting point.

Impact of Pressure on Boiling Points

The boiling point of a liquid is lowered under reduced pressure and increased under increased pressure. The atmospheric pressure is less on the top of a mountain and therefore water boils at a lower temperature. This temperature is too low to cook food properly.

It means that a longer time is required for cooking in hill stations. The time required for cooking vegetables and other foods can be greatly reduced if the boiling point of water is raised. This can be done by the use of a pressure cooker. A pressure cooker consists of a strong vessel of an aluminium alloy or stainless steel sealed so tightly that steam can be confined inside it with a pressure of about 2 atmospheres. The boiling point of water at this pressure will be about 120°C. When foods are cooked under these conditions there is a considerable saving of fuel and time. Since the cooking time is reduced the food value (vitamins and minerals) is retained better. Any possible oxidation of food material is also prevented because cooking takes place in an atmosphere of steam instead of air. The pressure cooker solves cooking problems at high altitudes also.

Humidity and Relative Humidity

Humidity is the amount of water vapour present in atmosphere. The amount of water vapour in atmosphere changes with time and weather. The air containing water vapour is called humid air. The amount of vapour present per unit volume of air is called the humidity of air. Humidity is generally measured in kg/m^3.

The knowledge of humidity helps us to predict weather. When the amount of water vapour in the air is small, the air appears to be dry and the humidity is low. When the amount of water vapour in the air is large, the air appears to be wet and the humidity is high. The degree of wetness of air is expressed in terms of its relative humidity.

Relative Humidity

The ratio of the mass of water vapour actually present in certain volume of air (m) to the mass of water vapour (M) required to saturate the same volume of air at the same temperature is called relative humidity (R.H)

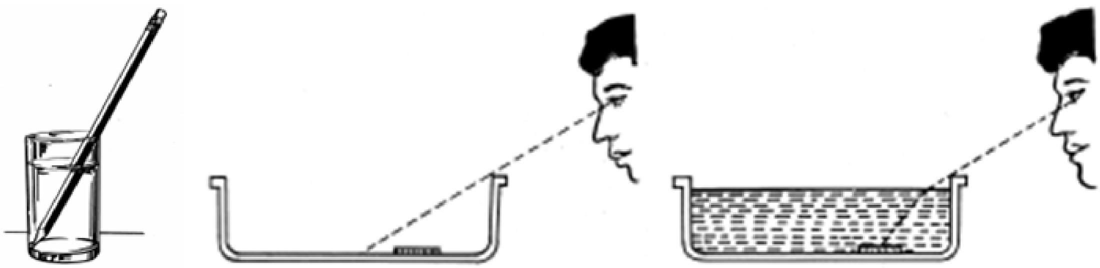
$$\text{Relative humidity} = \frac{m}{M} \times 100\%$$

If the air contains the maximum amount of water vapour its R.H is 100%. In such a case, water on earth cannot vaporate at all. If the relative humidity is less than 100% but still high, the rate of evaporation will be slow and the clothes do not dry up easily in such weather. The relative humidity varies from season to season. During rainy season, as the amount of water vapours in air increases, the relative humidity becomes more (R.H = 100%) More R.H is a permanent feature of coastal areas. Due to more R.H perspiration from our body does not evaporate and we feel sultry.

Light

Refraction of light

When we place a pencil in a beaker containing water, we observe that the pencil appears to be bent at the point where it just enters water. Again, when we put a coin in the bottom of an empty cup and position our head so that the coin is just off sight, we can bring it into our view without moving head or the cup, by just pouring water in the cup.



The above two observations lead us to conclude that the ray of light bends at the boundaries of air and water medium. The phenomenon of bending of light as it passes from one medium to another is known as the refraction of light.

Refraction is the change in direction of a wave **due to a change in its medium**. It is essentially a surface phenomenon.

The phenomenon is mainly in governance to the law of conservation of energy and momentum. Due to change of medium, the **phase velocity of the wave is changed but its frequency remains constant**. Refraction of light is the most commonly observed phenomenon, but any type of wave can refract when it interacts with a medium, for example when sound waves pass from one medium into another or when water waves move into water of a different depth. Refraction is described by Snell's law, which states that for a given pair of media and a wave with a single frequency, the ratio of the sines of the angle of incidence θ1 and angle of refraction θ2 is equivalent to the ratio of phase velocities (v1 / v2) in the two media, or equivalently, to the opposite ratio of the indices of refraction (n2 / n1):

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}.$$

An easy way to remember Snell's law is that

$$\begin{pmatrix}\text{refractiveindex}\\ \text{of the medium}\end{pmatrix} \times \begin{pmatrix}\text{sine of the angle}\\ \text{in the medium}\end{pmatrix} = \text{constant}$$

The refractive index of the medium with respect to air (or vacuum) is called the absolute refractive index of the material. The refractive index for light going from first medium to second is equal to the reciprocal of the refractive index for light going from second to first medium.

$$_1\mu_2 = \frac{1}{_2\mu_1}$$

The refractive index of glass with respect to water is equal to the ratio of refractive index of glass and refractive index of water with respect to air.

$$_{\text{water}}\mu_{\text{glass}} = \frac{_{\text{air}}\mu_{\text{glass}}}{_{\text{air}}\mu_{\text{water}}}$$

Similarly, the refractive index of water with respect to glass is:

$$_{\text{glass}}\mu_{\text{water}} = \frac{_{\text{air}}\mu_{\text{water}}}{_{\text{air}}\mu_{\text{glass}}}$$

The refractive index of the medium gives the light bending ability of that medium. Glass has higher refractive index than air. So more bending of light rays take place in glass. Glass is said to be optically denser medium and air is an optically rarer medium. The following table shows the refractive index of some common materials with respect to air or vacuum:

Substance	Refractive Index
Air	1.0029
Ice	1.3
Water	1.33
Ethanol	1.35
Sulphuric acid	1.43
Kerosene	1.44
Quartz	1.46
Glycerine	1.48
Benzene	1.5
Crown glass	1.52
Flint glass	1.65
Canadian balsm	1.53
Sodium chloride	1.54
Ruby	1.71
Diamond	2.42

