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Manisha Bansal Ma'am

(Director & Author)

12 Year's Teaching Experience

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Roma Invicta Arya

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01**Introduction to Units****Science**

Science is a word that comes from a latin word "scientia" which means knowledge.

It is the knowledge which humans have gained through observations and experiments, when organized systematically.

Science is discovered by a famous scientist galileo galilei.

Physical Science

The science which deal with non-living things are called **Physical Sciences**. For example, Physics, Chemistry, Geology, Geography, Astronomy, Astrology, Oceanology etc.

Biological Science

The science which deal with living things are called **Biological Sciences**. For example, Botany, Zoology, Ornithology, Entomology, Forensic science etc.

Physics

Physics is the branch of science which is devoted to the study of nature and natural phenomena.

Microscopic/Modern Physics

The microscopic physics related to study of ver finite answer that is atom,nucleus This make up **Modern Physics**. Most of it was developed after the year 1900.

Mesoscopic Physics

It involves the study of a few tens or hundreds of atoms or molecules. It is called **Mesoscopic Physics**.

Macroscopic/Classical Physics

The macroscopic domain includes the study of phenomena involving objects of finite size on terrestrial scale and even on astronomical scale. This makes up **Classical Physics**. Most of it was developed upto the year 1900.

Quantum Theory

Quantum Theory by Plane quantum

Mechanics

Mechanics deals with the study of motion and force that act on a body bin motion. propulsion of rockets, propagation of water waves, sound waves.

Thermodynamics

Thermodynamics deals with the study of heats and with how heat is transferred from one place to another . Modes of transfer of heat, efficiency of heat engines and refrigerators are also included in thermodynamics.
(RRB NTPC 16.04.2016)

Electrodynamics

Electrodynamics deals with the study of electric and magnetic phenomena associated with charged particles and magnetic materials. The basic laws governing these phenomena were given by Coulomb, Oersted, Ampere and Faraday. These laws were encapsulated by Maxwell in his famous set of

Optics

Optics involves the study of various phenomena connected with light and optical instruments like microscope, telescope etc.

Units and measurement**Physical Quantities**

All the quantities in terms of which laws of physics are described and whose measurement is necessary.

Scalar quantity

The physical quantities which have only magnitude but no direction.

Ex:- Mass, length, time, distance, speed, temperature, work etc.

Vector quantity

The physical quantities which have magnitude as well as direction.

Ex:- Displacement, velocity, acceleration, force, torque, gravitational intensity etc.

Unit

Measurement means the comparison of an unknown quantity with some known fixed quantity.

(SSC DELHI POLICE CONSTABLE 05.12.2017)



Units

Measurement of physical quantity term as units.

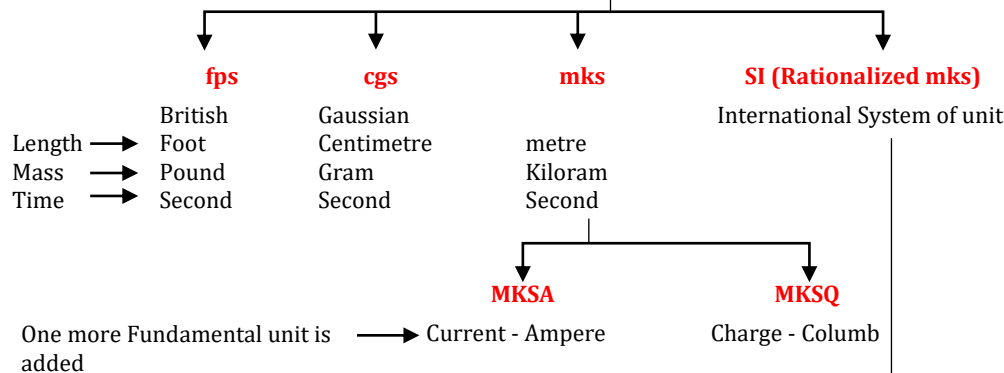
Fundamental Unit

Unit that do not depend on other for measurement are known Fundamental unit.
They are independent in nature

Derived Unit

Unit that derived from fundamental units are known to be Derived unit.
They are dependent on fundamental unit.

System of Units



Fundamental Units

Sr. No.	Basic Physical Quantity	Fundamental unit	Symbol used
1.	Mass	Kilogram	kg
2.	Length	Metre	m
3.	Time	Second	s
4.	Temperature (SSC CHSL 10.07.2019)	Kelvin	K
5.	Electric current	Ampere	A
6.	Luminous intensity	Candela	cd
7.	Amount of substances	Mole	mol

Supplementary Units

Sr. No.	Basic Physical Quantity	Fundamental unit	Symbol used
1.	Plane angle	radian	rad
2.	Solid angle	steradian	sr

NOTE:

(i) Two vectors are said to be equal if both magnitude and direction are same.

(SSC CGL 11.09.2016)

(ii) Plane angle is quantity that are used for the expression of arc/radius.

(SSC CGL 18.04.2022)

(iii) The term **ISO** is used for prefixed scientific term to describe something is constant.

(SSC CGL 12.06.2019)

In the measurement of very large distances, we use the following three units:

- Astronomical Unit (AU):** It is the distance between the earth and the sun.

$$1 \text{ AU} = 1.496 \times 10^{11} \text{ m} = 1.5 \times 10^{11} \text{ m}$$

- Light Year (ly):** One light year is the distance travelled by light in vacuum in one year.

$$1 \text{ ly} = 9.46 \times 10^{15} \text{ m}$$

(SSC CHSL 16.11.2014, SSC COMBINED MATRIC LEVEL 30.07.2006, SSC CGL 26.10.2014, SSC CPO SI, ASI ONLINE EXAM 05.06.2016)

- par sec:** the large distance of astronomical objects outside the solar system.

(SSC CPO SI, ASI 06.06.2021 & SSC CGL 10.09.2016)

$$1 \text{ par sec} = 3.1 \times 10^{16} \text{ m} \quad 1 \text{ par sec} = 3.26 \text{ ly}$$

Some other useful units of length are

1 inch = 0.0254 m	1 foot = 0.3048 m	1 yard = 0.9144 m
-------------------	-------------------	-------------------

1 mile = $1.609 \times 10^3 \text{ m}$	1 nautical mile = $1.852 \times 10^3 \text{ m}$	
For measuring very small areas		
1 barn = 10^{-28} m^2	1 acre = 4047 m^2	1 hectare = 10^4 m^2
For measuring heavy masses		
1 tonne or 1 metric ton = 1000 kg	1 quintal = 100 kg	1 slug = 14.57 kg
1 lb = 0.4536 kg		
The largest practical unit of mass is Chandra Shekhar Limit (C.S.L.)		
1 C.S.L. = 1.4 times the mass of sun.		

For measuring very small masses:

1 atomic mass unit = 1 a.m.u. or 1 u = $1.66 \times 10^{-27} \text{ kg}$.



Small mass is measure in carat unit

1 c = 200 mg

Some practical units of standard of time are:

- (i) **Solar day:** the rotation of earth on its axis. (around 24 hours)
- (ii) **Solar year (or year):** time taken by earth to complete one revolution of earth.
1 solar year = 365.25 average solar days
= 366.25 serial days
- (iii) **Lunar month:** time taken by moon to complete one revolution of earth. .
1 Lunar month = 27.3 days
- (iv) **Shake:** It is the smallest practical unit of time.
1 shake = 10^{-8} s

For measuring pressure

- (i) 1 bar = 1 atmospheric pressure = 10^5 N/m²
1 bar = 10^5 N/m² = 10^5 Pascal (Pa)
1 Millibar = 10^2 Pa
- (ii) 1 torr = 1 mm of Hg column
(SSC CGL 07.03.2020)

Two more units for general use are: (Nuclear Radioactivity)

1 curie (Ci) = 3.7×10^{10} disintegrations/sec
1 roentgen (R) = 2.58×10^{-4} C/kg.

Matric Prefixes

S.No.	Power of 10	Prefix	Symbol
1.	10^{-1}	deci	d
2.	10^{-2}	centi	c

3.	10^{-3}	milli	m
4.	10^{-6}	micro	μ
5.	10^{-9}	nano	n
6.	10^{-10}	Angstrom	Å
7.	10^{-12}	pico	p
8.	10^{-15}	femto	f
9.	10^{-18}	atto	a
10.	10^1	deca	da
11.	10^2	hecto	h
12.	10^3	kilo	k
13.	10^6	mega	M
14.	10^9	giga	G
15.	10^{12}	tera	T
16.	10^{15}	peta	P
17.	10^{18}	exa	E

NOTE;

- (i) A micron is equal to .001mm.
(SSC CONSTABLE (GD) & RIFLEMEN (GD) 22.04.2012)
- (ii) 1 Nanometer is equal to $1/10^9$ m
RRB GROUP-D 16/11/18
- (iii) Picometer is equal to 10^{-12} m
RRB GROUP-D 20/09/18
- (iv) One nanometer is equal to 10 raised to the power (-9)
(SSC CHSL 15.01.2017)
- (v) Unit used for expressing the nuclear radius
(SSC CAPFS ASI & DELHI POLICE SI 04.07.2017)

Dimensional Analysis

The seven fundamental or base quantities chosen in SI are called seven dimensions of the physical world. They are denoted with square brackets []. Thus, length is represented by [L], mass

by [M], time by [T], electric current by [A], thermodynamical temperature by [K], luminous intensity by [Cd] and amount of substance by [mol].

The Dimensions of a physical quantity are the powers (for exponents) to which the units of base quantities are raised to represent a derived unit of that quantity.

In mechanics, all the physical quantities can be written in terms of the dimensions of [L], [M] and [T].

Volume = length $\times$ breadth $\times$ height

Volume = [L] $\times$ [L] $\times$ [L] = [L³]

As units of mass and time are not required in representing volume, we write

Volume = [M⁰ L³ T⁰], and say that volume has zero dimension in mass and zero dimension in time in addition to 3 dimensions in length.

For velocity,

$$\text{Velocity} = \frac{\text{displacement}}{\text{time}} = \frac{[L]}{[T]}$$

$$\text{Velocity} = [M^0 L^1 T^{-1}]$$

↑
Dimensions

Dimensional formula

Dimensional equation

International system of units

Quantity	Symbol	Unit	Dimension formula	Previously asked
Length	M	meter	M ⁰ L ¹ T ⁰	
Mass	Kg	Kilogram	M ¹ L ⁰ T ⁰	
Time	s	Second	M ⁰ L ⁰ T ¹	
Temperature	K	Kelvin	M ⁰ L ⁰ T ⁰ K ¹	RRB Group-D 15/11/18 RRB Group -D 01/10/18 DELHIPOLICE CONSTABLE 02.12.2020
Electric current	A	ampere	M ⁰ L ⁰ T ⁰ A ¹	RRB GROUP-D 04/12/18 RRB GROUP-D 24/10/18 RRB ALP 30/08/18
Amount of substance	Mol.	Mole	M ⁰ L ⁰ T ⁰	RRB NTPC 28/12/2020 RPF CONSTABLE 05/02/19
Luminous intensity	Cd	Candela	M ⁰ L ⁰ T ⁰ Cd ¹	RRB JE 29/08/19 SSC CPO SI, 05.06.2021
Angle	Rad.	Radian	M ⁰ L ⁰ T ⁰	
Solid angle	Sr.	Steradian	M ⁰ L ⁰ T ⁰	
Frequency	Hz	Hertz	M ⁰ L ⁰ T ⁻¹	RRB NTPC 19/01/21
Weight ,force	N	Newton	M ¹ L ¹ T ⁻²	RRB NTPC 08/02/21 RRB NTPC 16/04/16 RRB NTPC 30/12/20
Pressure, stress	Pa	Pascal	M ¹ L ⁻¹ T ⁻²	RRB SSE 21/12/14



				RRB GROUP-D 04/10/18 RRB GROUP-D 01/10/18 RRB GROUP-D 25/09/18 RRB NTPC 09/04/16 RRB JE 25/05/14 SSC CHSL 04.08.2021
Heat, work ,energy	J	Joule	$M^1L^2T^{-2}$	RRB NTPC 28/01/21 SSC CHSL , DEO & PA/SA 06.12.22015 SSC CHSL 19.10.2020 SSC CHSL 16.11.2014 SSC CAPFS ASI 7 SI DELHI POLICE 05.07.2017)
Power ,radiant, flux	W	Watt	$M^1L^2T^{-3}$	RRB NTPC 11/02/21 RRB JE 24/05/19 RRB Group D 01/10/2018 RRB Group-D 22/10/18 RRB ALP 21/08/18 RRB Group-D 02/11/18 SSC CAPFS ASI 7 SI DELHI POLICE 05.07.2017)
Electric charge	C	Coulomb	$M^0L^0T^0I^1$	RRB GROUP-D 04/10/18 RRB GROUP-D 26/11/18 RRB ALP 31/08/18 RRB ALP 10/08/18 RRB NTPC 28/03/16
Momentum	P	Kg×meter/second	$M^1L^1T^{-1}$	RRB ALP 14/08/18 RRB GROUP-D 23/10/18 RRB GROUP-D 19/09/18 SSC CGL 13.08.2021
Volume	V	M^{-3}	$M^0L^3T^0$	
Distance	D	Meter	$M^0L^1T^0$	
Displacement	D	Meter	$M^0L^1T^0$	
Speed	S	Meter/second	$M^0L^1T^{-1}$	RRB group-d 01/10/18
Velocity	V	Meter/second	$M^0L^1T^{-1}$	
acceleration	A	Meter /second ² (SSC CGL 19.08.2017)	$M^0L^1T^{-2}$	RRB GROUP-D 15/10/18 RRB GROUP-D 24/09/18 RRB GROUP-D 11/10/18 RRB GROUP-D 19/19/18
Retardation	S	Meter/second ²	$M^0L^1T^{-2}$	RRB GROUP-D 03/10/18
Density	Rho	Kg/meter ³	$M^1L^{-3}T^0$	
Relative density	S	No unit (SSC CHSL 15.01.2017 & SSC CAPFS ASI & DELHI POLICE SI 07.07.2017)	$M^0L^0T^0$	RRB GROUP-D 03/12/18 RRB ALP & Tec.03/12/18
Voltage	V	Volt	$ML^2T^{-3}I^{-1}$	
Capacitance	F	Farad	$M^{-1}L^{-2}T^4I^2$	SSC CGL 21.04.2013
Resistance	Ω	Ohm	$ML^2I^{-2}T^{-3}$	RRB JE 28/06/19 SSC CAPFS ASI 7 SI DELHI POLICE 05.07.2017 & 02.07.2017 SSC CHSL 06.12.2015
Flux density	T	Tesla	$M^1LT^{-2}I^{-1}$	SSC CGL 27.04.2014
Radioactivity	Bq	Becquerel		SSC CHSL 09.07.2021
Magnetic induction	H	Henry	$M^1LT^{-2}A^{-1}$	
Magnetic permeability	μ	Henry per meter	$M^1L^1T^{-2}A^{-2}$	ALP 23/01/19
Magnetic flux		Weber or Maxwell	$M^1L^2T^{-2}I^{-1}$	RRB NTPC 13/03/21 SSC CHSL 20.12.2015



				SSC CAPFS ASI & DELHI POLICE 04.07.2017
Dynamic viscosity	μ	Pascal second	$M^1L^{-1}T^{-1}$	
Magnetic Field Strength	H	Ampere per meter	$M^1T^{-2}I^{-1}$	
Electric field	E	Volt per meter	$M^1L^1T^{-3}I^{-1}$	
Electrical resistivity		Ohm meter	$ML^2T^{-1}A^{-2}$	
Potential difference	U	Volt		
Conductance		Siemens		SSC CAPFS NIA SSF CONSTABLE 05.03.2019

Some important units :-

1. 1 Horse power = 746 watt

RRB ALP & Tec. 20/08/18

SSC STENOGRAPHER 11.09.2017 & SSC CGL 03.03.2020

SSC DELHI POLICE SI, CAPFS SI & CISF ASI 24.11.2020)

2. 1 Diopter = $1m^{-1}$

RRB JE 02/06/19 & SSC JE 29.01.2018)

3 1 Joule = $1N \cdot 1M$

RRB GROUP-D 15/10/18

4. 1 kWh = $3.6 \times 10^6 J$

RRB GROUP-D 20/09/18, 18/09/18, 27/09/18, RRB GROUP-D 03/10/18

5. 2 kWh = $7.2 \times 10^6 J$

RRB GROUP-D 03/12/18

6. 1 Killowatt = 1000 Watt

RRB GROUP-D 26/05/19 & SSC CHSL 21.03.2018

7. 1 Ampere = 1 Coulomb/1s

RRB GROUP -D 12/10/18

8. 1 Barrel = 159L SSC

STENOGRAPHER 11.09.2017

9. 1 Km/Hr = $5/18 M/S$

SSC CHSL 05.03.2018

Some important quantity with unit :

QUANTITY	UNIT	PREVIOUSLY ASKED
POWER OF LENS	DIOPTER	
LOUDNESS OF SOUND	DECIBEL	RRB GROUP-D 12/11/18 RRB JE 22/05/19 RRB JE 30/08/19 & SSC CGL 11.06.2019 SSC CPO 06.06.2016
LIGHT YEAR IS A UNIT OF	DISTANCE	RRB NTPC 14/03/21
STRENGTH OF WINDS IS MEASURED BY	BEAUFORT SCALE	RRB JE CBT 28/08/19
SOUND OBSERVED DURING THE MEASURE OF BLOOD PRESSURE	KOROTKOFF SOUNDS	RRB JE 01/09/19
ATOMIC RADIUS	NANOMETER	RRB JE 30/08/19
VOLUME	GALLAN	

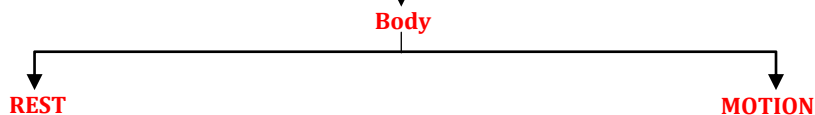
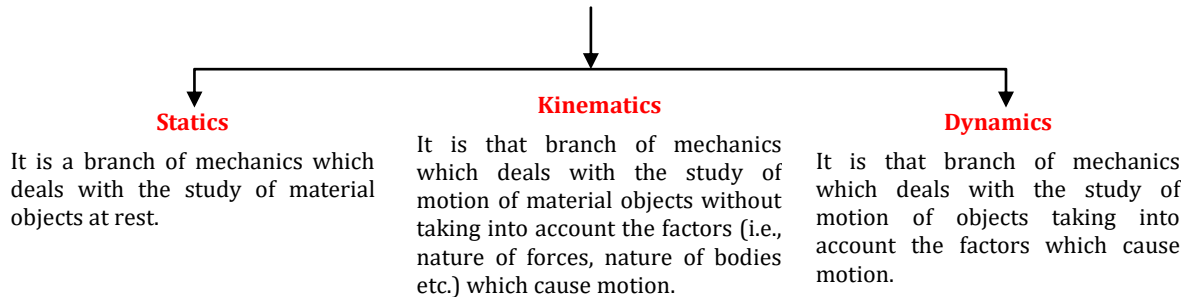


02

Mechanics

MECHANICS

The Branch of Physics which deals with the study of motion of material objects.



MOTION

The change of position with respect to time is known as motion.

We very well know that everything is moving for example our earth is revolve around the sun as well as its own axis. Moving of an object is motion. In short we can say that if object change their position according to time then it is motion.

Ex- walking, running etc.

Motion can be done on the basis of ;

1. Time
2. Speed
3. Distance
4. Path

TYPES OF MOTION:-

There are following types of motions that we discuss here are :

1. LINEAR MOTION
2. CIRCULAR MOTION
3. ROTATIONAL MOTION
4. OSCILLATORY MOTION
1. LINEAR MOTION- A motion of a body in a straight line with constant velocity is known as linear motion.
Ex- an athlete run on a track.
2. Circular motion- A motion of a body on the circumference of the circular path is known as circular motion.
Ex –earth revolve around the sun.
3. Rotational motion – A motion of a body along with the fixed orbit of the circular path is rotational motion.
Ex-earth rotation on its axis.

4. Oscillatory motion- a motion of the object in which they have to and fro motion is oscillatory motion.
Ex – a pendulum in the wall watch.
Other types of motion we have that is ;-
- uniform motion – a motion in which an object covers equal distance in equal time interval.

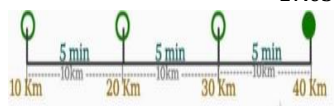
(SSC CHSL 04.03.2021)

- non-uniform motion- a motion of an object if it does not cover equal distance in equal time interval.

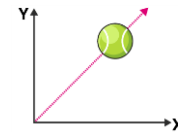
(SSC CHSL 07.03.2018)

- one-dimensional motion –a motion in a single direction (on axis)
- two dimensional motion- motion more than in one direction.(on plane)
- three dimensional motion-motion more than in two direction (in space)
- translation motion – motion of an object if their all particles cover same distance in same time interval.
- periodic motion-a motion on which body repeat their position in equal time intervals

(SSC MULTI TASKING STAFF 17.03.2013)



UNIFORM MOTION



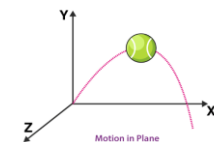
1-DIMENSIONAL MOTION



TRANSLATION MOTION



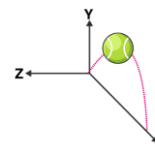
NON-UNIFORM MOTION2



2-DIMENSIONAL MOTION



PERIODIC MOTION



3- DIMENSIONAL MOTION



Key Terms

Distance

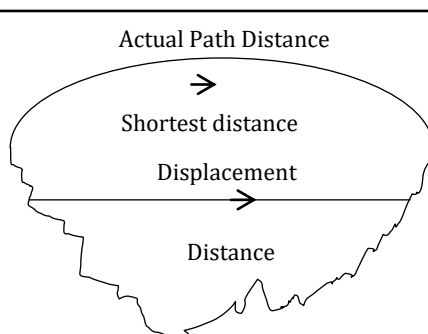
It is the actual path traveled by a body in a given period of time.
Distance is a scalar quantity and the SI unit is meter (m).

(RRB GROUP-D 12.10.2018)

Distance is always positive.

Distance covered by object is directly proportional to time.

(SSC CGL Pre. 2022, 01.12.2022 Shift-3)



Displacement

This is the shortest distance between two points. It is a vector quantity and the SI unit is meter (m).

Displacement may be positive, negative or zero

Speed

It is the ratio between the distance to the time.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{D}{T} = \frac{m}{s}$$

Speed is a scalar quantity.

(RRB GROUP-D 09.10.2018 & 31.10.2018)

(SSC CGL Pre. 2022, 13.12.2022 Shift-1)

(SSC CHSL 16.11.2014)&

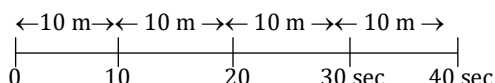
Distance - time graph shows speed of an object. *(SSC CGL Pre. 2022, 06.12.2022 Shift-4)*

Uniform

If object covers equal distance in equal intervals of time.

(SSC CGL Pre. 2022, 01.12.2022 Shift-4)

Distance →

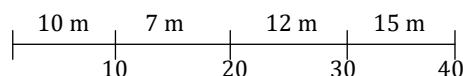


Time →

Non-Uniform

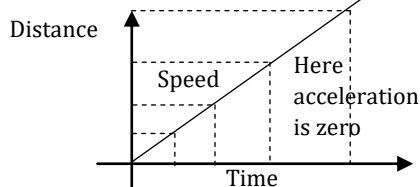
If object covers unequal distance in equal intervals of time

Distance →

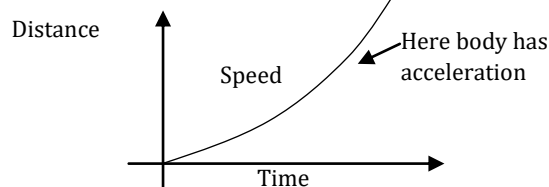


Time →

Graph:



Graph:



Velocity

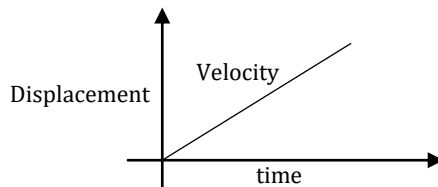
It is the ratio between displacement to the time.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}} = \frac{\text{m}}{\text{sec}}$$

(RRB GROUP-D 25.09.2018, 05.12.2018, 03.10.2018, 29.08.2018, 09.10.2018, 01.11.2018, 04.12.2018, 11.10.2018, 22.09.2018)

Uniform

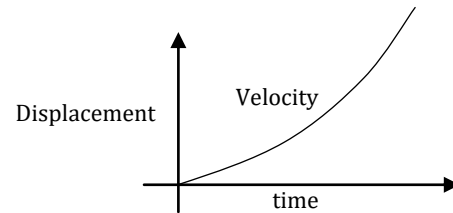
If object covers equal displacement in equal intervals of time



Motion of an object is Uniform if its velocity is constant.
(SSC CGL Pre. 2022, 06.12.2022 Shift-1)

Non-Uniform

If object covers unequal displacement in equal intervals of time



Acceleration

It is the ratio between the velocity to the time.

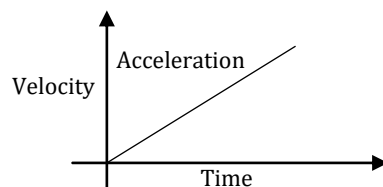
$$\text{Acceleration} = \frac{\text{Velocity}}{\text{time}} \Rightarrow \frac{\text{m/s}}{\text{sec}} = \frac{\text{m}}{\text{sec}^2} = \text{ms}^{-2}$$

(RRB GROUP-D 13.12.2018 & 15.10.2018, RRB ALP 17.08.2018

SSCCGL 19.04.2022 & (SSC CGL Pre. 2022, 01.12.2022 Shift-2, (SSC CGL Pre. 2022, 07.12.2022 Shift-1)

Uniform

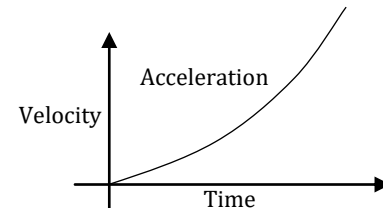
If object covers equal velocity in equal intervals of time



(RRB GROUP-D 22.10.2018)

Non-Uniform

If object covers unequal velocity in equal intervals of time



Note:

1. Zero acceleration means the velocity of object is constant.
(RRB GROUP-D 12/12/18)
2. Negative acceleration means opposite to the velocity.
(RRB ALP 09/08/18)
3. Positive acceleration means same to the velocity.
(RRB GROUP-D 04/12/18)
4. If a body moves with a constant speed in a circle then velocity remains constant.
(SSC CHSL 16.11.2014)

5. An object with constant speed is not accelerated.
(SSC CHSL 16.11.2014)
6. If a body is moving with a uniform acceleration its final velocity = 2* average velocity - initial velocity.
(SSC CHSL 06.03.2003)
7. The motion of freely falling body is an example of uniformly accelerated motion.
(SSC CGL Pre. 2022, 01.12.2022 Shift-4)
8. The motion of the body moving along a circular path is an example of **accelerated motion**.

(SSC CGL Pre. 2022, 07.12.2022 Shift-3)

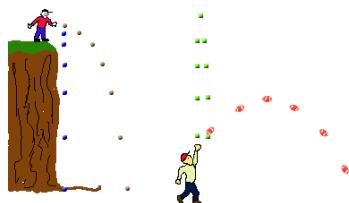
Projectile

Projectile is a motion that followed by the curved path when we throw an object by an angle with the horizontal plane.

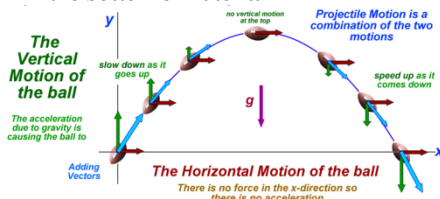
The path followed by a projectile is called its **trajectory**.

(RRB GROUP-D 16.11.2018)



**Examples of projectile are**

1. A body dropped from the window of a moving train. (SSC CHSL 16.11.2014)
2. A bomb released from an aeroplane
3. A bullet fired from a rifle.
4. A piece of stone thrown in any direction.
5. A javelin or hammer thrown by an athlete.
6. A jet of water issuing from a hole near the bottom of water tank.



Path of projectile projected horizontal from a certain height from ground is a parabolic path.

Time of Flight: It is the total time for which the projectile is in flight.

Horizontal Range: It is the horizontal distance travelled by projectile during its flight.

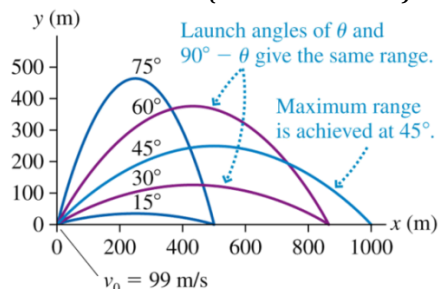
Hence to achieve maximum horizontal range, the object should be projected at **an angle of 45° with the horizontal direction**. This concept has been used by athletes in long

jump, javelin throw, cricket ball throw etc.

(SSC MTS 20.02.2011 & rrb group-d 16.11.2018)

In a projectile motion, fired from earth surface, has horizontal component of its velocity remains constant.

(SSC CGL 11.09.2016)

**Equations of motion**

There are 4 equations of motion that are used to study the motion of an object.

$$v = u + at \text{ (velocity and time equation)}$$

RRB ALP 10.08.18

$$s = ut + \frac{1}{2}at^2 \text{ (position and time)}$$

RRB GROUP-D 22.09.2018 &

28.09.2018 & SSC CHSL 03.06.2022)

$$v^2 = u^2 + 2as \text{ (position and velocity)}$$

RRB GROUP-D 12.12.2018

$$D_n = u + \frac{a}{2} (2n - 1)$$

Where,
u = initial velocity of object

(SSC CHSL 10.03.2018)

v = final velocity of object

a = acceleration of object

-a = negative acc = Retardation

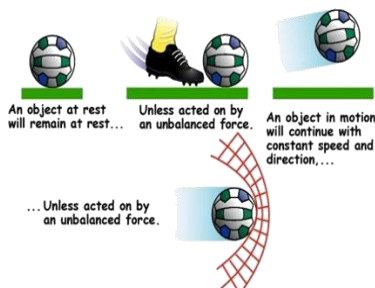
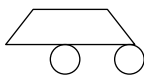
S = distance travelled by object

t = time taken by object

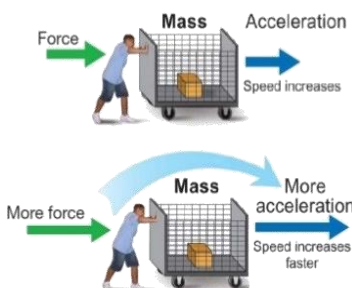
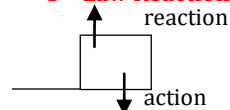
Newton's Laws of Motion**1st Law****(Law of Inertia)**

(SSC CHSL 20.01.2017)

Rest → Stays at Rest
Motion → stays in motion if external force is zero on Body.

**2nd Law**

More acceleration produced when more force is applied

**3rd Law Reaction**

Action = Reaction



D_n = distance travelled in n^{th} second

n = n^{th} second

Motion of an object under free fall, in this we consider Body is moving in uniform motion with constant acceleration g .

Where g = acceleration due to gravity

Taken as positive (+g)	Taken as negative (-g)
Generally, body moving down towards Earth is considered as moving with +g	Generally, body moving upward towards Earth is considered as moving with -g

Equations of motion for a body thrown down from a height with initial velocity = 0 i.e., initially body was at Rest

So, $g = +g$ downwards

$$v = u + at = 0 + gt = gt$$

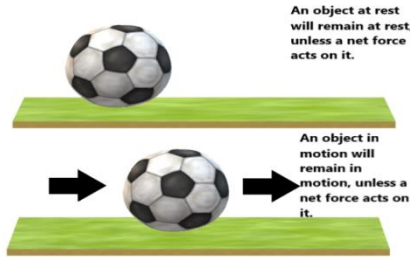
$$S = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}gt^2 = \frac{1}{2}gt^2$$

$$v^2 = u^2 + 2as = 0 + gs = 2gs$$

Note: For a body moving upwards, final velocity of body when it reaches Highest point = Zero (i.e. $v = 0$)

Force and Laws of Newton: There are three laws that are describe by sir Issac newton in 1687.

(SSC CAPFS ASI & DELHI POLICE SI 07.07.2017 & RRB GROUP-D 27.11.2018)

Newton First Law

It states that if a body is at rest or moving at a constant speed in a straight line, it will remain at constant speed unless it is acted upon by a force.

Inertia of a body is measured by the mass of the body. Heavier the body, greater is the force required to change its state and hence greater is its inertia. Inertia is given by a famous scientist that is Galileo Galilei.

The tendency of an object to resist change in static or dynamic condition is called inertia.

(RRB GROUP-D 20.09.2018, RRB JE 02.06.2019, RRB ALP 17.08.2018)

Inertia opposes motion

Body that have more mass than their inertia is also more.

Sometimes Newton 1 law is also called inertia law.

(RRB NTPC 04.01.2021)

Three types of Inertia

1. Inertia of Rest
2. Inertia of Motion
3. Inertia of direction

1. Inertia of Rest

It is the inability of a body to change by itself, its state of rest. This means a body at rest remains at rest and cannot start motion on its own.

For example

1. We are standing in a stationary bus and the driver starts the bus suddenly. We get thrown backwards with a jerk.

(RRB GROUP-D 05.11.2018)



2. When a horse starts suddenly, the rider tends to fall backwards on account of inertia of rest of upper part of the body but our feet had moved with horse in forward direction.
3. The dust particles in a mat fall off when it is beaten with a stick. This is because the beating sets the mat in motion whereas the dust particles tend to remain at rest and hence separate.

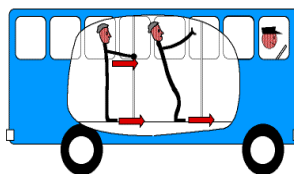
4. When we place a coin on smooth piece of cardboard covering a glass and strike the cardboard piece suddenly with a finger, the cardboard slips away and the coin falls into the glass. This happens on account of inertia of rest of the coin.

5. When we shake a branch of a mango tree, the mangoes fall down. This is because the branch comes in motion and the mangoes tend to remain at rest. Hence they get detached.

(RRB GROUP-D 04.12.2018)

2. Inertia of Motion

It is the inability of a body to change by itself, its state of uniform motion i.e. a body in uniform motion can neither accelerate nor retard on its own and come to rest.

**For example**

1. Suppose we are standing in a moving bus, and the driver stops the bus suddenly. We are thrown forward with a jerk.

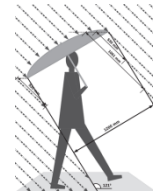
As the bus is suddenly stopped, our feet stop due to friction which does not allow relative motion between the feet and the floor of the bus. But the upper part of our body continues to move forward due to inertia. That is why we are thrown forward. The restoring muscular forces exerted on our body by our feet come into play and bring the body to rest.

2. When a horse at full gallop stops suddenly, the rider falls forward on account of inertia of motion.
3. A person jumping off a speeding train may fall forward. This is because his feet come to rest on touching the ground and the remaining body continues to move due to inertia of motion.
4. An athlete runs a certain distance before taking a long jump. This is because velocity acquired by running is added to the velocity of the athlete at the time of jump. Hence he can jump over a longer distance.
5. When a running car stops suddenly the passenger tends to lean forward because by applying brakes a person moves forward in the direction and the remaining body is in rest.

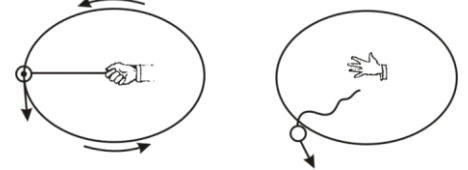
(SSC CHSL 21.10.2012)

3. Inertia of Direction

It is the inability of a body to change by itself, its direction of motion i.e. a body continues to move along the same straight line unless compelled by some external force to change it.

**For example**

1. An umbrella protects us from rain. It is based on the property of inertia of direction.
2. When a stone tied to one end of a string is whirled and the string breaks suddenly, the stone flies off along the tangent to the circle.



3. When a car rounds a curve suddenly, the person sitting inside is thrown outwards. This is because the person tries to maintain his direction of motion due to directional inertia while the car turns.
4. The rotating wheels of any vehicle throw out mud, if any, tangentially, due to directional inertia.
5. When a knife is sharpened by pressing it against a grinding stone, the sparks fly off along the tangent to the grinding stone, on account of directional inertia.

Newton 2 Law:**Momentum**

Momentum is defined as the product of mass and the velocity.

(RRB Group-D 25.09.2018 & SSC CHSL (10+2) 23.03.2018)

Momentum = mass * velocity

(RRB GROUP-D 16.11.2018)

$P = m \cdot v$

(RRB GROUP-D 23.10.2018)

P = momentum

M = mass



$V = \text{velocity}$

The SI unit of momentum is $\text{kg}\cdot\text{m}/\text{sec}$.

(SSC CHSL 30.01.2017)

Momentum is a vector quantity (magnitude and direction both)

(RRB GROUP-D 05/11/18, 12/12/2018 & 26.09.2018)

The rate of change of momentum of an object is proportional to the applied force.