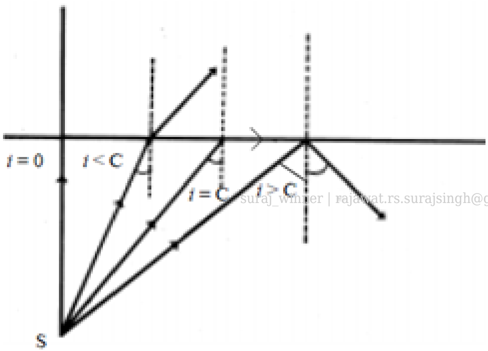
Measuring Refractive Index

The simplest way to measure the refractive index of a liquid is to measure its apparent depth and its real depth. We can place a scale inside a glass beaker containing liquid. Take another scale and hold it outside of the beaker by stand. View the scale from the top and adjust the outside scale until the bottom ends of both scales appear to be at the same level. Measure the heights h1 and h2 of the level of water surface on both scales. h1 and h2 are the real and apparent depth respectively. The refractive index of the liquid with respect to air.

$$_{air}\mu_{water} = \frac{\text{realdepth}}{\text{apparent depth}} = \frac{h_1}{h_2}$$

Total Internal Reflection

When a ray of light passes from an optically denser medium into a rarer medium; the refracted ray is bent away from the normal. A ray of light incident normal to the surface passes without any deviation. As the angle of incidence increases, the angle of refraction also increases and at a certain angle of incidence the refracted ray just grazes surface of water. This angle of incidence within a denser medium for which angle of refraction becomes 90° is called the critical angle. If the angle of incidence is increased beyond the critical angle, the ray bends inside the denser medium. This is called total internal reflection.



Relation between critical angle and refractive index

We know that

$$_{w}\mu_{a} = \frac{1}{_{a}\mu_{w}}$$

$$\frac{\sin C}{\sin 90^o} = \frac{1}{_{a}\mu_{w}}$$

$$\sin C = \frac{1}{_{a}\mu_{w}} \quad (\because \sin 90^o = 1)$$

$$_{a}\mu_{w} = \frac{1}{\sin C}$$

The above implies that refractive index of any medium with respect to air is the reciprocal of the sine of the critical angle.

Example:

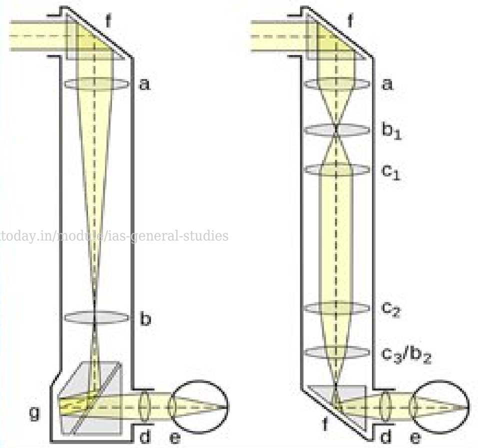
The critical angle of diamond is 24.4°. So C= 24.4° and μ=?

${}_{air}\mu_{diamond} = 1/\sin C$

${}_{air}\mu_{diamond} = 1/\sin 24.4° = 2.42$

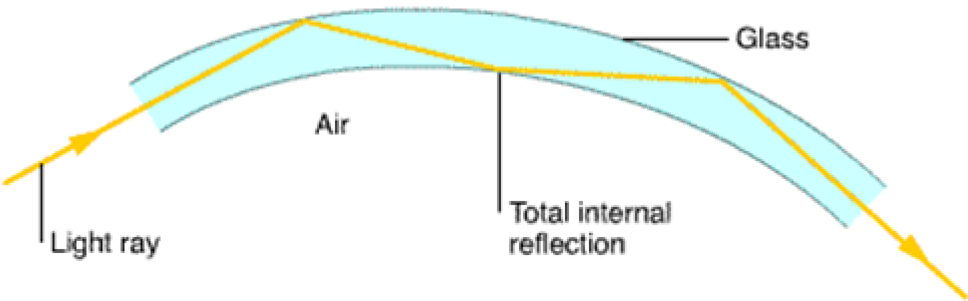
Working of a Periscope

There are two essential conditions for Total Internal Reflection. One is that the light must proceed from denser medium to a rarer medium. Second is that the angle of incidence in the denser medium must be greater than the critical angle. For example, a prism having an angle of 90° between its two refracting surfaces and the other two angles each equal to 45° is called a totally reflecting prism, because 45° is greater than the critical angle for glass (42°). Totally reflecting prisms are used in the construction of periscope. Periscope is used in the submarines to see objects above the surface of water.



Optical Fibres

An optical fibre is a device based on total internal reflection by which a light signal can be transmitted from one place to other with negligible loss of energy. An optical fibre is a long glass rod of only a few millimeters thick and it is quite flexible. The fibre glass consists of a cylindrical inner core that carries light and an outer concentric shell called cladding. The refractive index of inner core (m = 1.7) is relatively greater than that of cladding (m = 1.5). The rays of light travelling along the fibre cannot escape because they are totally reflected from the core-cladding interface. So the fibre of solid glass can be used as a light pipe.