(RRB NTPC 15.02.2021 & RRB GROUP-D 22.09.2018)

Force $\propto$ momentum

$F \propto d/dt mv$

$F \propto m dv/dt$ ($m = \text{constant}$)

$dv/dt = a$

$F \propto ma$

(RRB NTPC 12/02/21 & SSC CGL 20.08.2017)

This is also known as law of force.

(SSC CGL 12.04.2022)

The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the direction as the net force, and inversely proportional to the mass of the object

If a force F is applied on a body and mass of the body is m then formula is ;-

Force $\propto$ mass $\times$ acceleration

$F \propto ma$

$F = k ma$ ($k = \text{constant value} = 1$)

$F = ma$

$F = \text{kg} \cdot \text{ms}^{-2}$

$F = \text{Newton}$

(SSC CHSL 16.11.2014)

Unit of force is newton in SI unit system.

Note:-

- (i) Acceleration is directly proportional to the force.

(SSC CHSL 16.01.2017)

- (ii) 2 law of motion is related to momentum and it also helps to understand the effect.

(RRB GROUP-D 27/11/18), (RRB GROUP-D 30/10/18)

- (iii) If the velocity of the body is doubled then its momentum is doubles. (SSC CHSL 28.03.2018)

Examples:

1. A cricket player lowers his hands while catching a cricket ball. Thus he allows a longer time for his hands to stop the ball.



2. When a person falls from a certain height on a cemented floor, the floor

does not yield. The total change in linear momentum is produced in a smaller interval of time. Therefore, the floor exerts a much larger force. Due to it, a person receives more injury.

On the other hand, when a person falls on a heap of sand, the sand yields. The change in linear momentum is produced in much longer time. The average force exerted on the person by the heap of sand is therefore, much smaller and hence the person is not hurt.



3. **China wares and glasswares are wrapped in paper or straw pieces while packing.** Impact will take a longer time to reach the glass/chinawares. Average force exerted on the china or glasswares is small and changes of their breaking reduce.
4. **The vehicles like scooter, car, bus, truck etc. are provided with shocker.** When they move over an uneven road, impulsive forces are exerted by the road. The function of shockers is to increase the time of impact. This would reduce the force/jerk experienced by the rider of the vehicle.
5. **Bogies of a train are provided with the buffers.** They avoid severe jerks during shunting (joining of different boggies) of the train.
6. **It is difficult to catch a cricket ball than to catch a tennis ball.** The cricket ball being heavier has much larger momentum and therefore, exerts a much larger force on the hands during catch, in comparison to the force exerted by tennis ball.
7. **An athlete is advised to come to stop slowly, after finishing a fast race,** so that time of stop increases and hence force experienced by him decreases.
8. A metal ball and a rubber ball, both having the same mass, strike a wall normally with the same velocity. The rubber ball rebounds and the metal ball does not rebound. It will be concluded that the rubber ball suffers greater change in momentum.

(SSC CHSL 16.11.2014)

Newton 3 law:

If we put an action on a body then it must give an reaction this law of

newton is known as action and reaction law.

It also states that applied force on different body is in opposite direction.

(RRB ALP 31.08.2018)

Action and reaction are always opposite in magnitude.

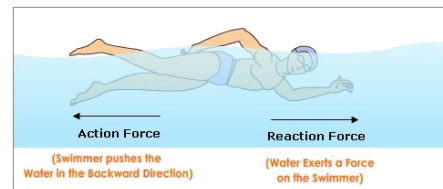
(SSC CAPFS ASI & DELHI POLICE 04.07.2017)

Action and reaction are always act on the same body then the resultant will be zero.

(SSC MULTI TASKING 16.09.2017)

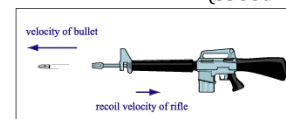
For Example:

1. **Walking:** While walking, a person presses the ground in the backward direction (action) by his feet. The ground pushes the person in the forward direction with an equal force (reaction). The component of reaction in the horizontal direction makes the person move forward.
2. **Swimming:** A swimmer pushes the water backwards (action). The water pushes the swimmer forward (reaction) with the same force. Hence the swimmer swims.

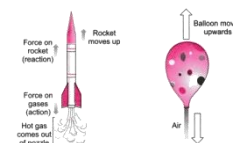


3. **Firing from a gun:** When a gun is fired, the bullet moves forward (action). The gun recoils backwards (reaction). So we are advised to hold our shoulder tightly.

(SSCCGL 10.09.2016)



4. **Flight of jet planes and rockets:** The burnt fuel which appears in the form of hot and highly compressed gases escapes through the nozzle (action) in the backward direction. The escaping gases push the jet plane or rocket forward (reaction) with the same force. Hence the jet or rocket moves



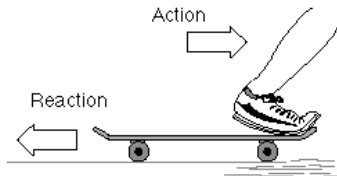
(RRB GROUP-D 02.11.2018 & SSC MULTI TASKING 16.02.2014)

5. **Rebounding of a rubber ball:** When a rubber ball is struck against a wall or



floor, it exerts a force on wall (action). The ball rebounds with an equal force (reaction) exerted by the wall or floor on the ball.

6. **It is difficult to walk on sand or ice:** This is because on pushing, sand gets displaced and reaction from sandy ground is very little. In case of ice, force of reaction is again small, because friction between our feet and ice is very little.

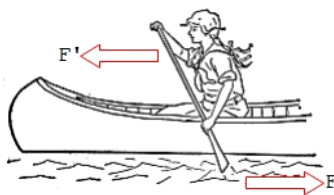


7. **Driving a nail into a wooden block without holding the block is difficult:** This is because, when the wooden block is not resting against a support, the block and nail, both move forward on being hit with a hammer. However, when the block is held firmly against a support, and the nail is hit, an equal reaction of the support drives the nail into the block.



(SSC CGL 09.08.2017)

8. **Rowing of a boat :** In this, the rower push the water backwards and in turn the water push the boat forwards there by boat moves in water



Some Important terms related to the Laws of motion.

1. Mass

It is defined as the amount of the matter inside a body. All the objects have a matter inside them and the measurement of the matter is the mass.

The SI unit of mass is Kilogram.

The dimensional formula for mass is $M^1L^0T^0$

Mass is a scalar quantity.

For ex- The amount of matter in a ball of steel is its mass.

(SSC CHSL 15.11.2015)

Mass and weight both are different terms there is an relationship between mass and weight it is:

$$W = m \cdot g$$

Where, W = weight of the body

m = mass of the body

g = gravitational constant

Here are some terms associated with mass that is

1. **Inertia** = it oppose the motion of the body

(RRB GROUP-D 11.10.2018)

Mass $\propto$ inertia $\propto$

It is also measure the inertia of body.

(SSC CAPFS ASI & DELHI POLICE SI 02.07.2017 & RRB GROUP-D 26.10.2018, 31.10.2018, 11.10.2018)

2. **Density** = mass per unit volume is density.

(RRB JE 30.08.2019, ALP 22.10.2019, RRB GROUP-D 05/10/18)

Density = Mass/volume

2. FORCES

it is defined as physical unit which changes or tends to change the state of rest or uniform motion of an object

(RRB ALP 21.10.2018 & SSC CGL 18.08.2021)

Push Or Pull Of An Object Is Force.

(SSC JE 29.01.2018 & RRB GROUP-D 10.10.2018)

$$F = m \cdot a$$

(RRB ALP 13.08.18 & ssc chsl 19.03.2018)

Where, F = force on a body

RRB GROUP-D 28.11.2018)

m = mass of the body

RRB GROUP -D 04.10.2018)

a = acceleration of the body

RRB GROPU-D 25.09.2018)

The SI unit of force is newton and it is a vector quantity.

The dimensional formula of force is $M^1L^1T^{-2}$

(SSC CGL 21.04.2003)

Example of forces- hoisting the flag , opening a door, lifting the curtain, pushing the boy

Note :

- Forces changes the speed of an object.
(RRB GROUP-D 04.10.2018)
- Force is responsible for changing the state of motion of an objects.
(SSC CAPFS ASI & DELHI POLICE SI 06.07.2017)
- If the force applied on an object is always is in the direction of motion, and the speed of object is increase.
(SSC CGL 19.08.2017)

Properties Of Forces:-

- Forces between two bodies are same and opposite in nature.
- Forces is interaction between two objects.
- Forces have magnitude and direction.
- When two equal forces are acting on a body and in the opposite direction, the force acting on a body becomes zero.

(angle is 180°)



(RRB GROUP-D 16.10.2018 & 28.09.2018)

- When two forces act on a body are same in direction then, total force act on a body is the sum of all the forces.



- Force is never alone in nature. it is mutual interaction between two objects.

Forces Are Divided Into Following Categories:

- Contact force
- Non-contact force

Contact force: Forces in which there is an contact between the surfaces and the object on which force is applied.

Example: Frictional force, normal force, applied force etc.

Non-contact forces: Forces in which there is no contact between the body or an object on which force is applied.

Example: Gravitational force, electrostatic force, magnetic force etc (RRB GROUP-D 04.10.2018)

1. Impulse

A certain amount of force is applied to a body with certain time that changes to cause momentum is called impulse.



The SI unit of Impulse is Newton - Second.

The dimensional analysis of impulse is $M^1L^1T^{-1}$

(SSC CPO 2022, 11.11.2022 Shift-3)

Law of Conservation of Momentum

If the sum of all the external forces (not internal forces) acting on a body is zero, then the change in momentum of the body will also be zero, i.e. momentum of the body will remain conserved or constant. For a body of mass m

$$P_{\text{initial}} = -P_{\text{final}}$$

$$\Rightarrow mv_{\text{initial}} = -mv_{\text{final}}$$

i.e.

- When two billiard balls collide with each other, the law of conservation is followed.
- When two cars hit each other in an accident, the law of conservation of momentum is followed.

SOME KEY POINTS TO REMEMBER:

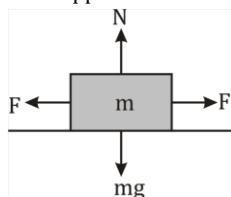
- If momentum is increase then velocity/speed is also increase.
(RRB GROUP-D 05.11.2018 & 26.11.2018)
Momentum $\uparrow$ Velocity
- If momentum is increase then their kinetic energy is doubled.
Momentum = $2 \times$ kinetic energy
Application of momentum:
 - Flying a rocket in a space is working on a principle of conservation.
(RRB GROUP-D 12.11.2018)
(SSC COMBINED MATRIC LEVEL 05.05.2002, SSC (10+2) LEVEL DATA ENTRY 04.12.2011)
- Jet engine works on the principle of conservation of momentum.
(SSC CAPFS ASI & DELHI POLICE SI 02.07.2017)

Friction

The force that opposes the relative motion when one body slips or rolls over another body. The force that exists between the surfaces of bodies is called frictional force.

(RRB GROUP-D 22.09.2018 & 18.09.2018)

For a body of mass m , F is the horizontal force applied to the body,



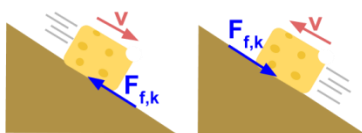
then friction force is $F = \mu N = \mu mg$

(when, $N = mg$) where, μ is coefficient of friction, N = Normal force, F = Applied force mg = Weight

Note:

- Friction is also present in relative motion between two layers of a fluid as the viscous force. It is also produced in gases.
- The work done by force of friction is always negative.
- Rough surface have high friction

(SSC SCIENTIFIC ASSISTANT 24.11.2017)



Types of Friction

Static Friction: It acts on objects when they are resting on a surface

Limiting Friction : The maximum friction that can be generated between two static surfaces in contact with each other. Once a force applied to the two surfaces exceeds the **limiting friction**, motion will occur.

Sliding friction : It is friction that acts on objects when they are sliding over a surface. Sliding friction is weaker than static friction. That's why it's easier to slide a piece of furniture over the floor after you start it moving than it is to get it moving in the first place. Sliding friction can be useful. For example, you use sliding friction when you write with a pencil. The pencil "lead" slides easily over the paper, but there's just enough friction between the pencil and paper to leave a mark

Rolling friction : It is friction that acts on objects when they are rolling over a surface. Rolling friction is much weaker than sliding friction or static friction.

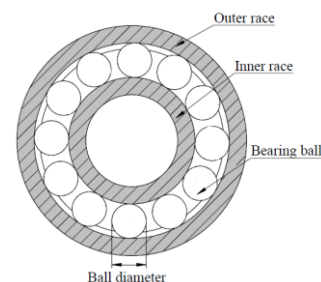
This explains why most forms of ground transportation use wheels, including bicycles, cars, 4-wheelers, roller skates, scooters, and skateboards

NOTE :- **STATIC FRICTION > SLIDING FRICTION > ROLLING FRICTION**

(RRB NTPC 27.04.2016)

Methods of Changing Friction

- By Polishing:** Polishing makes the surfaces smoother.
- By Lubrication:** Oil, Grease.
- By proper selection of materials:** Tyres are made of rubber. This is because friction between rubber and concrete is much less than friction between iron and concrete.



- By Streamlining:** Friction due to air is considerably reduced by streamlining the shape of the body (sharp in front) moving through air. Jets, aeroplanes, fast moving cars etc. are given streamline shape.
- By using Ball Bearings:** It consists of two co-axial cylinders A and C, between which suitable number of hard steel balls B are arranged.
- A thin cushion of air maintained between solid surface.

Note:

- The function of ball bearing in a wheel is to convert kinetic friction into rolling friction.

(SSC CGL 26.06.201)

- Friction can be reduced by polishing surfaces and use of lubricants.

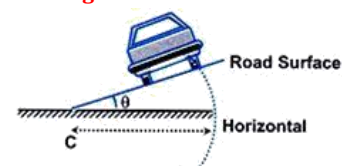
(SSC CAPFS ASI & DELHI POLICE SI

03.07.2017)

Applications:-

- The braking pads of cars.
 - moving a heavy box from one place from to another.
 - playing carom
 - holding a glass tumbler
- (RRB GROUP-D 20.09.2018)
- the movement of the door.

Banking of Roads



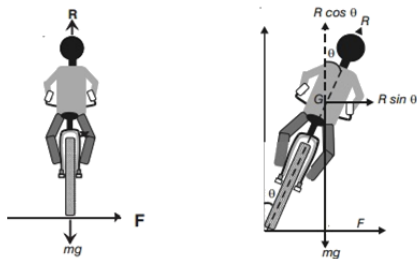
The maximum permissible velocity with which a vehicle can go round a level curved road without skidding depends on μ , the coefficient of friction between the tyres and the road. The value of μ decreases when road is smooth or tyres of the vehicle are worn out or the road is wet and so on. Thus force of friction is not a reliable source for providing the required centripetal force to the vehicle. A safer course of action would be to raise outer edge of the curved road above the inner edge. By doing so, a component of normal reaction of the road shall be spared to provide the



centripetal force. This phenomenon of raising outer edge of the curved road above the inner edge is called banking of roads.

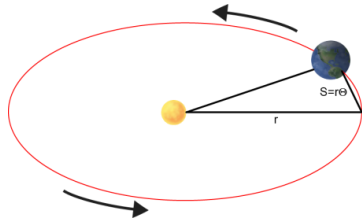
(SSC CGL 08.08.2017)

Bending of A Cyclist



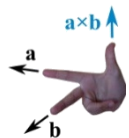
When a cyclist takes a turn, he also requires some centripetal force. If he keeps himself vertical while turning, his weight is balanced by the normal reaction of the ground. In that event, he has to depend upon force of friction between the tyres and the road for obtaining the necessary centripetal force. As force of friction is small and uncertain, dependence on it is not safe. To avoid dependence on force of friction for obtaining centripetal force, the cyclist has to bend a little inwards from his vertical position, while turning. By doing so, a component of normal reaction in the horizontal direction provides the necessary centripetal force.

ANGULAR MOTION



Angular Displacement

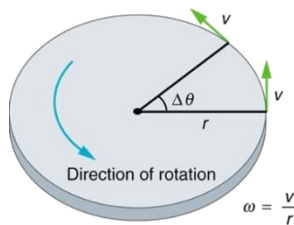
Thus, angular displacement of the object moving around a circular path is defined as the angle traced out by the radius vector at the centre of the circular path in a given time.



Angular Velocity

Angular velocity of an object in circular motion is defined as the time rate of changes of its angular displacement.

It is generally denoted by ω (omega) and is measured in radian per second (denoted by rad.s^{-1}). Its dimensional formula is $[\text{M}^0 \text{L}^0 \text{T}^{-1}]$.



Relation between Linear Velocity and Angular Velocity

$$v = \omega r$$

Angular Acceleration

Angular acceleration of an object in circular motion is defined as the time rate of change of its angular velocity.

$$\alpha = \lim_{\Delta t \rightarrow 0} \frac{\Delta \omega}{\Delta t} = \frac{d\omega}{dt}$$

SI unit angular acceleration is rad.s^{-2} and its dimensional formula is $[\text{M}^0 \text{L}^0 \text{T}^{-2}]$.

Relation between Linear Acceleration and Angular Acceleration

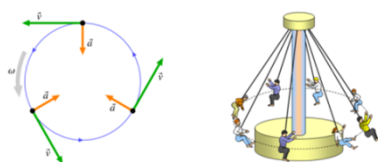
$$a = \alpha r$$

Uniform Circular Motion

When a point object is moving on a circular path with a constant speed (i.e. it covers equal distances on the circumference of the circle in equal intervals of time), then the motion of the object.

In uniform circular motion, the velocity of the object (represented by the tangent to the circular path at a given instant) is changing its direction continuously, hence it is a case of uniformly accelerated motion and their kinetic energy is also changed.

(SSC CGL 27.10.2016)



(a) **Time Period:** In circular motion, the time period is defined as the time taken by the object to complete one revolution on its circular path.

(b) **Frequency:** In circular motion, the frequency is defined as the number of revolutions completed by the object on its circular path in a unit time.

(c) **Relation between time period and frequency**

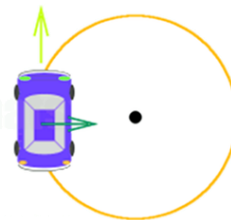
$$T = 1/\nu \text{ or } \nu = 1/T \text{ or } \nu T = 1$$

(d) **Relation between angular velocity, frequency and time period**

$$\omega = \frac{\theta}{t} = \frac{2\pi}{T} = 2\pi \nu$$

Centripetal Force

It is the force towards the centre of circle, which is necessary to bind the motion of a particle on the circular path. It is radially inward to a body. The magnitude of the centripetal force is



$$F_c = \frac{mu^2}{r}$$

where, m is mass of a body on circular track, u is linear velocity of body on circular track and r is radius of circular track.

$$\text{And } F_c = m\omega^2 r = \frac{mu^2}{r} (\because u = r\omega)$$

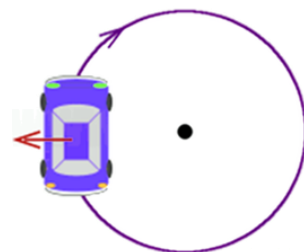
where, ω is angular velocity of the body. For Ex- the moving car around a curve is centripetal force.

(SSC CGL 28.08.2016)

Centrifugal Force

It is radially outward force, which is just opposite to centripetal force (but equal in magnitude). It is emphasized as the imaginary force or pseudo force. The magnitude of centrifugal force,

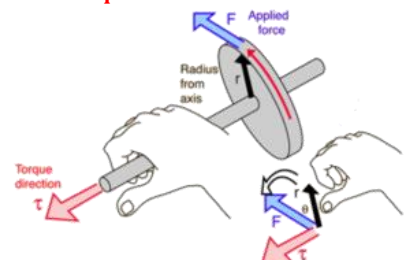
$$F_{cf} = m\omega^2 r$$



where, ω is angular velocity of the body. Cream separator, centrifugal drier, washing machine etc., work on the principal of centrifugal force.

(SSC CGL 29.08.2016, SSC HIGHER SECONDARY LEVEL DATA ENTRY OPERATOR & LDC 27.11.2010, SSC (10+2) 20.10.2003 & 04.12.2011)

Torque



The **moment of a force** or the **torque** due to a force gives us the turning effect of the force about the fixed point/axis. It is measured by the magnitude of force and perpendicular distance of the line of action of force from the axis of rotation.

Torque is represented by a Greek letter τ .

Moment of force or torque = force $\times$ perpendicular distance

$$\vec{\tau} = \vec{r} \times \vec{F} = r F \sin \theta$$

The SI unit of torque is newton-meter(Nm)

(SSC STENOGRAPHER 11.09.2017)

If torque of an body is zero then angular momentum is zero.

(SSC CHSL 20.01.2017)

Angular Momentum

Angular momentum of a body about a given axis is the product of linear momentum and perpendicular distance of line of action of linear momentum vector from the axis of rotation.

$$\vec{L} = \vec{r} \times \vec{p}$$

Principle of Moments

According to the **principle of moments**, a body will be in rotational

equilibrium if algebraic sum of the moments of all forces acting on the body, about a fixed point is zero.

Centre of Mass

If all external forces acting on a body were applied at center of mass, the state of rest/motion of body remains unaffected.

Where mass of body is supposed to be at center of mass.

(SSC CGL 28.08.2016)

Centre of Gravity

The **centre of gravity** (CG) of a body is a point where the weight of the body acts and total gravitational torque on the body is zero.

(RRB GROUP-D 18.09.2018)

Equations of Rotational Motion

Three simple relations between rotational kinematic variables are:

$$(i) \omega = \omega_0 + \alpha t$$

$$(ii) \theta = \omega_0 t + \frac{1}{2} \alpha t^2 \text{ and}$$

$$(iii) \omega^2 - \omega_0^2 = 2 \alpha \theta$$

Rotational Inertia/Moment of Inertia

A quantity that measures the inertia of rotational motion of the body is called

rotational inertia or **moment of inertia** of the body.

MOI depend upon axis of rotation, form of mass and distribution of mass.

(SSC CGL 20.07.2014)

Kinetic Energy of Rotation

Kinetic energy of rotation of a body is the energy possessed by the body on account of its rotation about a given axis.

$$\text{K.E. of rotation} = \frac{1}{2} I \omega^2$$

Radius of Gyration

The **radius of gyration** of a body about a given axis the perpendicular distance of a point P from the axis, where if whole mass of the body were concentrated, the body shall have the same moment of inertia as it has with the actual distribution of mass. This distance is represented by K.

$$K = \sqrt{\frac{r_1^2 + r_2^2 + \dots + r_n^2}{n}}$$

Analogy between Linear Motion and Rotational Motion

Linear Motion	Rotational Motion
1. Distance displacement (s)	1. Angle or angular displacement (θ)
2. Linear velocity, $v = \frac{ds}{dt}$	2. Angular velocity, $\omega = \frac{d\theta}{dt}$
3. Linear acceleration, $a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$	3. Angular acceleration, $\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$
4. Mass (m)	4. Moment of inertia (I)
5. Linear momentum, $p = m v$	5. Angular momentum, $L = I \omega$
6. Force, $F = m a$	6. Torque, $\tau = I \alpha$
7. Also, force, $F = \frac{dp}{dt}$	7. Also, torque $\tau = \frac{dL}{dt}$
8. Translational K.E. = $\frac{1}{2} m v^2 = \frac{p^2}{2m}$	8. Rotational K.E. = $\frac{1}{2} I \omega^2 = \frac{L^2}{2I}$
9. work done, $W = F s$	9. Work done, $W = \tau \theta$
10. Power, $P = F v$	10. Power, $P = \tau \omega$
11. Linear momentum of a system is conserved when no external force acts on the system. (Principle of conservation of linear momentum)	11. Angular momentum of a system is conserved when no external torque acts on the system. (Principle of conservation of angular momentum)
12. Equation of Translational motion (i) $v = u + a t$ (ii) $s = ut + \frac{1}{2} a t^2$ (iii) $v^2 - u^2 = 2 a s$, where the symbols have their usual meaning.	12. Equations of Rotational motion (i) $\omega_2 = \omega_1 + \alpha t$ (ii) $\theta = \omega_1 t + \frac{1}{2} \alpha t^2$ (iii) $\omega_2^2 - \omega_1^2 = 2 \alpha \theta$, where the symbols have their usual meaning.
13. Distance travelled in nth second, $S_{nth} = u + \frac{a}{2} (2n - 1)$	13. Angle traced in nth second, $\theta_{nth} = \omega_1 + \frac{\alpha}{2} (2n - 1)$



03

Work, Energy & Power

Work

When a body is displaced by applying a force on it, then work is said to be done. if a body is displaced by a distance 's' on applying a force F on it,

Then the work done is given by $W = F \cdot S$.

(RRB GROUP-D 10.12.2018 & SSC CGL 17.08.2021)

The SI unit of work is **Joule**.

(SSC CGL Pre. 2022, 01.12.2022 Shift-1)

It is a **scalar quantity**.

If there is an angle θ between the direction of force and direction of displacement, then work done is given by $W = F \cdot S \cos \theta$

(RRB ALP 20.08.2018)



If θ is acute angle, then work is positive.

(RRB GROUP-D 19.09.2018)

If θ is right angle, then work is zero.

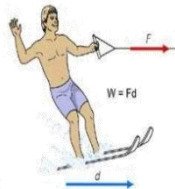
If θ is obtuse angle, then work is negative

(RRB ALP 21.08.2018)

In SI System, the unit of work is Joule.

In CGS system, the unit of work is erg, i.e.

1 joule = 10^7 erg

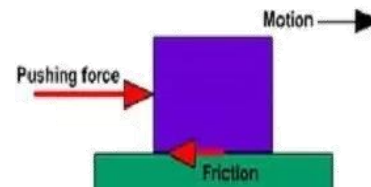
Nature of Work done1. **Positive Work**

Work done by gravity on a body falling freely is positive.

i.e. when force and displacement are in same direction

Work done is positive if

$\theta < 90^\circ$ (**acute angle**)

2. **Negative Work**

Work done is negative if $\theta > 90^\circ$ (**Obtuse angle**)

For example,

- When a body is moved over a rough horizontal surface, the motion is opposed by the force of friction. Hence, work done by frictional force is negative.
- When brakes are applied on a moving vehicle, work done by the braking force is negative.
- When a positive charge is moved closer to another positive charge, work done by electrostatic force of repulsion between the charges is negative.

3. **Zero Work**

(RRB GROUP-D 11.12.2018)

Work done = 0

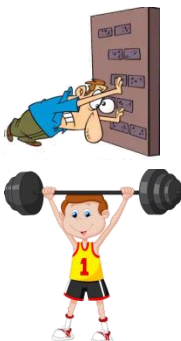
If $S = 0$

Displacement = 0

For example,

(i) When we push hard against a wall, the force we exert on the wall does no work, because $\vec{s} = 0$.

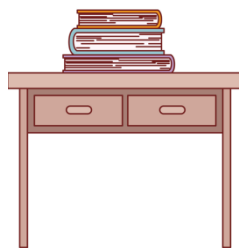
(ii) A weightlifter holding a 100 kg mass steadily on his shoulder for 30 second does no work on the load during this time, because $\vec{s} = 0$.



If $F = 0$

For example,

(i) A block moving on a perfectly smooth horizontal table is not being acted by any external force (as there is no friction).



If $\theta = 90^\circ$

For example,

(i) When a coolie carrying some load on his head moves on a horizontal platform, $\theta = 90^\circ$. Therefore work done by the coolie is zero.

(ii) When a person carrying a brief case moves on a horizontal road, work done by the person is zero.

(iii) When a body tied to one end of a string is rotated uniformly in a circle.

$\theta = 90^\circ$ and $W = F S \cos 90^\circ = 0$.

**NOTE:**

When the direction of the force applied and the direction of movement of the object is perpendicular to each other then no work is done.

(RRB Group-D 24.10.2018)

POWER

Power is measured as the time rate of doing work.

(RRB GROUP-D 15.10.2018)

It is a **scalar quantity**.

It's SI unit is **J/s (joule /sec)** or **watt (W)** and

(SSC CGL 19.10.2014)

CGS system is **erg/s**.

(RRB GROUP-D 05.10.2018)

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}} \Rightarrow P = \frac{W}{t}$$

(RRB ALP 14.08.2018 & RPF SI 24.12.2018)

Some other units of power are as follows

1 kilowatt = 10^3 watt

1 mega watt = 10^6 watt

1 horse power = 746 watt

(RRB GROUP-D 25.10.2018)

Note:

$$\text{Average power} = \frac{\text{Total used energy}}{\text{Total time}}$$

(RRB GROUP-D 25.10.2018 & SSC CHSL (10+2) 21.03.2018)

Energy (RRB Group-D 16.11.2018)

It is the **capacity to do work** and hence energy growth is directly linked to well being and prosperity across the globe.

The unit of energy is Joule in SI unit system.

The unit of energy in CGS system is erg.

The commercial unit of energy is kilowatt-hour. (KWh)



(RRB GROUP-D 18.09.2018 & SSC MTS 18.09.2017 & SSC STENO. 18/11/22 SHIFT-1 & SSC CGL Pre. 2022, 06.12.2022 Shift-4)

Energy in food can be measured in calorie.
(SSC CAPFS ASI & DELHI POLICE SI

One calorie = 4.2 joule

(SSC STENOGRAPHER 12.09.2017)

Electron – volt is a unit of energy.

(SSC CGL 13.08.2021)

NOTE:

(light emitting diode) LED is most helpful in energy

(SSC STENOGRAPHER 12.09.2017)

Types of Energy

Electrical Energy Wherever there's a current flowing, there's electrical energy. 	Light Energy Anything luminous gives off light energy — things like the Sun, light bulbs, candles. 	Sound Energy Anything noisy gives off sound energy — things like Vocal cords, speakers and musical instruments. 
Thermal (Heat) Energy Everything has some heat energy — the hotter it is, the higher is its temperature and the more heat energy it has. 	Gravitational Energy Anything in a gravitational field (i.e. anything that can fall) has potential energy — the higher it goes, the more it has. 	
Chemical Energy Anything with energy which can be released by a chemical reaction — things like food, fuels and batteries. 	Kinetic (Movement) Energy Anything that moves has kinetic energy. 	Elastic Energy Anything stretched has elastic energy — things like rubber bands, springs etc. 

Kinetic Energy

The energy expressed by a body due to its motion (or momentum) is called kinetic energy and it is given by

$$KE = \frac{1}{2}mv^2 = \frac{p^2}{2m}$$

As momentum $p = mv$

$\therefore KE$

$$\frac{(mv)^2}{2m} = \frac{p^2}{2m} \Rightarrow p = \sqrt{2m(KE)}$$

where, v is velocity of the body, m is the mass of body and p is the momentum.

Kinetic energy of a moving body depends upon mass and velocity.

(RRB ALP 14.08.2008 & SSC CGL 02.09.2016)

Falling coconut, wind of a windmill use, a person walking etc.

(RRB NTPC 09.02.2021)

NOTE:

- Kinetic energy is increase with increase in speed.
(RRB GROUP-D 13.08.2018 & SSC CHSL 11.12.2003)
- When the speed of an object is halved, its kinetic energy becomes $\frac{1}{4}$ of the original

(SSC CAPFS ASI & DELHI POLICE SI 03.007.2017)

- If both mass and velocity of a body is increased to twice of their magnitude, the kinetic energy will increase by 8 times.

(SSC CAPFS SI, CIDF ASI & DELHI POLICE SI EXAM-22.06.2014)

- If the momentum of a body is doubled, then the kinetic energy is becomes 4 times.

(SSC MTS 16.09.2017)

- Kinetic energy is the supplied heat energy stored during change in temperature of substances.

(SSC CGL 02.09.2016)

- Gas has more kinetic energy than other of the following state of matter.

(RRB GROUP-D 12.11.2018 & 26.10.2018)

- A stone is dropped from the roof of a house towards the ground. the kinetic energy of the stone will be maximum because we know kinetic energy increase with increase in Speed.

(SSC CHSL 11.12.2003)

- If value of work is positive then the kinetic energy is also increase

(RRB Group-D 20.09.2018)

The energy expressed by a body due to its position in the space is called its potential energy

and it is given by $PE = mgh$ where, g is gravitational acceleration acting on the body, m is mass of body and h is height through which the body is raised.

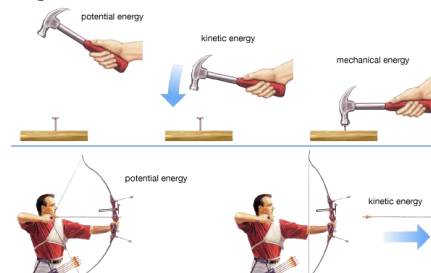
Stretching a rubber band, winding the key of a toy car, a wound watch, when a body falls from an aeroplane, then here is in increase in potential energy etc

(SSC MULTI TASKING STAFF 17.03.2013 & RRB GROUP-D 31.10.2018 & SSC MTS 18.09.2017)

Potential energy is increased with increase in height.

(RRB GROUP-D 23.10.2018)

The kinetic energy of a body is positive while the potential energy either positive or negative.



Potential Energy

Fossil Energy



Fossil fuels are non-renewable sources of energy. It is formed due to decomposition of buried dead organisms. Fossil Fuels contain coal, petroleum and natural gas. Methane can be found in hydrocarbon fuels.

Hydroelectric Energy

Hydroelectric energy is the production of electrical power through the use of the gravitational force of falling or flowing water. In our country, more than 23% of water is used in production of hydroelectric power.

Wind Energy

The energy possessed by wind due to its high speed is called wind energy. So, the wind possess kinetic energy. It is used in production of electricity. Its applications are wind mill, wind generator and wind farm energy.

Wastage Substance Energy

It is renewable source of energy, which is made available from waste materials derived from biological sources. It is used to make methane gas. Gobar gas is an example of wastage substance energy.

Nuclear Energy

It is found, when U^{235} nucleus break up into lighter nuclei on being bombarded by slow neutron, a large amount of energy released is called nuclear energy. Nuclear reactors convert nuclear energy into electricity. It cannot be stored.

Geothermal Energy

Energy that derived from the heat of earth is called geothermal energy.

(SSC CGL 11.06.2019)

The energy that can be harness heat stored below the earth's surface.

(SSC CHSL 04.12.2011)

Mechanical Energy

The sum of potential energy and kinetic energy are mechanical energy.

(RRB ALP 30.08.2018, 13.08.2018 & 10.08.2018)

Mechanical energy = potential energy + kinetic energy

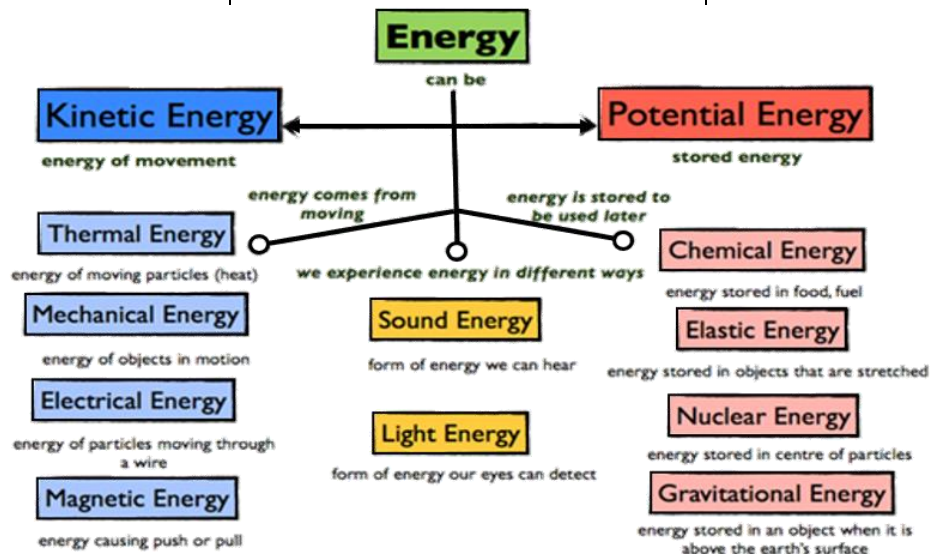
(RRB GROUP-D 01.10.2018, 12.11.2018 & 19.09.2018)

For ex- a flying jet possesses both kinetic energy and potential energy.

(SSC CAPFS ASI & DELHI POLICE SI 03.07.2017)

When a freely falling object eventually stops on reaching the ground its potential energy decreases and its kinetic energy increases.

(SSC STENOGRAPHER 11.09.2017)



Law of conservation of energy

According to the law of conservation of energy, "energy can neither be created nor be destroyed, but it can be transformed from one form to another." e.g. When a knife is rubbed against grinding stone, the mechanical energy changes into heat. When an arrow is stretched in a bow, the muscular energy changes into potential energy

(RRB GROUP-D 11.10.2018, 16.10.2018 & 27.11.2018)

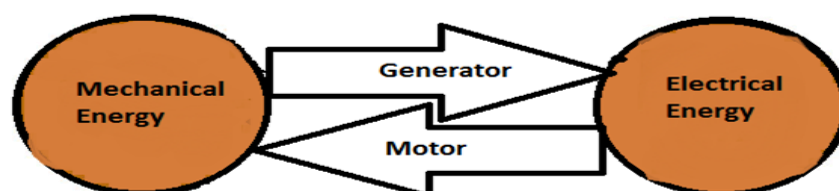
Transformation of energy

The conversion of energy from one form to another is known as transformation of energy. e.g. a freely falling body has its greater speed at the lower level from the earth while with lower speed at higher level from the earth. This is because potential energy is being transformed into kinetic energy for the body. Higher is the height, a body is raised up, higher potential energy it gains.