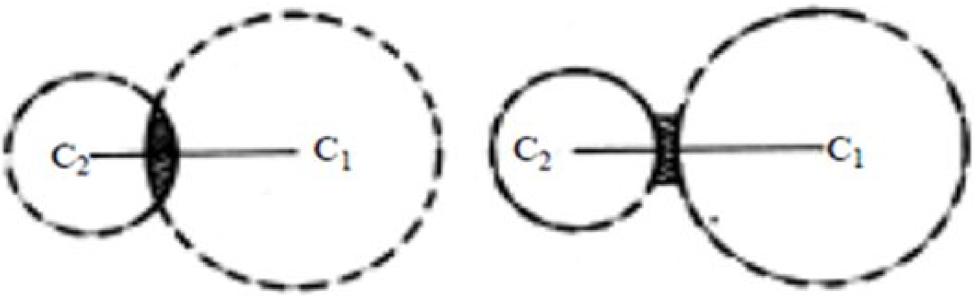


Optical fibres can carry light round bents. This allows doctor to see inside our body. (endoscopy). Optical fibres can also carry information in the form of a digital code of light pulses with minimum loss. They carry telephone messages and computer data. Fibre optics technique is used to destroy tumours in solid organ like liver.

Lenses

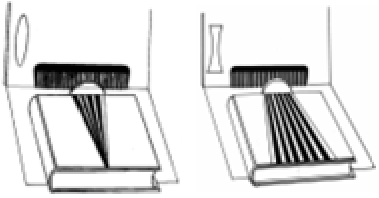
A lens is a thin piece of a transparent material bounded by two spherical surfaces or by one spherical and other plane surface. The width or diameter of a lens is called the **aperture of the lens**. The geometric centre of a lens is known as its **optic centre** (O). The centre of curvature (C) is the centre of the sphere of which its surface forms a part. The radius of curvature (R) of a surface is the radius of the sphere of which the surface forms a part. The line passing through the centres of curvature of the two surfaces and optic centre of a lens is called the **principal axis.**

Radius and Centres of curvature of lenses

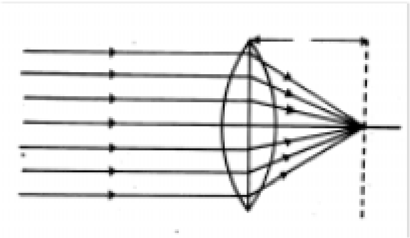


(i) Convex lens   (ii) Concave lens

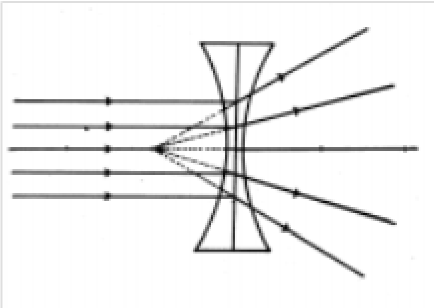
When we place a comb in between the torch light and the convex lens and adjust the lens, we observe that the light rays converge at a point. In the case of concave lens, the rays appear to diverge from a point.



A beam of rays parallel to the principal axis after refraction through the lens actually converges at a point on the principal axis. This point is called **principal focus of a convex lens**.



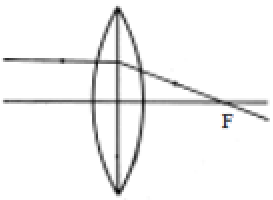
A beam of rays parallel to the principal axis after refraction through a concave lens appear to diverge from a point on the principal axis. This point is called **principal focus of a concave lens**.



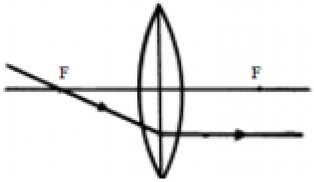
The focal length of a lens is the distance between optic centre and principal focus of the lens.

Behavior of Rays in Convex Lens

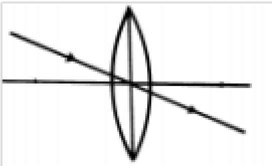
An incident ray which is parallel to the principal axis, after refraction, passes through the principal focus on the other side of the lens.



An incident ray which passes through the principal focus, after refraction, emerges parallel to the principal axis

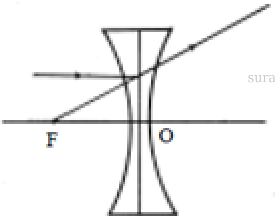


An incident ray which passes through the optic centre goes straight without deflection.

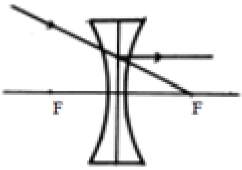


Behavior of Rays in Concave Lenses

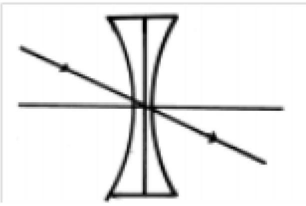
An incident ray which is parallel to the principal axis, after refraction, appears to diverge from the principal focus on the same side of the lens as the incident light.



An incident ray which proceeds towards the principal focus, after refraction, emerges parallel to the principal axis.



An incident ray which passes through the optic centre goes straight without deflection.



Real Images and Virtual Images

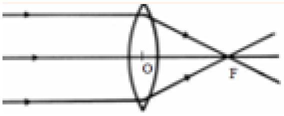
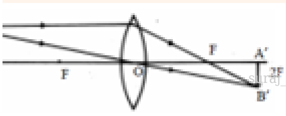
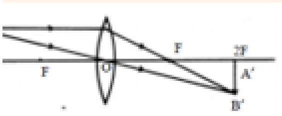
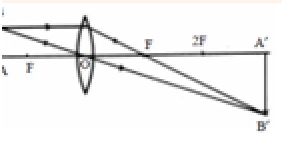
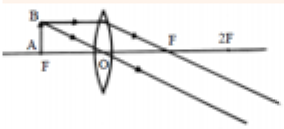
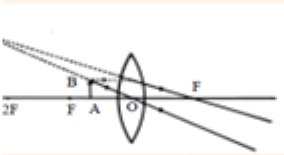
The image formed by the actual intersection of refracted rays through a lens is called the real image.

The real images can be caught on the screen and they are inverted.

The images that appear without actual intersection of the refracted rays are called virtual images.

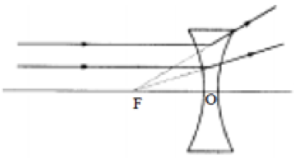
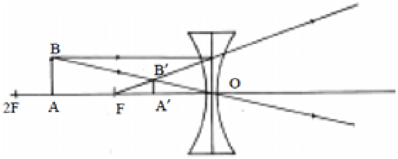
Convex Lens

As the object is moved closer to the lens, the image distance increases and the image size increases. At 2F, the object distance equals the image distance. As the object distance approaches one focal length, the image distance and size approach infinity. When the object distance is one focal length, there is no image. When the object distance is less than one focal length, the images are virtual erect and located on the same side of the object. Finally, if the object distance approaches zero, the image distance also becomes zero. The image size ultimately becomes equal to the object size.

Ray Diagram	Position of Object	Position of Image	Nature and Size of Image	Practical Application
	at infinity	at F	real, point-sized	Telescope objective lens
	beyond 2F	between F and 2F	real, diminished inverted	Camera
	at 2F	at 2F	real, same sized, inverted	Terrestrial telescope invert the image so that it is upright.
	Between 2F and F	beyond 2F	real, enlarged inverted	Projector
	at F	at infinity	real, infinitely large, inverted	Spotlights
	between F and O	on the side of the object	virtual, enlarged, erect	Magnifying Glass

Concave Lens

When an object is moved closer to the concave lens, the image distance decreases and the image size increases with respect to that of previous image. As the object approaches the lens, its virtual image on the same side of the lens also approaches the lens and image size increases. If the object is placed at the optic centre, the virtual erect image of same size will be formed at the optic centre itself.

Ray Diagram	Position of Object	Position of Image	Nature and Size of Image
	at infinity	at F	Virtual, Point-Sized
	between infinity and O	between F and O	Virtual, Erect And Diminished

Lens Formula & Power of the Lens

The relationship between the object distance (u), the image distance (v) and the focal length (f) of the lens is called lens formula.

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

From the above formula, Focal length of a lens is obtained as follows:

$$f = \frac{uv}{u+v}$$

The power of a lens is the measure of its ability to produce convergence or divergence of a parallel beam of light. The power of a lens depends on its focal length. The power of a lens is defined as the reciprocal of its focal length in metres. The unit of power of a lens is dioptre (D).

If two lenses of focal length f_1 and f_2 are in contact, then:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$$

And

$P = P_1 + P_2$

For example, if a lens has a focal length of 40 cm, its power would be: $1/40 \times 10^{-2} = 100/40 = 2.5D$

Twinkling of Stars

Heat energy radiated by the earth changes the density of the atmospheric layers continuously. This changing density of the air layers near the ground affects its refractive index. Due to the refraction of light rays from the star, path of these rays goes on varying. Hence the eye some times receives more light with the result that the star appears brighter and sometimes it receives only a few rays or no rays which make the star appear fainter. The brighter and fainter appearance of the star with varying time is called the twinkling of the stars.

Mirage

A mirage is an optical illusion observed in deserts or over hot extended surfaces like a coal tarred road. During hot days the lower layers of air near the earth's surface are hotter and lighter than the upper layers away from the earth's surface. Cold air is more dense than warm air and has therefore a greater refractive index. As light passes from colder air across a sharp boundary to significantly warmer air, the light rays bend away from the direction of the temperature gradient. When light rays pass from hotter to cooler, they bend toward the direction of the gradient. If the air near the ground is warmer than that higher up, the light ray bends in a concave, upward trajectory. Hence light from an object (say the top of a tree) undergoes a series of refraction and total internal reflections and bends upwards. Once the rays reach the viewer's eye, the visual cortex interprets it as if it traces back along a perfectly straight "line of sight". This line is however at a tangent to the path the ray takes at the point it reaches the eye. The result is that an "inferior image" of the sky above appears on the ground. The viewer may incorrectly interpret this sight as water which is reflecting the sky, which is, to the brain, a more reasonable and common occurrence. In the case where the air near the ground is cooler than that higher up, the light rays curve downward, producing a "superior image". **Superior Image is common in polar areas, which is known as Looming.**

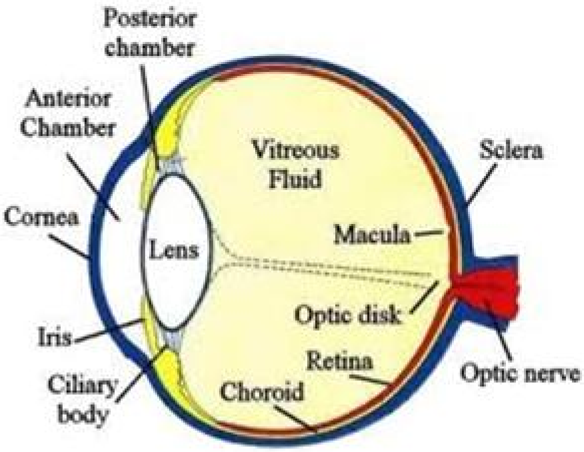
Due to the mirage, a traveller sees shimmering pond of water some distance ahead of him. This optical illusion is called mirage. Thus, *Mirage is due to the combination of Refraction as well as Total Internal Reflection of light.*

Human Eye & Eye Defects

Our eyeball is nearly spherical with white outer layer called the sclera. Here is a short description of how our eye works.

Working of Human Eye

The light enters the eye through a curved transparent tissue called **Cornea**. In humans, the refractive power of the cornea is approximately 43 dioptres. While the cornea contributes most of the eye's focusing power, its ***focus is fixed***. The curvature of the lens, on the other hand, can be adjusted to "tune" the focus depending upon the object's distance. *The cornea has no blood supply; it gets oxygen* *directly through the air. Oxygen first dissolves in the tears and then diffuses throughout the cornea to keep it healthy.*



Behind the cornea, is a circular diaphragm called iris which has a central hole called pupil. The size of the pupil aperture is adjusted by muscle action and controls the amount of light entering the eye. The converging crystalline lens composed of glassy fibres is situated behind the iris. The shape and curvature of the crystalline lens is controlled by ciliary muscles. The images are formed on the retina by adjusting and changing the curvature of the lens. This is called accommodation of the eye. The eye ball contains a fluid in front of the lens and a gelatinous material in the space behind it. The retina of the eye consists of two types of photo sensitive rods and cones. *The more numerous rods have a greater sensitivity to light, but do not respond to colour. Rods work well when the light is dim. The cones are sensitive to bright light and colour. They are helpful to us to see things in colour.* Special optical nerves carry the messages from retina to the brain which interprets the images as erect images. The functioning of the eye is similar in many ways to that of a camera. Both have a lens but eyes are advanced because curvature of the camera lens cannot be changed.