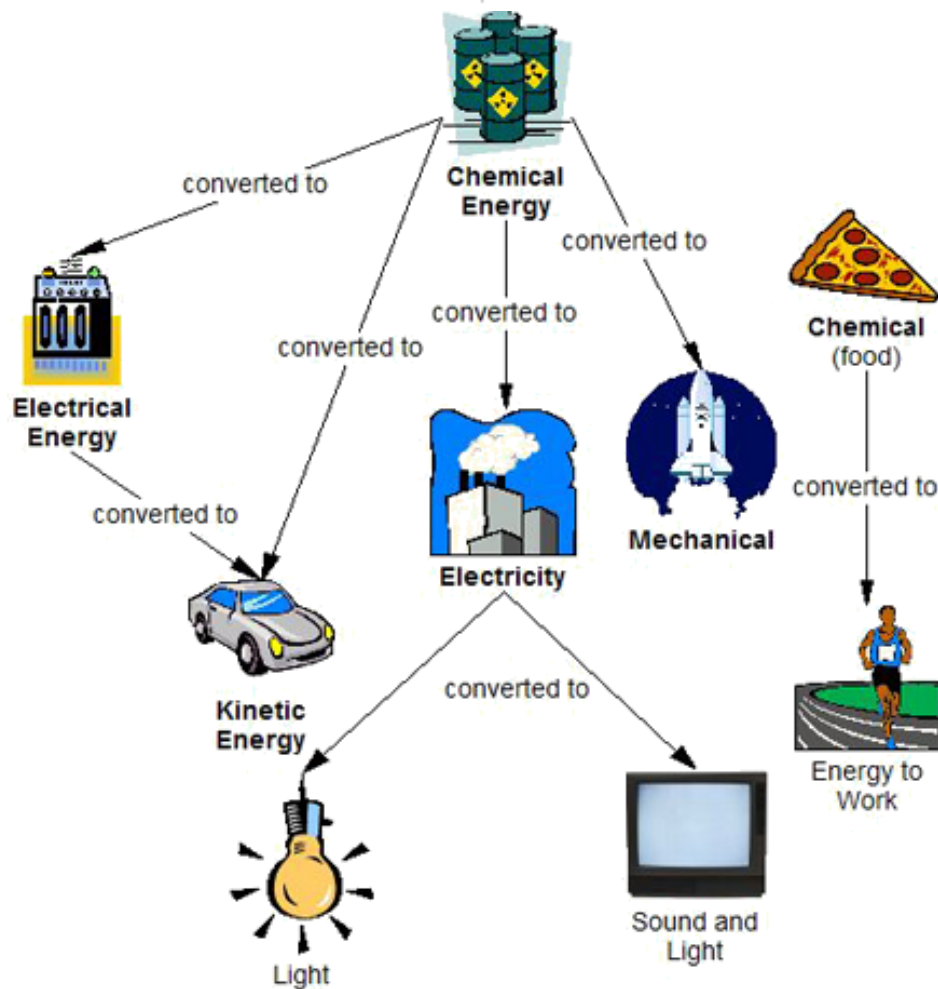
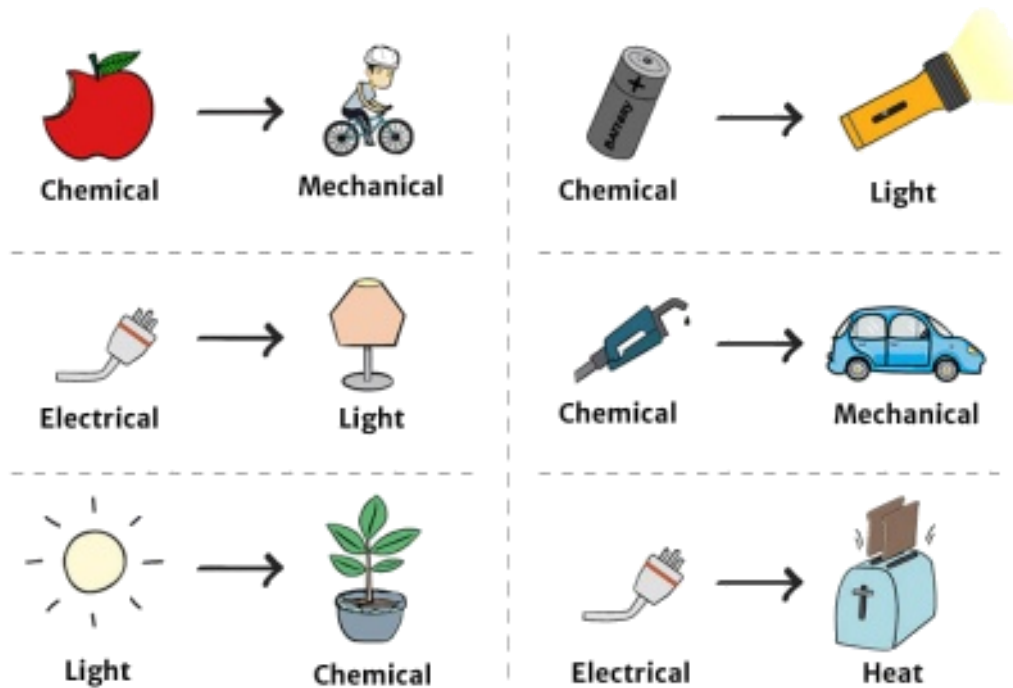
The phenomenon of transformation of energy from useful form to useless form is known as **dissipation of energy**.

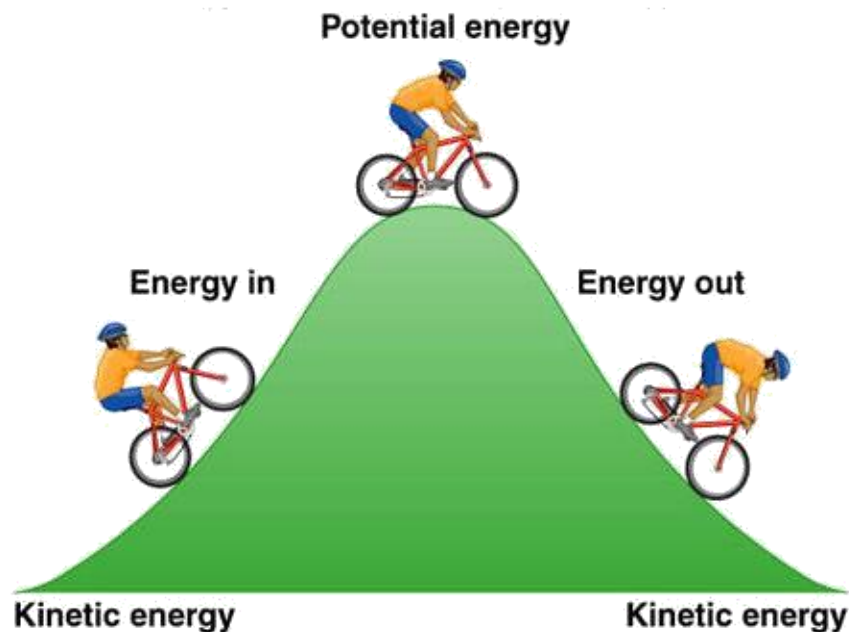
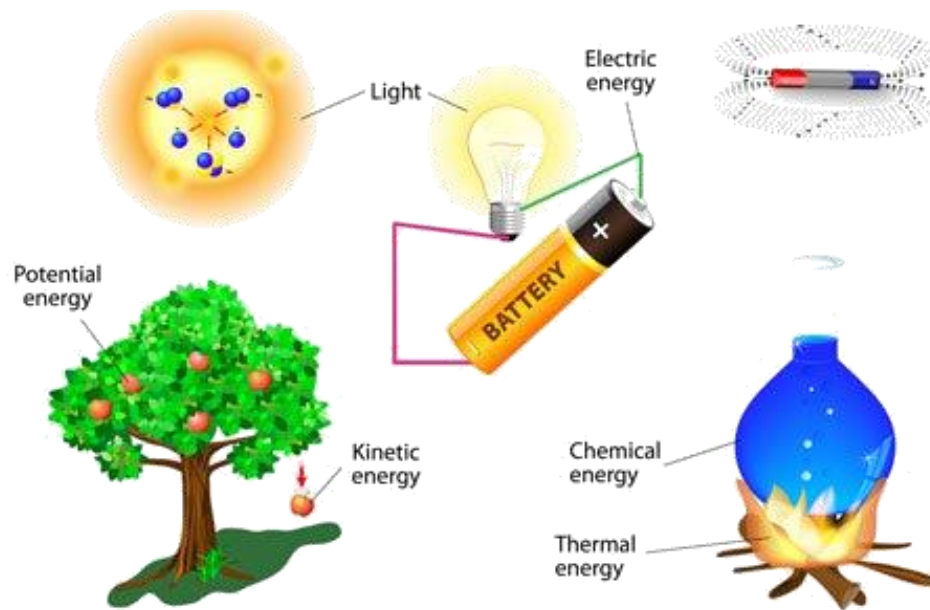
Note:

Transformer is a device, which change the voltage level (either increase or decrease) of electrical energy and does not convert one form of energy into another form.



Energy Conversion





If an object falls freely its potential energy is converted into kinetic energy.

(SSC CHSL 22.03.2018)

Microphone is a device which transforms the sound signal to current signal.

(SSC CGL 11.11.2012 & SSC (10+2) 21.10.2012)

In a water lifting electric pump, we convert electric energy into potential energy.

(SSC MULTI TASKING 17.03.2013)

Photovoltaic cell is a device that is used to convert solar energy into electricity.

(SSC CGL 26.10.2014)

Wind turbine convert kinetic energy into mechanical power.

(SSC CGL 13.06.2019)

Dynamometer is a device that convert mechanical energy initial electrical energy.

(SSC SECTION OFFICER 05.06.2005, SSC TAX ASSISTANT 29.03.2009, SSC CONSTABLE (GD) 22.04.2012, SSC (10+2) 21.10.2012, SSSC DELHI POLICE SI 19.08.2012,)

Rectifier is a device that is used to convert alternating current into direct current

(SSC CGL 28.08.2016)

The current flows in a telephone line is electric energy.

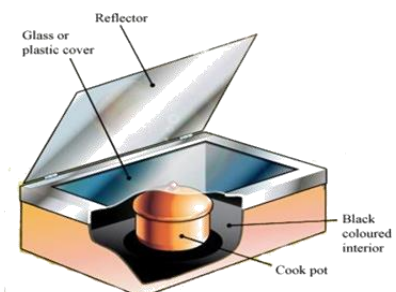
(SSC STENOGRAPHER 14.09.2017)

Hdroelectric power station that converted potential energy into kinetic energy.

Work Energy Theorem or Work Energy Principle

According to this principle, work done by net force in displacing a body is equal to change in kinetic energy of the body.

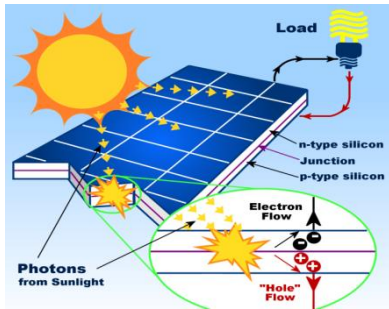
Solar Cooker



A black surface absorb more heat as compared to a white or a reflecting surface under identical conditions. Solar cookers and solar water heaters use this property as their working principle. Some solar cookers achieve a higher temperature by using mirrors to focus the rays of the sun. Parabolic troughs are used to concentrate

sunlight. Solar cooker with parabolic troughs can attain temperature upto 290°C . Solar cookers are covered with a glass plate and hence air trapped around the food and loss of heat energy is minimized as glass is bad conductor of heat.

Solar Panel



A **solar panel**, also known as a **PV (Photo voltaic panel)** or module, is a device that collect sunlight and converts it into electric current. Solar panels collect clean renewable energy in the form of sunlight and convert that light into electricity which can then be used to provide power for electrical loads. Solar panels are comprised of several individual solar cells which are themselves composed of layers of silicon, phosphorous (which provides the negative charge) i.e p type material, and boron (which provides the positive charge) i.e n type material. Solar panels absorb the photons and in doing so initiate an electric current. The resulting energy generated from photons striking the surface of the solar panel allows electrons to be knocked out of their atomic orbits and released into the electric field generated by the solar cells which then pull these free electrons into a directional current. This entire process is known as the **Photovoltaic Effect**. An average home has more than enough roof area for the necessary number of solar panels to produce enough solar electricity to supply all of its power needs. Excess electricity generated goes onto the main power grid, paying off in electricity use at night. In a well-balanced grid-connected configuration, a solar array generates power during the day that is then used in the home at night.

NOTE:

1. A solar panel, also known as a PV (Photo voltaic panel) or module, is a device that collect sunlight and converts it into electric current.
(SSC CAPFS ASI & SI DELHI POLICE SI 04.07.2017)
2. The group of solar cells joined together in a definite pattern is called a solar cell panel.

(SSC CGL 04.09.2016)

3. Direct conversion of solar energy with the use of a photo voltaic cell results in the production of electrical energy.

(SSC CHSL 04.12.2011)

Solar Energy in India:

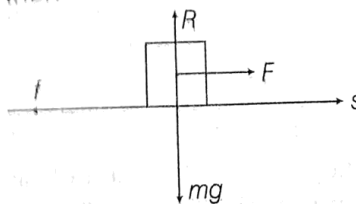
The development of solar energy in India is very beneficial because the geographical conditions of India are helpful in this. The light of the sun has been specially placed for India to meet its energy needs. Another advantage of solar energy is its carbon-free nature.

India receives solar power at the maximum time of the year. In a year, India receives energy equivalent to 5000 trillion kWh per hour. The daily average is 4 to 7 kwh/m² in clear weather.

The total scale allows for domestic and commercial customers who generate electricity from solar power on their own.

Some important units :-

1. **Work** done by a force on the body is equal to the scalar product of force and displacement of body in the direction of force.
Work, $W = \mathbf{F} \cdot \mathbf{s} = F_s \cos \theta$
Where, θ = angle between force (F) and displacement (s)
2. The work done on an object by a force can be positive, negative as well as zero. e.g. If the angle θ is less than 90° , then $\cos \theta$ is **positive** and thus $F_s \cos \theta$ is the work. If θ is greater than 90° (upto 180°), then θ is **negative** and thus $-F_s \cos \theta$ is the work. if θ is equal to 90° , then $\cos \theta$ is zero and thus, leads to **zero** work done.
3. If an object move on rough surface in horizontal direction, then



(i) Work done by reaction force R or mg is $W_1 = 0$ because force and displacement are perpendicular to each other.

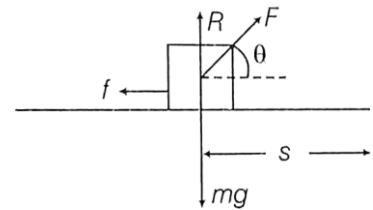
(ii) Work done by pulling force F,
 $W_2 = F_s \cos 0^{\circ} = +F_s$

(iii) Work done by frictional force f,
 $W_3 = f_s \cos 180^{\circ} = -f_s$

(iv) net work done due to all these forces,

$$W_{\text{net}} = W_1 + W_2 + W_3 = 0 + F_s - f_s = (F - f)s$$

4. The work done in revolving the particle on circular path is zero.
As angle between F and s, $\theta = 90^{\circ}$, $W = F_s \cos 90^{\circ} = 0$
5. If angle between force and displacement is θ , then for net work done is given by



$$W = F_s \cos \theta - f_s = (F \cos \theta - f) s$$

7. **Spring force**, $F_s = -kx$, where k is a force constant and x is the extension and compression in the length of spring.
If $x = 0$, then $F_s = 0$
8. **Conservative force** may be defined as one for which work done in moving between two points X and Y is independent of the path taken between the two points.
Work done by a conservative force for a round trip is zero.
9. The force is said to be **non - conservative force**, if the work done by the force depends on the actual path followed by the body for a displacement between any two points.
10. **Energy** is defined as the capacity or ability of a body of do work.
Some commonly used units of energy are
 $1 \text{ erg} = 10^{-7} \text{ J}$
 $1 \text{ cal} = 4.186 \text{ J} \cong \text{J}$
 $1 \text{ kcal} = 4186 \text{ J}$, $1 \text{ k Wh} = 3.6 \times 10^6 \text{ J}$
and 1 electron - volt = $1 \text{ eV} = 1.60 \times 10^{-19} \text{ J}$
11. **Kinetic energy** is the capacity of a body to do work by virtue of its motion. Motion may be either translational or rotational.

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

Where, m = mass of the body
and v = velocity of the body
As momentum $p = mv$

$$\therefore KE = \frac{(mv)^2}{2m} = \frac{p^2}{2m} \Rightarrow p = \sqrt{2m(KE)}$$

12. **Potential Energy** is the energy stored in a body or a system by virtue of its position in a field of force or due to its configuration.



13. **Change in potential energy** of a body between any two points is equal to the negative of work done by the conservative force in displacing the body between these two points without there being any change in kinetic energy. Thus,
 $dU = -dW = -\mathbf{F} \cdot d\mathbf{r}$
 and $U_2 - U_1 = -W = -\int_{r_1}^{r_2} \mathbf{F} \cdot d\mathbf{r}$
 (i) **Elastic potential energy** is given by
 $U = \frac{1}{2}kx^2$
 Where, k = spring constant
 and x = compression or expansion in spring.
 (ii) **Gravitational potential energy** is given by $U = mgh$ where, m = mass of the body,
 g = acceleration due to gravity
 and h = height
 (iii) **Electrostatic Potential energy** is given by
 $U = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r}$
 Where, ϵ_0 = permittivity of medium,
 q_1, q_2 = magnitudes of charges
 and r = distance between charges
14. **Work – energy theorem** states that the work done by all the forces (conservative or non-conservative, external or internal) acting on a particle or on object is equal to the change in its kinetic energy.
 This is given by $K_f - K_i = W$
 Where, K_f and K_i are the final and initial kinetic energies of the body.
15. **Law of conservation of energy** states that the total mechanical energy of a system remains constant if the internal forces are conservative and external forces do not work.
 Thus, when a system passes from one position to other position then
 $U_i + K_i = U_f + K_f$
16. **Power** is defined as the rate of doing work. If an agent does work W in time t , then its average power is given by
 $P_{av} = \frac{W}{t}$
 Power is scalar quantity and its SI unit is watt, where $1W = 1Js^{-1}$
17. **Collision** is defined as an isolated event in which two or more colliding bodies exert relatively strong forces on each other for a relatively short time, as a result of which the kinetic energy and momentum of the colliding particles, change.
 Total linear momentum and total energy of the colliding bodies remain conserved in all sorts of collisions.
18. For every type of collision,
 $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$ (i.e., linear momentum of colliding body or system is conserved) where, m_1 and m_2 = masses of the body which undergo collision, where, u_1 = initial velocity of body of mass m_1
 u_2 = initial velocity of body of mass m_2
 v_1 = final velocity of body of mass m_1
 and v_2 = final velocity of body of mass m_2
19. In a **perfectly elastic collision**, total energy and total linear momentum of colliding particles remain conserved. Moreover, the forces involved in interaction are conservative in nature and the total kinetic energy before and after collision remains unchanged.
20. **Coefficient of restitution** (e) is the ratio of the relative velocity of separation after the collision to the relative velocity of approach before collision,
 i.e. $e = \frac{v_2 - v_1}{u_1 - u_2}$
 For an elastic collision, $e = 1$
 For an inelastic collision, $e < 1$



04**Gravitation****Famous Scientists**

Galileo
Studied that all bodies fall towards earth with constant acceleration

Tycho-Brahe
Studied planets with naked eye.