The points between which the eye can see distinctly are called far point and near point. The far point is normally without limit (infinity) and near point depends on the accommodation of the crystalline lens.

When we move a pencil slowly towards our nose. At some points, we observe that the pencil appears blurred. This is the near point. For a normal human eye, the near point is 25 cm from the eye.

The near point increases with the age as shown below:

Short-sightedness or Myopia

The inability to see the distant objects clearly and distinctly is called short sightedness. This defect arises when the image is formed infront of the retina. A short sighted person can see near objects clearly. This may arise due to either excessive curvature of the cornea or elongation of the eyeball. This defect is corrected by wearing glasses with a concave lens.

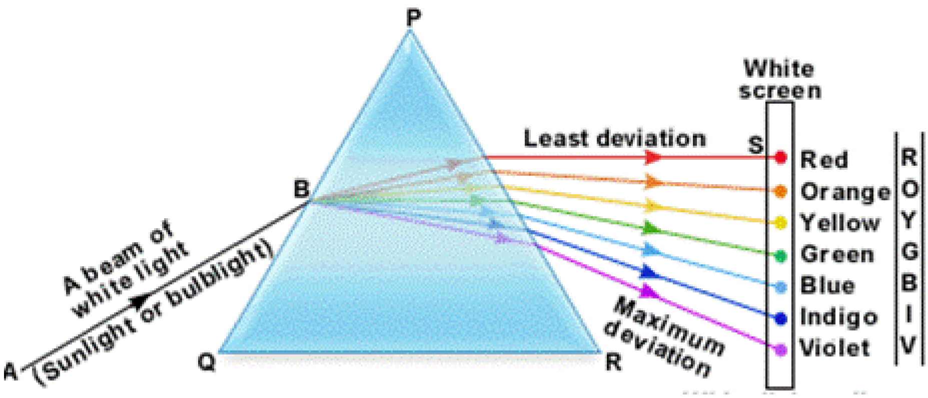
Long sightedness (or) Hypermetropia

The inability to see near objects clearly and distinctly is called long sightedness. This defect arises when the image is formed behind the retina. This defect may arise due to shortening of eye ball. A long sighted person can see the distant objects clearly. This defect is corrected by wearing spectacles with convex lens (converging) of appropriate focal length. A converging lens will correct this defect by converging the incoming rays so that the image is formed on the retina.

Longsightedness occurs naturally with age. As we grow old, our ciliary muscles weaken, and the crystalline lens looses its elasticity or hardens which limits the eye's accommodation. Some persons may have both Longsightedness and short sightedness defects. They should wear glasses consisting of both converging and diverging lenses on the same piece of glass. This is called bifocal glass. The bifocal lens was invented by Benjamin Franklin.

Dispersion of Light

When a beam of white light is passed through a prism, white light splits up into different colours. Consequently a coloured pattern is obtained on the screen.



This splitting of white light into its constituent colours is called dispersion of light. The coloured patent obtained on the screen is called a spectrum. The colours are not in strips but change gradually through many different shades of colour. The colours of the spectrum of white light are violet, indigo, blue, green, yellow, orange and red (VIBGYOR). The white light is a mixture of different colours. Each colour is associated with light of a particular wavelength. Red light has longer wavelengths than the blue light. The angle of deviation by a prism is not the same for all the wavelength (colours) of light. Hence the prism disperses white light into its constituent colours. **The red is deviated least and the violet most.**

Color	wavelength
Violet	400 – 440
Indigo	440 – 460
Blue	460 – 500
Green	500 – 570
Yellow	570 – 590
Orange	590 – 620
Red	620 – 720

Color of Objects

The colour of an object depends upon the colour of light it reflects. If all colours are reflected the object appears white. If some colours are reflected, the object appears coloured. The colour seen by the eye is the colour of the reflected light. A ball appears red when it is seen through a piece of red glass. White objects reflect all colour and black objects absorb all colours. Red objects reflect red only and absorb other colours.

Primary Colors, Secondary colors and Complimentary Colors

Primary colours are sets of colours that can be combined to make a useful range of colours. For human applications, three primary colours are usually used, since human colour vision is trichromatic. For additive combination of colours, as in overlapping projected lights or in CRT displays, the primary colours normally used are red, green, and blue. For subtractive combination of colours, as in mixing of pigments or dyes, such as in printing, the primaries normally used are cyan, magenta, and yellow, though the set of red, yellow, blue is popular among artists. The colours obtained by mixing of any two primary colours are called secondary colours. Two colors are called complementary if, when mixed in the proper proportion, they produce a neutral color (grey, white, or black). The common complimentary colors are:

- red + green + blue
- yellow + blue
- magenta + green
- cyan + red

Sound Related Topics

Sound waves come from vibration of material objects. For example, vibrations of vocal cards in the larynx, and the vibrating strings of the sitar produce sounds. The frequency of the sound wave is same as the frequency of the vibrating source. A medium such as air, liquid or solid is required for transmission of sound. Solids and liquids are good conductors of sound whereas air is a poor conductor. Sound waves cannot travel in vacuum. Sound waves are longitudinal waves in gases and liquids, but they can be either longitudinal or transverse waves in solids.

Key Features of Sound

Pitch and Frequency

The sensation of a frequency is referred as pitch of a sound. *A high pitch sound corresponds to a high frequency sound wave and a low pitch sound corresponds to a low frequency sound wave.* The human ears are sensitive detectors to sounds with frequencies between 16 and 20,000 Hz. Any sound with a frequency below 16 Hz is known as infrasonic and above 20,000 Hz is known as ultrasonic. Cats and dogs are capable of hearing sounds of frequencies higher than 20,000 Hz. Dolphins can produce high pitched sounds of frequency as high as 1,00,000 Hz.

Loudness

The loudness of a sound wave depends on the *amplitude of the wave*. The bigger the amplitude, the louder the sound. The loudness of a sound is measured in decibels (db). Exposure to a noise level of 85 db or above can damage or impair hearing.

Whenever there is a need to increase loudness of a sound, it can be achieved by setting a greater mass of air into vibration. For example, instruments such as violin, guitar, sitar etc. have sound boxes attached to increase the loudness. In a loudspeaker, the vibrating cone has a large surface area and a large mass of air in contact with the cone is set into vibration to produce a loud sound.

The Speed of Sound

The speed of a sound does not depend on its pitch and loudness. At 0°C in dry air, the speed of sound is about 331 meters per sound and at room temperature in air it is 344 meters per second. Sound waves travel faster through warm air than cold air. It is calculated that for each degree rise in temperature, the speed of sound is increases by 0.61 metre per second. The speed in air slightly increases with presence of water vapour i.e. the speed of sound increases with humidity. The speed of sound also depends on the medium. It is high in solids, less in liquids, and the least in gases. For example, in steel the speed of sound is nearly 15 times as great as in air. The speed of sound is much less than the speed of light. This is the reason why thunder is heard much after the flash is seen. Similarly, the sound from an airplane does not appear to come from the plane at all, but from a point far behind it.

Reflection of Sound, Echo

Whenever waves meet an obstacle, they have the property of being reflected. When a sound wave reflects after hitting a distant object such as a wall, an echo is heard. But the minimum distance of the reflecting surface from the source of sound to hear an echo is 17 metres. If the distance is less than 17 metres, then the echo reaches us in less than 0.1 second and the echo cannot be distinguished as a separate sound. It gives the impression of the original sound being prolonged. This is called reverberation. Reverberation can also occur when a series of echoes are heard due to more than one reflecting surface.

The speed of sound can be measured by using an echo. For example, echoes of ultrasonic waves can be used to measure depth of sea-beds or finding the location of submerged objects. Ultrasonic waves are also used for finding faults in the interiors of solids and mapping of underground structures for oil and mineral deposits. Bats produce ultrasonic waves and use echoes to determine distance of the objects on their way. Ultrasonic waves are also used in medical diagnosis and treatment. Sound waves pass through various tissues, and from the pattern of echoes, tumours, lesions and other defects are detected.

Refraction of Sound

The character of sound waves to travel faster in warm air than in cold air causes bending of sound waves when they pass through successive layers of air that have different temperatures. This bending property is called refraction. On warmer days, the air near the ground is warmer than the air above and due to this the speed of sound waves near the ground is higher. It results in bending of the sound away from the ground. On colder days, the reverse will happen and the sound waves bend towards the earth. This is reason for hearing of sounds over longer distances on a cold day.

Resonance

Depending on the factors such as the elasticity and shape of the object, each vibrating object has a natural frequency. A resonance occurs when an object oscillates at its natural frequency, as a result of impulses received from some other system vibrating with the same frequency. Resonance can happen in different kinds of systems: acoustical, mechanical, electrical and optical. Resonance leads to increased amplitude of vibration. In some cases, the amplitudes that result from resonance can be disastrous. This is the reason for ordering soldiers to break up while crossing a suspension bridge. The resonant vibrations caused by the marching may severely damage the bridge. Oscillations also occur in an electrical circuit. A radio receiver is tuned to a particular frequency when the oscillating electrical circuit inside the radio is set into resonance with incoming signals.

Doppler Effect

The frequency of a wave changes depending on the motion of the source or observer. This is known as Doppler Effect. When the source approaches the listener, the frequency of a sound appears to be higher and vice versa.

Radar guns used by the police to check the speeding vehicles use Doppler Effect. The radar gun sends out a radio pulse and wait for the reflection. Then it calculates the Doppler shift in the signal to determine the speed of the vehicle. In astronomy, Doppler Effect is 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 redder. Doppler Effect is also used to detect the rotation of a star or for tracking a moving object, such as a satellite, from a reference point on the earth.

Sonic Boom

A sonic boom is an impulsive noise similar to thunder caused by a supersonic (faster than sound) aircraft that produces a cone of sound called a shock wave.

Musical Scale

A musical scale is a group of pitches arranged in an ascending order. The diatonic scale includes the notes with frequencies: 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

Music recording company Dolby Laboratories Inc. has developed techniques to reduce noise levels in recorded music. Dolby noise reduction works in tandem to improve the signal-to- noise ratio. Dolby A, Dolby B, Dolby C, Dolby SR and Dolby S are the noise reduction systems developed by the company.

Magnetism Basics

A simple magnet is a magnetised bar of iron. It attracts and holds iron pieces but does not attract pieces of copper. Those materials attracted by a magnet comes under magnetic materials and those not attracted are described as non-magnetic. Examples for strong magnetic materials include iron, nickel, cobalt and certain alloys whereas copper, glass, wood, etc. are non-magnetic materials. However, in presence of strong magnets, even non-magnetic substances show feeble magnetism. A bar magnet when suspended with a thread tied exactly in its middle, after oscillating for a little it comes to rest in the north-south direction. The end pointing to north direction is called north pole of magnet and the end pointing to south direction is called south pole of magnet. Like poles of two magnets repel and unlike poles of two magnets attract.