Theories

Newton
Universal law of gravitation (1665)

Geocentric
Earth at center
By **Ptolemy**

Heliocentric
Sun at center
By **Copernicus**

Kepler Law (RRB NTPC 20/01/21)**1st Law**

Every planet revolves around the sun in an elliptical orbit.
1st Law is based on *Inverse Square Law*.
Closest point – **Perihelion**
Farthest point – **Aphelion**

(RRB NTPC 27.03.2021, 16.04.2016 & 05.04.2016)
(SSC MULTI TASKING STAFF 24.03.2013)

2nd Law

2nd Law (Law of Areas)
Based on *Law of conservation of Angular Momentum*.

3rd Law

3rd Law (Law of Periods)
(Time period) $T^2 \propto R^3$ (Semi major axis)
(SSC CAPFS SI & ASI, DELHI POLICE SI EXAM 20.03.2016)

Some Concepts**Newton's Law of Gravitation**

The force of attraction between two objects is directly proportional to the product of their masses and inversely proportional to the square of distance between them.

(RRB GROUP-D 08.10.2018)

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

(RRB GROUP-D 12.10.12 & 05.11.2018)

where,

G = universal gravitational constant = $6.67 \times 10^{-11} \text{ N-m}^2/\text{kg}^2$.

(SSC CHSL 12.03.2018 & SSC CHSL 01.06.2022)

(RRB GROUP-D 05.10.2018, 20.09.2018 & 23.10.2018)

- G is a scalar quantity.
- The dimensional formula of G is $M^{-1}L^3T^{-2}$ (SSC CHSL 10.11.2013 & 16.11.2014)
- Discover of G had done by **Henry Cavendish**.

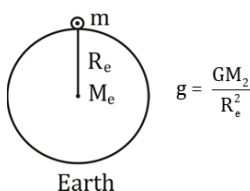
(SSC MTS 09.08.2019 & (SSC CGL Pre. 2022, 08.12.2022 Shift-3)

(RRB ALP 09.08.2018, RRB GROUP-D 22.10.2018 & 30.10.2018)

Acceleration Due to Gravity

The force of attraction exerted by the earth on a body is called gravitational pull or gravity. When this force acts on a body, it produces acceleration to the body.

The acceleration produced in the motion of a body under the effect of gravity is called acceleration due to gravity. It is denoted by g (9.8 m/s^2). Its SI unit is m/s^2 . Then,



Where,

M_e = mass of the earth

r_e = radius of the earth

Note:

- Acceleration due to gravity does not depend on the mass of the object falling below " m ".

(RRB GROUP-D 08.10.2018 & 10.1A)

- Two bodies kept at a certain distance feel a gravitation force F to each other. If the distance between them is made double the former distance, the force will be $\frac{1}{4}$.

(SSC CAPFSSI, CISF ASI & DELHI POLICE SI EXAM 22.06.2014)

- A person can jump higher on the moon surface than on the earth because the acceleration due to the gravity in moon smaller than that of the earth.

(SSC CGL 16.08.2015)

Example of Gravity are:

- Keeps the stars connected together.
- The moon it is in orbit.
- Tides due to moon and sun.
- Moon movement around the earth (RRB GROUP-D 01.12.18 & 15.10.2018)
- The force that binds us to the earth.
- Atmospheric air is held to the earth by gravity

(SSC CGL 26.06.2011)

Gravitational Field

The space surrounding the material body in which its gravitational force of attraction can be experienced is called gravitational field. The intensity of gravitational field at a point is equal to the force acting on the unit mass

at that point and it is given by $\frac{GM}{r^2}$.

Gravitational Potential

Gravitational potential at a point in gravitational field is equal to the work done in carrying a unit mass from infinity to that point. Gravitational potential due to mass m

at a distance r is $V = -\frac{GM}{r}$

Gravitational Potential Energy

Gravitational potential energy of a body at a point is equal to work done in assembling the system of masses from the infinity to its present configuration. Gravitational



potential energy of mass m at a distance r is

$$U = -\frac{GM_e m}{r}$$

Potential energy of a particle of mass m on

the earth's surface is $U = -\frac{GM_e m}{R_e}$

Satellite

A satellite is a body which is revolving continuously in an orbit around a comparatively much larger body.

Natural

The satellite are

Artificial

These are man-made

made by nature

Earth: moon is a natural satellite

Jupiter: Has 16 natural satellites

Saturn: 18 natural satellites (moons)

• 1st artificial satellite was launched by RUSSIANS' (Sputnik I on 4 oct, 1957)

• India: 1st Artificial satellite, Aryabhata in 1975

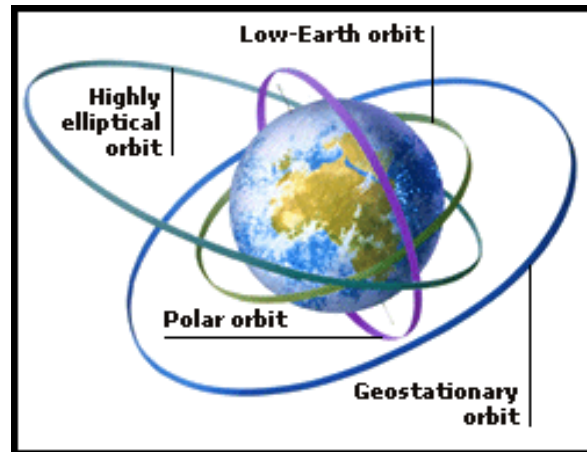
• Some other satellites launched by India

• Bhasker, Rohini, Apple, IA, IB, Insat, IRS.

Note:

Radiowaves are used for communication in artificial satellites.

(SSC CAPFS ASI & DELHI POLICE SI 02.07.2017)



Types of Satellite

Geo Stationary Satellite/ Geosynchronous Satellite

- It appears **stationary** to an observer on earth.
- It rotates with **same angular speed** as that of earth.
- **Speed** of satellite Relative to Earth = **0**
- Its period of revolution is **24 hours** (RRB NTPC 17.01.2017)
- It should be at a height nearly **36000 km** above the equator of earth. (SSC MTS 27.02.2011)
- Its orbital speed is nearly **3.1 km/s**
- These are used for short range warning

Polar Satellite

- These are those satellites which revolve in polar orbits around earth.
- The altitude of polar satellites is about **500 to 800 km** from the surface of the earth.
- The time period of revolution of polar satellites is about **100 minutes**.
- A polar satellite crosses any location on earth **many times a day**.
- Every location on earth lies within the observation of polar satellite **twice each day**.
- These are used for long term forecasting.

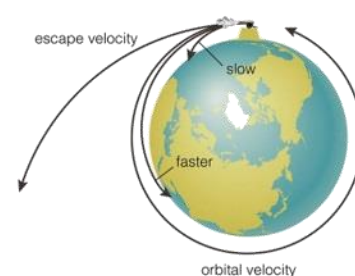
The minimum number of geostationary satellite needed for un interrupted global coverage is 2.

(SSC MTS 20.02.2011)

Meteorology: It is a branch of atmospheric sciences which involves atmospheric physics and atmospheric chemistry with a major focus on **weather forecasting**.

Some key terms

Orbital Speed



It is the minimum speed required to put the satellite into a given orbit around earth.

Orbital Speed of a satellite

- (i) It is independent of the mass of satellite

(ii) It decreases with an increase in the radius of orbit or increase in the height of satellite.

(iii) It depends upon the mass and radius of the earth/planet around which the revolution of satellite is taking place.

Direction of orbital speed of satellite at an instant is along the tangent to the orbital path of satellite at the instant.

Binding Energy

The energy required to remove the satellite from its orbit around the earth to infinity is called **Binding energy** of the satellite. Binding energy is equal to negative value of



total mechanical energy of a satellite in its orbit.

Escape Velocity/ Speed

Escape speed on earth (or any other planet) is defined as the minimum speed with which a body has to be projected vertically upwards from the surface of earth (or any other planet) so that it just crosses the gravitational field of earth (or of that planet) and never returns on its own.

Earth escape velocity is 11.2 km/sec.

In our solar system Venus has the lowest escape velocity with

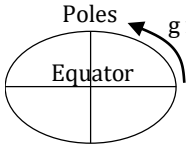
Time Period

It is the time taken by satellite to complete one revolution around the earth and is denoted by T.

Terms Related to Satellite	
Orbital Speed v_0 When a satellite is orbiting very close to the surface of earth. $v_0 = 7.92 \text{ km s}^{-1}$	Binding Energy BE = - Total Mechanical Energy of Satellite
Escape Velocity/ Speed For earth = 11.2 km/sec	Time Period For Earth, T = 84.6

(RRB NTPC 18.01.2017 & SSC CHSL 13.01.2017)
For moon = **2.3 km/sec**
For sun = **618 km/sec**
For Venus = **10.36**
Km/sec. (minimum)
(SSC STENO. 18.11.2022 SHIFT-3)

Minutes

Variation of g			
Variation with height As height increases, gravity decreases At h = radius of earth $h = 6400 \text{ km}$, $G' = g/4$ Gravity becomes one fourth	Depth As depth inside earth $\uparrow$, $g \downarrow$ At centre of earth, $g = 0$ $g = \text{max}$ at surface of earth	Shape of Earth Value of g is max. at poles and min at equator. (RRB NTPC 02.03.2021 & ALP 23.01.2019)  As we move from equator to poles, value of g increases	Speed of Rotation of Earth As rotational speed of earth increases, $g \downarrow$ at all places except at poles. $g' = g - R\omega^2 \cos^2 \lambda$ (ω = angular speed of rotation of earth $\lambda = 90^\circ$ at poles & 0 at equator)

- The value of g is minimum at equator and maximum at poles (it happens due to shape of the earth) And zero at the centre of the earth
- Value of g also depends upon the mass and radius of earth. Through the mass of the earth is fixed and the value of radius is ever changing because the earth is not round instead sphere in shape.

(RRB JE 14.12.2014 & RRB GROUP -D 12.11.2018)

(RRB NTPC 02.03.2021)

The variation of g in lift			
Lift moves up	Lift goes down	Lift moves with uniform speed	Lift rope breaks
When lift moves up in, then the value of g and W is increased. Lift up $\uparrow$ $g \uparrow$ $W \uparrow$ (RRB NTPC 07.04.2016)	When lift goes down, then the value of g and W is decrease. Lift down $\downarrow$ $g \downarrow$ $W \downarrow$ (SSC CGL 16.08.2015)	When lift moves up or down at a uniform speed, then there will be no change in the weight or g . Uniform No g No W	If lift rope was break then person falls down like a free body and there weight and g is zero. rope (*), $g = 0$, $w = 0$

Note:

Mass do not change whether the lift goes up or lift goes down or if it in rest because it is a property that do not effect by gravity. it is a quantity that matter possessed by a body.

(SSC CHSL 10.11.2013)

WEIGHT

Force of gravity exerted on an object is called weight.

Weight = mass * gravitation acceleration

$W = m \times g$

$W = \text{kg} \times \text{m/s}^2$

$W = \text{Newton (kg} \times \text{m/s}^2)$

The SI unit of weight is Newton(N).

Weight of a body is maximum at poles and minimum at equator because it directly depend on the gravitation acceleration.

(SSC CHSL 04.11.2012)

Weight of a body is act through the center of gravity.

(SSC MULTI TASKING 23.02.2014)

Weight of a body at the centre of a earth is zero.

(SSC CAPFS CPO SI & ASI, DELHI POLICE SI EXAM 20.03.2016)

If we move from the equator to the north and south poles then its weight increase.

(RRB GROUP-D 22.10.2018)

- The weight of the body is increase when we move from equator to poles

(RRB GROUP-D 22.10.2018)

Weight of a body on a moon:

Moon, $^1 = \frac{g}{6}$

Weight, $w^1 = \frac{w}{6}$

Weight of body on moon is 1/6 of earth.

(SSC CAPFS ASI & DELHI POLICE SI 05.07.2017 & SSC CAPFS SI, DELHI POLICE SI & CISF ASI EXAM 12.12.2019)

When An Object Is Transferred From Earth To Moon Then Its Mass Remains Same.

(SSC STENOGRAPHER 14.09.2017)

Free fall

It is a motion in which only the gravity force applies on body.

Free fall is possible only in vaccum.

(RRB GROUP-D 19.09.2018)

Under free fall condition the body falls into state of weightless.

(RRB GROUP-D 10.10.2018)

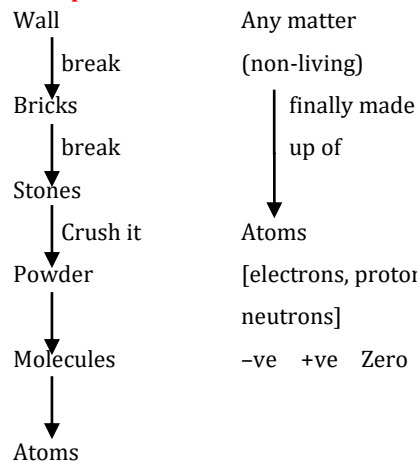
During the free fall of the object the decrease in potential energy, at any point in its path, appears as a n equal amount of increase in kinetic energy.

(SSC CHSL 20.03.2018)



Concept of charge: - As we know, every material is made up of atom.

Concept of Atom



Charge or Electric Charge: It is the physical property of matter that causes it to experience a force when placed in electromagnetic field.

Electric Charge is of 2 types	
Positive Charge (+)	Negative Charge (-)

Depending on the no. of electrons, a body acquires **+ve or -ve** charge.

If a body has excess of electron then it said to be **Negatively charge**.

If a body is deficient of electron then it said to be **Positively charge**.

Charge on electron is considered negative

Charge on proton is considered positive

The SI unit of electric charge is a coulomb (C).

(SSC CGL Pre. 2022, 05.12.2022 Shift-2)

Charge on electron or proton is e where $1e = 1.6 \times 10^{-19}$ coulomb (C).

Quantization of charge: It states that charge on anybody will always be an integer multiple of 1 unit of charge

i.e. charge $Q = ne$;

n = no. of electrons

e = charge on 1 electron

Ex: If an atom gains 10 electrons from outside, charge = $-ve = 10 \times 1.6 \times 10^{-19}$ C

Like charges and Unlike charges

$\begin{matrix} + & + \\ - & - \end{matrix} \left[\text{Repel} \right]$
 $\begin{matrix} + & - \\ - & + \end{matrix} \left[\text{Attract} \right]$

Like charges repel each other Unlike charges attract each other

It is a **scalar quantity**.

Properties of Electric Charge

- Two like charges repel each other, while two unlike charges attract each other.
- Charge is invariant.

- A charged body attracts lighter neutral body.
- During any process, the net electric charge of an isolated system remains constant.
- Charge is conserved i.e., it can neither be created nor be destroyed.

Density and charge Density

$$\left[\text{Density} = \frac{\text{Mass}}{\text{Volume}} \right]$$

Linear Charge Density **Surface Charge Density** **Volume Charge Density**

$$\lambda (\text{lambd}) = \frac{\text{Charge}}{\text{Length}}$$

$$\sigma (\text{Sigma}) = \frac{\text{Charge}}{\text{Area}}$$

$$\rho (\text{rho}) = \frac{\text{Charge}}{\text{Volume}}$$

Conservation of Charge

Conservation of charge is the property by virtue of which total charge of an isolated system always remains constant or conserved.

(Isolated system is the system in which there is no effect of external environment on the internal properties of the system)

Additivity of Charge

Additivity of charge is a property by virtue of which total charge of system is obtained simply by adding algebraically all the charges present anywhere on the system.

$$q = q_1 + q_2 + q_3 + \dots + q_n$$

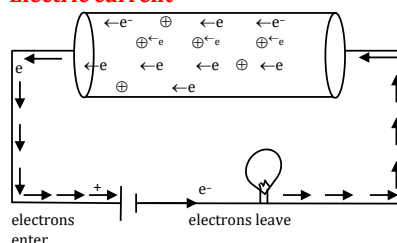
Power signs have to be used while adding the charges in a system. For example, if a system contains charge $+q$, $-2q$, $+3q$ and $+3q$ and $+5q$, then the total charge of the system is $= +q - 2q + 3q + 5q = +7q$

Superposition Principle

According to superposition principle, total force on any charge due to a number of other charges at rest is the vector sum of all the forces on that charge due to other charges, taken one at a time. The forces due to individual charges are unaffected by the presence or absence of other charges.

$$\vec{F}_0 = \vec{F}_{01} + \vec{F}_{02} + \vec{F}_{03} \dots + \vec{F}_{0n}$$

Electric current



When a battery source is connected to a wire, it creates a force on electrons due to which electrons move in fixed direction and

this movement of electrons produces a current.

Or Current is a term to represent movement of charge carriers.

(RRB JE 23.05.19)

The electric current in a circuit is made possible by the motion of free electron.

(RRB ALP 17.08.21, RRB JE 14.12.14, RRB GROUP-D 11.10.18)

SI unit of Current is Ampere (A).

Direction of Current: Electrons flow from **Negative (-ve) to Positive (+ve)** direction

Electric Current is a scalar quantity.

(SSC CGL 08.08.2017)

The frequency of electric current is zero.

(SSC CGL 03.09.2016)

A Wire that carrying current is negatively charged.

(SSC MTS 10.03.2013)

Formula for Current

As current = flow of charge carriers

= movement of charge carriers

= change in position of charge carries with time

$$\text{Current} = \frac{\text{Charge}}{\text{time}}$$

$$I = \frac{Q}{t} \text{ or } 1 \text{ Ampere} = \frac{1 \text{ Coloumb}}{1 \text{ Sec}}$$

(SSC CPO 2022, 11.11.2022 Shift-2)

& SSC CGL Pre. 2022, 08.12.2022 Shift-2)

or $Q = IT$

(RRB JE 25.05.19)

Conductor/Insulator of Electricity:

The material which allow current to pass from it very easily is known as **Conductor**.

Eg: copper, aluminium, zinc, gold, nichrome, silver

(RRB GROUP-D 02.11.18)

The material which do not allow current to pass from it or if pass then very negligible amount of current is pass, then it known to be **Insulator**.

Eg: dry wood, bakelite, asbestos, ceramic, diamond, paper, mica and quartz, nitrogen, oxygen, sulphur.