Earth's Magnetism

Earth also has magnetism however its origin is still not clear. It is believed that the motion of charges in the molten outer core creates the magnetic field. Earth's magnetism may be due to heat arising from the earth's inner core. The heat may be responsible for cause of convection currents in the molten outer core.The flow of ions and electrons would produce a magnetic field. It is probably the combination of such convection currents with the rotational effects of the earth are source of the earth's magnetic field.The South Pole of the Earth is located upon the Antarctic Continent in the southern hemisphere.The North Pole is located in the middle of the Arctic Ocean. At any place on the earth, the magnetic north is not usually in the direction of the geographic north. The angle between the two directions is called the declination. Mariners using compasses must allow for declination in determining the true north. The angle made by a freely suspended bar magnet with the horizontal is called the dip of the place. On the equator, the dip is zero and on the poles it is 90°.

Magnetic Resonance Imaging (MRI)

MRI is a non-invasive medical test that uses a magnetic field and pulses of radio wave energy to take images of internal organs of the body.The images are examined on a computer monitor, printed or copied on a compact disc. MRI does not use x-rays.

Electricity Related Topics

Static electricity refers to an imbalance of electric charges within or on the surface of a material. The charge remains until it is able to move away by means of an electric current or electrical discharge.

Electricity by Friction

Friction produces the electric effects. The well-known example is, a hard rubber comb attract small pieces of paper after using it on a dry hair. It is because after rubbing, the comb becomes charged with electricity. The same effect is noticed when a plastic pen is rubbed on a coat sleeve. Static electricity is the electricity produced by friction between two dissimilar objects. Based on the nature of the objects, one object becomes a positive charge and the other an equal negative charge. For example, when a glass rod is rubbed with silk, the rod becomes positive charge and the silk an equal negative charge. Like charges repel and unlike charges attract.

Electrification by friction involves transfer of electrons (negatively charged particles of an atom). In the example of a glass rod rubbed with silk, some electrons from the rod transferred the silk. By losing electrons, the glass becomes positively charged and by gaining the same number of electrons silk acquires an equal negative charge.

In case of hollow metallic conductors, when they are charged with static electricity it is found that the charge remains on the outside of the conductor; the inner surface remains uncharged. This is the reason for when a car is struck by lightning, persons sitting inside are shielded from the electricity as the charge remains on the outer surface. In case of a pear-shaped conductor, the charge is concentrated on and near the pointed end. When the charge on the conductor is increased, the pointed end starts losing charge. A pointed end also acts as a collector of charge. The lightning conductor works on this principle.

Lightning Conductor

Lightning involves heavy discharge of electricity between two charged clouds or between a charged cloud and the earth. Lightning conductors are used in tall buildings for protection from lightning. A lightning conductor is a thick copper strip fixed to an outside wall of the building. The upper end of the strip consists of several sharp spikes reaching above the highest part of the building and the lower end is connected to a copper plate buried in the earth. When lightning occurs, the lightning conductor accepts any electric discharge.

Insulators, Conductors, Superconductors and Semiconductors

All the substances can be arranged based on their ability to conduct electrical charge. Almost all metals are good conductors and most non-metals are poor conductors or insulators. Metals conduct electricity as they have a large number of free electrons whereas insulators have no free electrons. With decreasing of temperature, the resistance of metals to flow of electricity reduces. At near absolute zero temperatures, metals have almost zero resistance and become superconductors. It is also discovered that certain ceramics can behave as superconductors at relatively high temperatures of above 100K. Currently, scientists are working on in the field of high temperature superconductivity hoping to achieve it at room temperatures. Materials such as silicon and germanium have electrical resistivity in between those of conductors and insulators. Such materials are called as semiconductors. They are good insulators in their pure crystalline form but their conductivity increases by adding small amounts of impurities. After the addition of impurities, they become n-type and p-type semiconductors.

Transistors

Transistors used in radios, televisions, computers and other devices are composed of both n-type and p-type semiconductors. They need very little power and in normal use they work indefinitely.

Integrated Circuits (IC)

An integrated circuit is an arrangement of multifunction semiconductor devices. It consists of a single-crystal chip of silicon containing both active and passive elements and their interconnections.

Current Electricity

Electric current is different from static electricity and it involves the flow of electric charge. The flow of electrons in solid conductors, and the flow of ions and electrons in liquids constitute the current. To maintain continuous flow of current in a circuit, it is essential to have an electromotive force that can be provided by a cell or a generator.

Electrical Resistance

Conductors such as a metallic wire offer some obstruction when electric current flows through it. This character of conductors to offer obstruction 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).

$R= \rho (l/a)$; ρ is a constant called the resistivity of the material of the wire.

With increasing temperature, resistivity of a good conductor increases whereas resistivity of a semiconductor decreases.

Electric Cell

In cells, chemical energy is converted into electrical energy. Cells are of two types viz. primary and secondary. Examples of primary cells include torches, radios, etc. The constituents of a dry cell are a negative electrode, a positive electrode and an electrolyte. The negative electrode is made with zinc as it is the outer shell of the cell. A carbon rod surrounded by a mixture of carbon and manganese dioxide acts as the positive electrode. The electrolyte is a mixture of ammonium chloride and zinc chloride in the form of a paste. A dry cell produces about 1.5 volt.

Lead cells which are used for ignition and lighting on motor car are secondary cells. Secondary cells are used as storage cells or accumulators. Due to their low internal resistance, secondary cells are capable of giving large currents. They can be recharged after they discharged. They are used in emergency lights in hospitals and other buildings.

Car Battery

In a car battery, there is a combination of 6 lead-acid secondary cells each with 2.04 volts. These cells use lead plates as electrodes and sulphuric acid as the electrolyte. The car battery provides large currents for a short time as large currents are required to start the engine. After engine started, the alternator provides power to the car.

Effects of Electric Current

Magnetic Effect

When current flows through a wire, a magnetic field is developed around it. If a current-carrying wire is brought near to a bar of iron, it gets magnetised and when the current flow is stopped, the iron bar loses its magnetism. Electromagnets produced in this way have lot of applications. They are used for lifting and transporting steel plates, scrap iron etc. They are also used in electric bells, telephone receivers, etc.