(RRB JE 29.05.19, RRB ALP 29.08.18, RRB GROUP-D 16.11.18)

Types of Electric Current

According to its magnitude and direction, electric current is of two types as given below

AC and DC are the form of voltage flow.

(RRB NTPC 30.04.16)

1. Direct Current (DC)

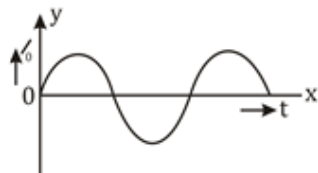
An electric current whose magnitude and direction do not change with time, is called direct current.



E.g. a cell, battery or DC dynamo are the sources of direct current.

2. Alternating Current (AC)

An electric current, whose magnitude changes continuously and direction changes periodically is called alternating current, e.g. AC dynamo is the source of AC.



Current Density

Current Density (J) at a point in a conductor is defined as the amount of current flowing per unit area of the conductor around that point provided the area is held in a direction normal to the current.

I be the current

Cross-sectional area A

$$J = \frac{I}{A} = \frac{q/t}{A}$$

$$I = JA \cos \theta = \vec{J} \cdot \vec{A}$$

Mobility

Mobility of charge carrier (μ), responsible for current is defined as the magnitude of drift velocity of charge per unit electric field applied, i.e.

$$\mu = \frac{\text{drift velocity}}{\text{electric field}} = \frac{v_d}{E}$$

where Drift Velocity (v_d) is the velocity acquired by the electrons present inside a wire when it is placed inside external electric field (E).

Average Relaxation

Average Relaxation time

$$= \frac{\text{Mean free path of electron}}{\text{drift speed of electron}}$$

Drift Velocity

Drift velocity is defined as the average velocity with which the free electrons get drifted towards the positive end of the conductor under the influence of an external electric field applied.

The drift velocity of electrons is of the order of 10^{-4} ms^{-1} . It is denoted by V_d .

Circuit Diagram

S. No.	Component	Symbol
1	An electric cell	
2	A battery or a combination of cells	
3	Plug key or switch (open)	
4	Plug key or switch (closed)	
5	A wire joint	
6	Wires crossing without joining	
7	Electric bulb	
8	A resistor of resistance R	
9	Variable resistance or rheostat	

Ohm's Law

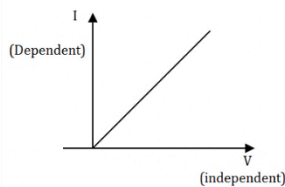
In 1827, a German physicist George Simon Ohm found the relationship between the current I , flowing in a metallic wire and the potential difference across its terminals.

(SSC STENO 17/11/2022 SHIFT-2)

The potential difference V , across the ends of a metallic wire in an electric circuit is directly proportional to the current flowing through it, provided its temperature remains the same. This is called Ohm's law.

(RRB JE 14.12.14, RRB GROUP-D 11.10.18, 10.10.18, 26.11.18, 13.12.18, 15.10.18 & SSC CAPF 05.06.2016)





In other words

$$V \propto I$$

$$\text{Or } V/I = \text{constant}$$

$$V/I = R$$

$$V = IR$$

$$V = A \times \Omega$$

(SSC CHSL 06.06.2012)

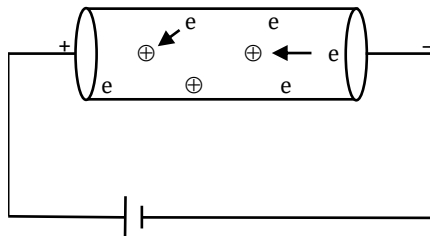
Where, V= voltage

R= resistance I = Electric current

Ohm's law valid in case of conductor.

(SSC CHSL 10.11.2013)

Resistance



Resistance is the measure of opposition to current flow in an electrical circuit.

The ratio of applied voltage to the current through the material is then known as resistance.

(RRB ALP 21.08.18)

SI unit of resistance is ohm (Ω).

(SSC CHSL 05.07.2019)

According to Ohm 's' law ,

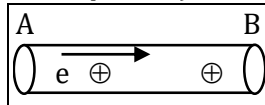
$$R = V/I$$

(RRB ALP 21.08.18)

$$1 \Omega = 1 \text{ volt} / 1 \text{ ampere}$$

Factors on which resistance depends:

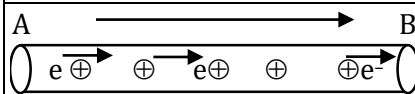
1. $R \propto l$ (Length of conductor) (Directly Proportional)



Here e^- has to travel smaller distance to reach from A to B

So, faces less hindrance

Hence $R = \text{less}$

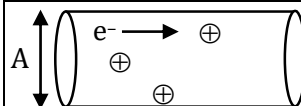


Here e^- has to travel more distance to reach from B to A

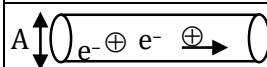
So, faces more hindrance

Hence $R = \text{high}$

2. $R \propto \frac{1}{A}$ (Cross sectional area of conductor) (Inversely Proportional)



e^- has more space to cross so, faces less hindrance
i.e. $R = \text{less}$



e^- has to cross narrow space so faces more hindrance,
i.e. $R = \text{high}$

3. The nature of the material

Formula for resistance

$$R \propto l$$

$$R \propto 1/A$$

$$\text{Then, } R \propto l/A$$

$$R = \frac{\rho l}{A}$$

ρ → resistivity
 l → length of wire
 A → Area of wire

$$\rho = \frac{RA}{l}$$

ρ (rho) is a constant of proportionality and is called the electrical resistivity of the material of the conductor.

The SI unit of resistivity is Ωm .

Resistivity in decreasing order

	Material	Resistivity (Ωm)
Conductors	Silver	1.60×10^{-8}
	Copper	1.62×10^{-8}
	Aluminium	2.63×10^{-8}
	Tungsten	5.20×10^{-8}
	Nickel	6.84×10^{-8}
	Iron	10.00×10^{-8}
	Chromium	12.09×10^{-8}
	Mercury	94.0×10^{-8}
	Manganese	1.84×10^{-6}
Alloys	Constantan (Alloy of Cu and Ni)	49×10^{-6}
	Managanin (Alloy of Cu, Mn and Ni)	44×10^{-6}
	Nichrome (Alloy of Cu, Mn and Ni)	100×10^{-6}
Insulators	Glass	$10^{10} - 10^{14}$
	Hard Rubber	$10^{13} - 10^{16}$
	Ebonite	$10^{15} - 10^{17}$
	Diamond	$10^{12} - 10^{13}$
	Paper (dry)	$10^{12} - 10^{13}$

Insulator > alloys > Conductors

The metals and alloys have very low resistivity and because of this they are good conductors of electricity. While the insulator has good resistivity and they are bad conductor of electricity.

Rheostat- A device that is used to change the resistance in a circuit.

Resistor -it is type of component that limit or regulates the electric current in a circuit.

In some electrical gadgets , we often use resistors in various combinations. That is :-

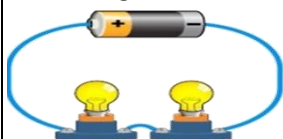
Resistor in series or parallel

(RRB GROUP-D 12/11/18)

(i) Series

(ii) Parallel

Series	Parallel
Current remains same	Voltage is same
When two or more resistor are connected in series then same amount of current flows through them but voltage across each resistor is different from each other. If there is any broken or fault occur in the circuit then the entire circuit is turned off.	When two or more resistor are connected in parallel then same amount of voltage flows through them but current across each resistor is different from each other. If any fault occur, then it easily disconnected or connected easily.
So, total resistance is $R = R_1 + R_2 + R_3$	So, total resistance $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$
Ex- street light	Ex- Electric bulb and electric heater



Temperature effect on Resistance

Conductor	Semi-Conductor
Temperature $\uparrow$, $R \uparrow$ (fixed ion vibration $\uparrow$)	Temperature $\uparrow$, $R \downarrow$ (Because more charge carriers are present)

Materials used for making Resistance

Manganin: It is in an alloy of Copper Manganese and Nickel.

Eureka: It is in an alloy of Copper and Nickel

Constantan: It is in an alloy of Copper and Nickel

NOTE:

(i) The resistance of human body (dry condition) is of the order of 10^4 .

(SSC CGL 19.10.2014)

(ii) Pure silicon is the substances, the resistance decreases with increases in temperature.

(SSC (10+2) 21.10.2012)

(iii) If electric resistance is to be decreased, then the number of resistances should be connected in parallel.

(SSC CGL 31.08.2016)

(iv) Resistance depends upon the **resistivity, length of wire & area of Crosssection.**

(SSC JE 22.01.2018 & SSC JE 24.01.2018)

(v) Higher is the resistance of material, Lower is its conductance.

(vi) Resistance is affects by temperature, nature of substance, conductor length, area of transverse passage.

(RRB GROUP-D 03.12.18, 17.09.18, 12.12.18)

(vii) Wheatstone bridge is used for measurement of resistance value & it have Wheatstone bridge is an arrangement of **four resistors** used for accurate measurement of resistance.

(RRB JE 14.12.14,

(SSC CPO 2022, 11.11.2022 Shift-2)

(viii) Current controller is used to control the resistance in electric circuit.

(RRB GROUP-D 11.10.18)

Electrical Circuit

Electrical circuit consists of electrical components, connective wire, cells (batteries) and plug keys.

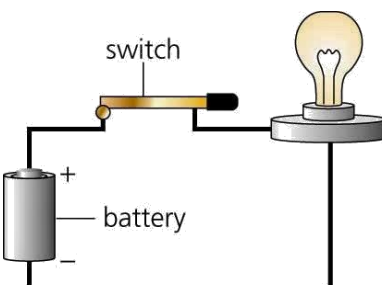
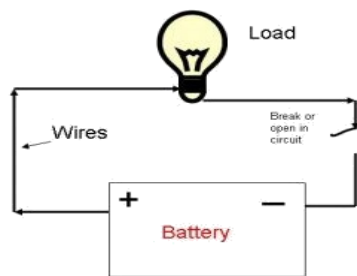
(RRB GROUP-D 12.11.18)

A continuous conducting path consisting of wires and other resistances and a switch between the two terminal of a cell or a battery along which an electric current flow is called a electric circuit.

A closed and continuous path of electric current is called electric circuit.

(RRB JE 27.05.19)

Open Circuit: When no load is connected across battery **Closed Circuit:** When current flows through load.



Circuit is Incomplete So, No current flows

As the circuit is complete so current flows

Electrical Conductivity (σ)

Electric conductivity (σ) of a conductor is defined as the reciprocal of its resistivity. It is represented by σ ,

$$\text{i.e. } \sigma = 1/\rho$$

Electrical conductivity depends on the following factors:

(i) Nature of material of conductor: As number density of electrons is different and $\sigma \propto n$ (number density of electrons in a conductor), so conductivity of different material is different.

(ii) Temperature of the conductor: When temperature of the conductor increase then the value of relaxation time τ decreases.

As $\sigma \propto \tau$, so, conductivity of a conductor decreases.

	Symbol unit	
Current	I	Ampere (A)
Charge	Q	Columb (C)
Resistance	R	Ohm (Ω)
Conductance	G	Siemens or mho (Ω)

Electrostatic Shielding

Electrostatic shielding/screening is the phenomenon of protecting a certain region of space from external electric field.

Relaxation time is the **time** interval between two successive collisions of **electrons** in a conductor, when current flows.

Super Conductivity

As the temperature decrease, the resistance of the material also decreases, but when the temperature reaches a certain critical value (called critical temperature or transition temperature), the resistance of the material completely disappears i.e., it becomes zero.

(SSC CGL 20.07.2014)

So, Superconductivity is the property by virtue of which a metal alloy or oxide etc. shows zero resistance at a very low temperature.

(SSC CGL 19.10.2014)

At very low temperature, lead behaves as a superconductor.

(SSC CGL 06.09.2016)

First theory of superconductivity London theory.

(SSC CPO 06.06.2016)

Application of super conductors

1. Super conductor are used for making very strong electromagnets.
2. Super conductivity plays an important role in material science research and high energy particle physics.
3. Super conductivity is used to produce very high speed computers.
4. Super conductors are used for the transmission of electric power.

Electrical Capacity

Electrical capacity of a conductor is numerically equal to the charge required to raise its potential by unity. Capacitance is a positive quantity only.

The unit of capacitance is **farad**.

$$1 \text{ farad (F)} = \frac{1 \text{ coulomb (C)}}{1 \text{ volt (V)}}, \text{ i.e.,}$$

A conductor is said to have a capacity of one farad, when a charge of one coulomb raises its potential by one volt.

IF two charged objects of equal capacity are connected with a wire current will not flow

(RRB GROUP-D 28.09.18)

Electric field Intensity: Electric field intensity (E) at any point is defined as the electrostatic force acting per unit positive charge (q_0) at that point.

or Number of field lines crossing normally per unit area at that point.

$$\text{or } E = \frac{F}{q_0} = \frac{\text{Electrostatic force}}{\text{unit +ve charge}}$$

$$\text{Unit } E = \frac{\text{Newton}}{\text{Columb}} = \text{NC}^{-1}$$

Electric Potential/Electromotive Force:

We define electric charge between two points in an electric circuit carrying some



current as the work done to move a unit charge from one point to the other.

$$V = \frac{\text{Work done}}{\text{Charge } q_0} = \frac{W}{q_0}$$

(RRB GROUP-D 11.12.18)

$$\text{unit} = \frac{\text{Joule}}{\text{Coulomb}}$$

The SI unit of electric potential difference is volt(V), named after Alessandro Volta . an Italian physicist.

$$1V = 1 \text{ Joule} / 1 \text{ Coulomb}$$

$$1V = 1 \text{ J C}^{-1}$$

Potential difference is measured by an instrument called Voltmeter. The voltmeter is always connected in parallel across the points.

Electric Power:

$$\text{Power} = \frac{\text{work}}{\text{time}} = \frac{I^2 R t}{t} = I^2 R$$

(SSC JE 22.01.201 & SSC CAPFS, NIA, SSF CONSTABLE & ASSAM RIFLES RIFLEMEN 05.03.2019)

$$\text{As } V = IR, I = \frac{V}{R}, R = \frac{V}{I} \quad P = VI$$

$$\text{So, } P = I^2 R = \left(\frac{V}{R}\right)^2 R = \frac{V^2}{R} \quad 1 \text{ Watt} = 1$$

ampere volt

$$P = I^2 R = I^2 \left(\frac{V}{I}\right) = VI. \quad 1 \text{ Kilowatt} = 10^3 \text{ W}$$

$$\text{So, } P = I^2 R = VI = \frac{V^2}{R} \quad 1 \text{ Megawatt} = 10^6 \text{ W}$$

1 horse power (hp) = 746 Watt

Q. A bulb of 484 Ω is producing light when connected to 220 V supply. What is electric power of bulb.

$$P = \frac{V^2}{R} = \frac{(220)^2}{484} = \frac{220 \times 220}{484} = 100 \text{ Watt}$$

Electrical Energy: It is the total electric work done or energy supplied by source of emf in maintaining the current in electric circuit for given time.

$$\text{Energy} = E = VIt = \text{electric power} \times \text{time}$$

SI unit: Joule, 1 joule

$$= 1 \text{ volt} \times 1 \text{ ampere} \times 1 \text{ second}$$

Commercial unit of electricity = 1 KWh = Board of Trade Unit (BOT)

$$1 \text{ KWh} = 1000 \text{ watt} \times 1 \text{ hour}$$

So, 1 KWh is the total electric energy consumed when an electrical appliance of power 1 KW works for one hour.

$$1 \text{ KWh} = 3.6 \times 10^6 \text{ Joule}$$

No. of units of electricity consumed = No. of

$$\text{KWh} = \frac{\text{Watt} \times \text{hour}}{1000}$$

Ex: A bulb of 100 W is operating for 6 hours a day. Find units of energy consumed in 7 days.

$$\rightarrow \text{Energy consumed} = \text{Power} \times \text{time}$$

$$= 100 \times (6 \times 7) = 4200 \text{ Wh}$$

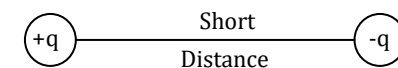
$$\text{Units} = 1 \text{ KWh} = \frac{4200}{1000} \text{ kWh} = 4.2 \text{ kWh}$$

The electric energy that we consumed in homes, industries etc are expressed in kilowatt hour.

(RRB GROUP-D 13.12.18)

Dipole:

In an equal dipole, charge are placed on equal and opposite point for short distance.



Dipole $\rightarrow$ charge increase

$\rightarrow$ distance is very short.

Dipole moment (P):

It tells the capacity of dipole.

It is a vector quantity.

Electron

$$\text{charge} = 1.6 \times 10^{-19} \text{ C}$$

$$\text{mass} = 9.1 \times 10^{-31} \text{ kg}$$

Proton

$$\text{charge} = 1.6 \times 10^{-19} \text{ C}$$

$$\text{mass} = 1.6 \times 10^{-27} \text{ kg}$$

Current Direction

Current $\rightarrow$ + to -

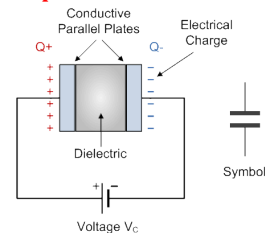
E.F. $\rightarrow$ + to -

Dipole moment $\rightarrow$ - to +

Current(I) - Scalar quantity

Current Density(J) - Vector quantity

Capacitor



A capacitor is an arrangement for storing large amounts of electric charge and hence electric energy in a small space.

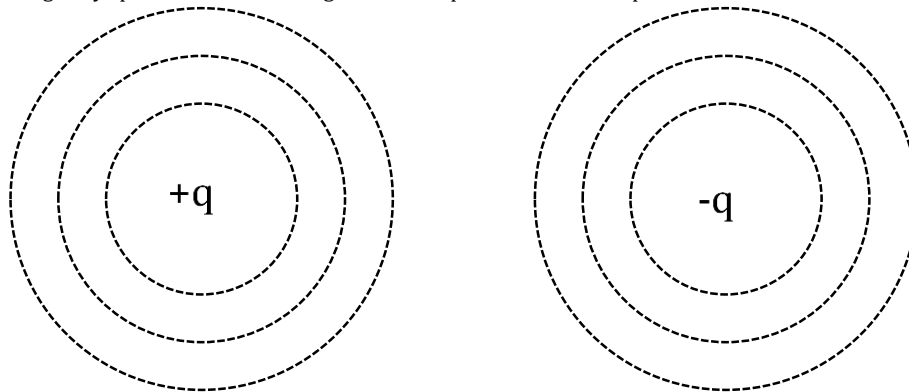
Capacitors or condensers are used in many electrical appliances, like electric fans, electric motors, in oscillator circuits, in radio tuning, in ignition system of engines in vehicles, in filter circuits etc. In the microelectronic age we live, microscopic capacitors form the memory banks of computers.