Chemical Effect, Electrolysis

When electric current passes through a solution, it results in decomposition of the solution into negative and positive ions. Positive ions are collected at the negative electrode i.e. cathode and negative ions are collected at the positive electrode i.e. anode. This process is called electrolysis. This process is widely used in electroplating.

Heating Effect

When electric charge flows through a conductor, it results in heating of the conductor i.e. electric energy is converted into heat energy. The heating effect is used in a wide variety of appliances such as geyser, room heater, etc. These appliances use coils of nichrome, which are heated with flow of current. In an electric iron, the heating element is placed between two thin sheets of mica, which is highly insulating and can withstand high temperatures.

Motor Effect

If a current-carrying conductor is placed at right angles to a magnetic field, a force acts on the conductor. When a current-carrying rectangular coil is placed in a magnetic field, the coil starts rotating as a couple acts on the coil. This is the mechanism used in an electric motor i.e. in an electric motor, electric energy is converted into mechanical energy. Electric motors are used in electric fans, washing machines etc. In loudspeakers, energy is transferred from electric current into mechanical energy of vibration.

Electric Generator (Dynamo)

The electric generator works on the principle identical to that of an electric motor. In a generator, the armature is rotated in the magnetic field and an emf is generated in it due to electromagnetic induction. Thus a generator converts mechanical energy into electrical energy. With a minor change in construction, a generator can produce alternating emf or direct emf. The corresponding currents produced are called alternating Current (ac) and direct Current (dc).

Inverter

An inverter converts DC to AC. The inverters for home and office purpose are designed to convert DC from a battery to AC, and also to charge the battery. If there is a power failure, the inverter automatically switches on the AC, converted from the battery's DC. After the mains supply is restored, the inverter automatically switches to a mode where it starts charging the battery.

Power Generation and Transmission

Power stations generate electricity of 11 kilovolts (kV) and it is stepped up to 132 kV for transmission to main substations. In a high voltage power transmission, there is little power-loss in the transmission cables. In the main substations, the voltage is stepped down to 33 kV.This voltage is further stepped down and consumers are supplied at 220V. As the voltage is alternating, 220 is the effective value of the voltage.The frequency of a.c. is 50 Hz (cycle per second).

Domestic Electric Installation

Electricity is supplied to houses by using two cables, the "live" cable and the "neutral" cable. A third cable is also used for safety purposes. It is called the "earth" and is connected to the earth terminal provided in the building. From the meter installed in a house, connections are made to the distribution board through a main fuse and a main switch.

Fuse

A fuse is a short piece of wire that has a low melting point. It is generally made of a tin-lead alloy. Fuse melts and breaks whenever there is short circuiting, overloading, voltage fluctuation, etc. This will protect the electrical appliances and also prevents fire accidents.Fuses are always connected in the live wire. Nowadays, miniature circuit breakers (M CBs) are replacing fuses.

A circuit breaker automatically protects an electrical circuit from damage caused by overload or short circuit. Unlike a fuse, a circuit breaker need not be replaced. It needs to be reset manually to resume normal operation.

Earth
The earth wire is used for safeguarding of electrical appliances against shocks.

Flexible Cables
All electrical appliances comes with three-core flexible cables. The cables insulations 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
In a three pin plug, one pin is longer and thicker, and the other two are similar. The longer pin is used for earthing and it is connected to the green wire of the appliance. The other pins are connected to the red (or brown) and the black (or blue) wires. As the earth pin is longer, an appliance is always first earthed before it is connected to the live circuit. In a socket, the lower right hole is used for the live connection and the left hole is for the neutral connection, and the top bigger hole is for the earth.All switches in a house are connected to the live wires. If they are connected in the neutral wire, the sockets would remain live even if the switches are in off position.

Electric Light

Incandescent Lamp or Filament Lamp
In electric lamps, electrical energy is converted to light energy. In electric lamps, a tungsten filament

is connected between two lead-in wires. The tungsten filament is heated with passage of current and emits light.The reason for use of tungsten is it has a high melting point of 3,400°C. The electric lamp also contains a small quantity of argon (an inert gas) to prevent evaporation of tungsten. Air is not used as it would oxidise the tungsten.

Fluorescent Tubes
A fluorescent tube consists of mercury vapours at low pressure. When electricity flows through the tube, the mercury vapours emit invisible ultraviolet rays. These ultraviolet rays fallon the fluorescent coating on the inside of the tube and emit visible light. In a fluorescent tube very little heat is produced, so almost all the electrical energy is converted to light energy. The fluorescent tubes are cheaper and efficient.

Compact Fluorescent Lamps
In incandescent light bulbs, lot of electricity is wasted in the form of heat. A CFL (compact fluorescent lamp) is a miniature fluorescent tube that works 4 to 6 times more efficient than an incandescent bulb. A 15W fluorescent bulb can produce the same amount of light as a 60W incandescent bulb. Mercury used in the fluorescent lamps is a hazardous substance. Most light sources including fluorescent bulbs emit a small amount of UV, but it is far less than the amount produced by natural daylight.

Cost of Electricity
Electricity consumption is measured in the unit kWh. From the power rating of electrical appliances,

we can calculate the consumption of electrical energy. By knowing the rate per unit, one can work out the cost of consumption.

Working of Some Electronic Devices

TV Remote Control

A TV or music system remote control contains a chip (an integrated circuit) and other components, such as a diode, a transistor, capacitor, etc. When a key is pressed, remote control translates it into *infra-red signals* which are received by the electronic circuit in the TV, and the desired operation is performed.

Cordless Phone

Cordless phones are directly plugged into an existing telephone socket that essentially serves as a wireless extension to the existing phone wiring. A cordless phone has two parts viz. a base unit and a hand set. The hand set can communicate with a number of frequencies (channels) in the 46-48 MHz bands. Based on the quality, a cordless phone can permit mobility (range) up to 100 m.