Defibrillator:

A defibrillator is a device used to save the life of a person suffering a heart stroke.

The heart undergoes ventricular fibrillation due to rapid and asymmetric spasms of the heart muscles. To save the person's life, a shock is given to the heart with a defibrillator to regulate the heartbeat.

Electric Field: It is an imaginary space around the charge, where its presence can be experienced.



$\therefore$ Experienced means if you bring another charged particle, it shows some response.
(Attraction or repulsion)

To study electric field and its direction, we draw electric field lines.
(Imaginary lines)

When we add or remove an electron from an atom, we get charge on it. As the electrons in the outer orbit are loosely bound so by

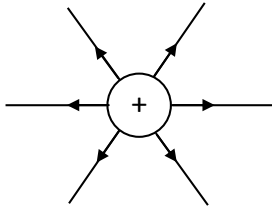


providing small amount of energy to the atom, we can create charge on it.

If an atom loses an electron it acquires positive charge as number of electrons are less than the number of protons present in the nucleus so overall effect of positive charge increases

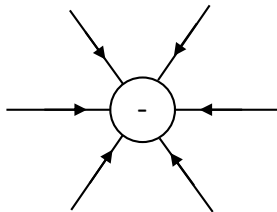
On the other hand, if we add an electron to the atom, the number of electrons in the outer shell increases than the number of protons in the nucleus so overall negative charge appears on the atom.

❖ For positive charge



Electric field lines are radially outwards

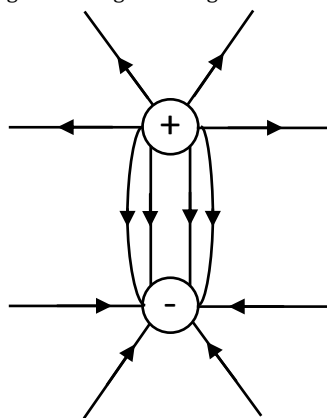
❖ For negative Charge



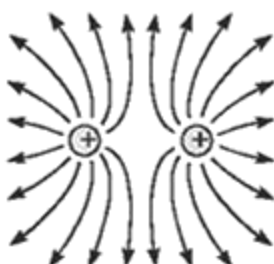
Electric field lines are radially inwards.

❖ For positive and Negative Kept Together

Electric field lines move from positive to negative charge forming continuous curves



❖ For 2 Like Charges



Neutral point

Properties of electric field lines.

- Continuous lines
- Do not form closed loops
- Never intersect [as else at that point, we get two directions]
- Always normal (perpendicular) to the surface of conductor.
- Magnitude of field is represented by Density of field lines.

Heating effect of current or Joule's Heating Effect or Joule's Law of Heating

The law which relates the resistance of conductor to current flow is called joule law. the phenomenon of production of heat in a resistor by the flow of an electric current through it is called heating effect of electric current.

(RRB NTPC 26.04.16 RRB GROUP-D 11.10.18)

$$\text{Heat Produced} = H = I^2 R t \text{ joule} = \frac{I^2 R t}{4.2} \text{ (Calorie)}$$

I = Current R = Resistance T = Time

Heat = work = Energy

Cause of heat: Collisions of electrons with fixed ions/atoms of conductor.

Here,

Electrical Energy $\xrightarrow{\text{Converted to}}$ Heat Energy

Practical Application Of Heating Effect Of Electric Current

Here are so many example of heating effect of electric current that is electric iron, electric toaster, electric oven, electric kettle, electric heater etc.

Electric heating produces light, as we will we seen in **Electric Bulb**. It is composed by a filament that is made up from tungsten which have approximate value of melting point is 3880°C. It can be thermally isolated as much as possible, using insulating material etc. the bulbs are filled with inactive nitrogen and oxygen to increase the life of filament.

Fuse ---- That protect our electric appliances by stopping the flow of electric current. The fuse is placed in series with the device. It consists a piece of wire made up of a metal or alloy (alloy of tin and lead) of appropriate melting point, for example aluminium, copper, iron, lead etc. The fuse wire is made up of very low melting point & High Conductivity. The rating of fuse used in a household electric circuit is provided on the basis of current.

(SSC MTS 30.04.2017, RRB GROUP -D 24.09.18, RRB NTPC 05.01.2021, SSC JE 23.01.2018, SSC CHSL 04.12.2011, SSC CGL 06.09.2016 SSC STENOGRAPHER 09.01.2011 & SSC CGL 09.03.2020 & (SSC CPO 2022, 11.11.2022 Shift-3)

If a current increased then the specified value flows through the circuit the temperature of fuse is also increases. This melts the fuse wire and circuit break. the fuse wire is usually enclosed in a carriage of porcelain or similar material with metal ends. the fuse used for domestic purpose are rated as 1A, 2A, 3A, 5A, 10A etc.

For an electric iron which consumes 1KW electric power when operated at 220V, a current of (1000/220)A that is 4.54A will flow in circuit. In this case, a 95A must be used.

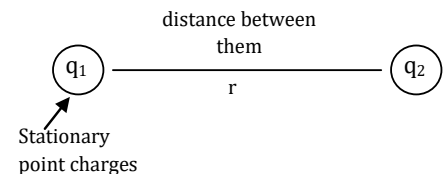
Precautions:

(SSC JE 29.01.2018)

- Fuse should be connected in the circuit.
- Too many appliances should not be connected in single circuit.
- Faulty appliances should not be connected in the circuit.

Columb's Law: It States that the force of attraction or repulsion between two points charges is directly proportional to the product of the magnitude of the charges and inversely proportional to the square of the distance between them

(RRB ALP 10.08.2018 & SSC CGL 03.03.2020 & 12.04.2022)



$$F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$$

Where $F \propto q_1 q_2$ (directly proportional to magnitude of charges)

$F \propto \frac{1}{r^2}$ (Inversely proportional to square of distance between them)

(RRB JE 14/12/14)

Where ϵ_0 = Electrical permittivity = 8.85×10^{-12} units

Unit of ϵ_0 ,

$$\text{As } F = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}$$

$$\epsilon_0 = \frac{1}{F(4\pi)} \frac{q_1 q_2}{r^2} = \frac{C \cdot C}{N \cdot m^2}$$

$$\epsilon_0 = C^2/N - m^2 \text{ and } \frac{1}{4\pi\epsilon_0} = \text{constant} = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$$

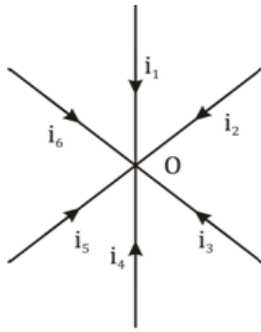
Kirchhoff's Law

- **Kirchhoff's Current Law (KCL)/ Junction Law**

It states that, the net current on a junction in an electrical circuit will be zero, i.e. net incoming current to the junction is equal to net outgoing current to the junction.

(SSC CHSL (10+2) 22.01.2017 & SSC CPO 2022, 10.11.2022 Shift-2)





i.e. the net current at the junction O is given by

$$i_1 - i_2 + i_3 - i_4 + i_5 - i_6 = 0$$

$$\Rightarrow i_1 + i_3 + i_5 = i_2 + i_4 + i_6$$

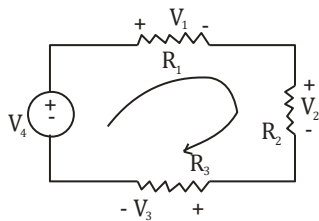
Incoming current = Outgoing current

It is based on the law of conservation of charge.

• Kirchhoff's Voltage Law (KVL)

In any closed circuit, the algebraic sum of the products of the current and resistance of each part of the circuit is equal to the total emf in the circuit.

$$\sum iR = \sum E$$



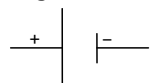
$$V_4 = V_1 + V_2 + V_3$$

$$V_4 = iR_1 + iR_2 + iR_3$$

i.e. sum of voltage drops of all the resistors is equal to the source voltage in magnitude. It is based on law of conservation of energy

Cell

Single unit is called cell



Group of cells is called Battery

(SSC SCIENTIFIC ASSISTANT 25.11.2017)



A dry cell is usually made up of metallic cylinder. It has a flat base and metallic cap on top. The metallic cap on the top is the positive (+) end of the cell. The base is the negative (-) end of the cell. A cell usually produces 1.5V of current.

(SSC DELHI POLICE 05.12.2017)

A current carrying conductor is associated with an electrostatic field.

(SSC MTS 16.02.2014)

	Cell/Storage Cell/Accumulator's
- Irreversible - Cannot be charged once used. - Chemical energy $\rightarrow$ Electrical Energy - Ex: Voltaic Cell - Dry Cell - Daniel Cell - Leclanche Cell - Initial cost is low but operating cost is high	- Reversible - Can be recharged again and again - Chemical energy $\leftrightarrow$ Electrical energy - Ex: Lead Acid Accumulator (Pb + dil. H_2SO_4) - Edison Cell or Alkali Accumulator (Ni-Fe) - Initial cost is high but operating cost is low.

Charge Q	C - Columb
Current I	A - Ampere
Voltage V	V - Volt
Magnetic Flux Φ	wb - weber
Magnetic Flux Intensity H	Tesla
Resistance R	ohm
Resistivity ρ	ohm m (ohm metre)
Conductivity σ	mho or siemens
Impedance Z	Ohm (Ω)
Susceptance Y	Mho
Capacitance C	Farad
Inductance L	Henry
Inductive Reactance X_L	Ohm
Capacitive Reactance X_C	Ohm
Frequency ν	hertz

Types

Primary Cell	Secondary
--------------	-----------



Magnets and Magnetic Field

Magnet

It is any piece which attracts small pieces of iron. It shows the process of

- Attraction (for dissimilar poles)
- Repulsion (for similar poles)

Any magnet always has 2 poles. 

North Pole (N) and South Pole (S)

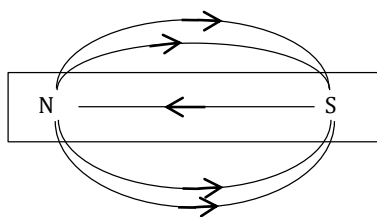
A freely suspended magnet always aligns in the north-south direction.

(RRB NTPC 27.01.21 & 16.04.16)

Magnetic field: The region around the magnet in which the effect of magnetism is experienced is called the magnetic field.

(RRB GROUP-D 26.11.2018)

Magnetic field lines: These are the imaginary lines drawn to study the magnetic field.

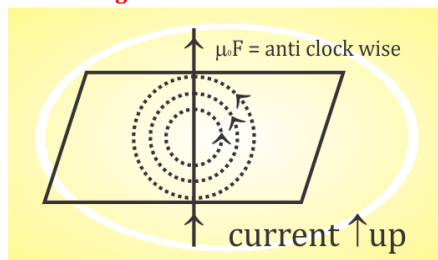


These travel

- N to S = Outside the magnet
- S to N = Inside the magnet.

(SSC JE 25.01.2018)

Unit of magnetic field



Gauss - Cgs unit

Tesla (T) = SI unit

(SSC CGL 13.06.2019)

1 T = 10⁴ Gauss.

Note: Magnetic field is a vector quantity.

Direction of magnetic field: By right hand thumb rule or Maxwell's screw rule.

According to Right Hand thumb rule, if we imagine, linear wire to be held in grip of right hand, where

Thumb → Points directions of current

Fingers → Points direction of M. field

i.e. if current up ↑ → M.F. → anticlock wise direction

If current down ↓ → M.F. → Clockwise direction

Earth's magnetic field at its surface = 3.5 × 10⁻⁵ T (Approx)

Types of Magnet

Permanent Magnets

→ Bar Magnet

→ Horse Shoe

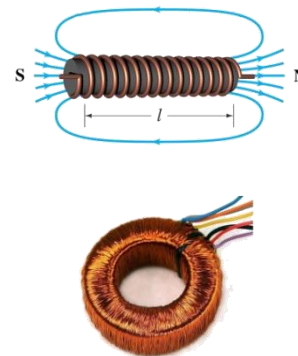
→ Circular Magnet



Temporary Magnets

→ Solenoid

→ Toroid



Magnets

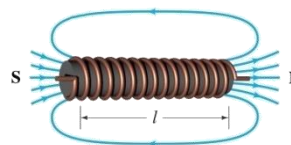
Natural

- These are found in nature
- Irregular in Shape



Artificial

- These are man made
- Posses Definite shape



Gauss Theorem

In Electrostatics

Electric flux through a closed surface

$$\phi_E = \oint \vec{E} \cdot d\vec{s} = \frac{q}{\epsilon_0}$$

In Magnetism

It tells that the net magnetic flux (ϕ_B) through any closed surface is zero.

$$\phi_B = \oint \vec{B} \cdot d\vec{s} = 0$$

Where, flux = number of field lines passing through a particular area.



Types of Magnetic Materials

Diamagnetic Substance

The diamagnetic substances are those in which the individual atoms/molecules/ions do not possess any net magnetic moment on their own.

When such substances are placed in an external magnetising field, **they get feebly magnetised in a direction opposite to the magnetising field.**

Ex:- Antimony, Bismuth, Copper, Lead, Gold, Silver, Diamond, Zinc, Quartz; Water, bronze (**RRB NTPC 13.01.2017**) Alcohol, Mercury; Air, Hydrogen, Nitrogen and all inert gases like Helium, Neon, Argon, etc.

Paramagnetic Substances

Paramagnetic substances are those in which each individual atom/molecule/ion has some net non zero magnetic field of its own. When such substances are placed in an external magnetised field, **they get feebly magnetised in the direction of the magnetising field.**

Ferromagnetic Substance

Ferromagnetic substances are those in which each individual atom/molecule/ion has a non zero magnetic moment, as in a paramagnetic substance.

When such substances are placed in an external magnetising field, **they get strongly magnetised in the direction of the field.**

Soft

When external magnetic field is removed, **magnetization disappears** in some of the materials like soft iron. These materials are Soft Ferromagnets.

Hard

The magnetization persists even after removal of external magnetic field. Such materials are Hard Ferromagnets.

Note:

(i) Vacuum is considered as non-magnetic material.

(RRB JE 14.12.2014)

(ii) Magnet stone do not have magnetic properties like a permanent magnet.

(RRB NTPC 31.03.2016)

(iii) Bronze is not attracted by a simple magnet.

(RRB NTPC 19.01.2017)

Curie Temperature

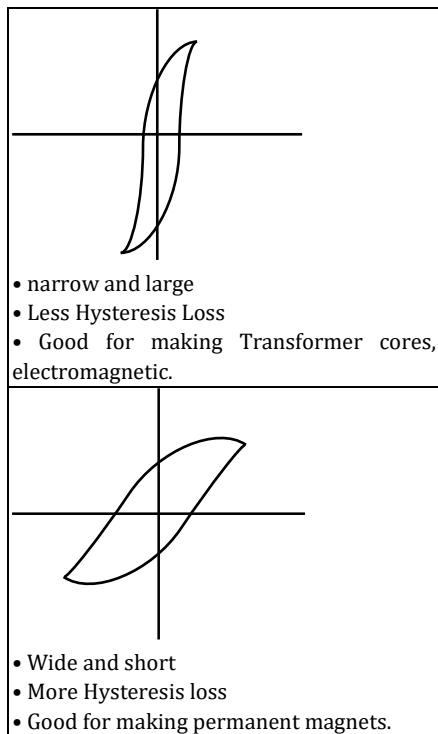
When a magnet is heated, it loses its magnetization. The temperature at which ferromagnetic substance becomes paramagnetic is called Curie Temperature.

(SSC CGL 16.05.2010 & 30.08.2016)

Ferromagnetic $\xrightarrow[\text{(Heating)}]{\text{Curie Temperature}}$ Paramagnetic

Hysteresis Curve

It tells us the behavior of the natural when it is magnetized and demagnetized i.e. it is taken through the cycle of magnetization Hysteresis curve for



Geomagnetism: The branch of Physics which deals with the study of magnetism of earth is called terrestrial magnetism or geomagnetism.

The strength of this field at the surface of earth is approximately 0.1 gauss or 10^{-5} tesla. The field is not confined only to earth's

surface, it extends upto a height nearly 5 times the radius of earth ($\approx 5 \times 6400 \text{ km} = 32000 \text{ km}$)

Tangent Galvanometer: It is an instrument which is used for detection and measurement of low electric currents. It is based on tangent law in magnetism.

Bohr Magnetron (μ_B): Bohr magneton is the minimum magnetic dipole moment associated with an atom due to orbital motion of an electron in the first stationary orbit of the atom.

Magnetic field strength: Magnetic field strength or magnetic field induction or flux density of magnetic field being equal to the force experienced by a unit positive charge moving with unit velocity in a direction perpendicular to the magnetic field.

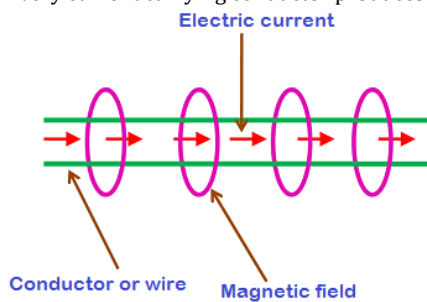
Magnetic Permeability (μ): It is the ability of a material to permit the passage of magnetic lines of force through it.

Relative magnetic permeability of a material: It is defined as the ratio of magnetic permeability of the material (μ) and magnetic permeability of free space (μ_0)



Magnetism from Electricity

Every current carrying conductor produces a magnetic field around it. It is due to spin of electrons.



Note:

Static charge (at rest) → Produces only electric field

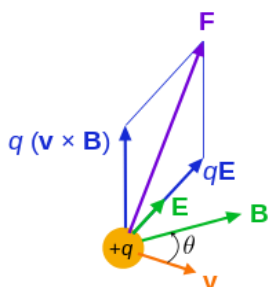
Moving charge → Produces Electric field & Magnetic field

Force on a charged particle in EOF and MOF:

Whenever a charged particle is kept in uniform E.F. or M.F. or both, it experiences a force and shows Trajectory

In uniform electric field	In uniform magnetic field + electric field	Magnetic field only
• follows a parabolic path • used in CRT (Cathode Ray Tubes) of Televisions.	• follows helical path ↓ - Circular + linear	• follows a circular path

Lorentz force



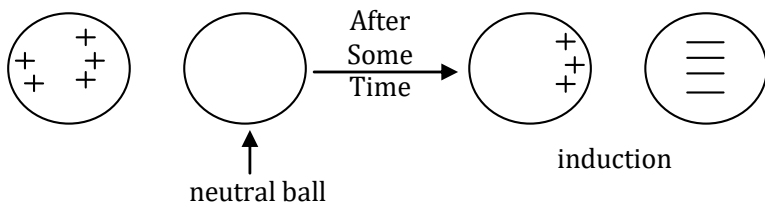
It is the force experienced by a charged particle when it moves in a space having both electric and Magnetic fields.

Lorentz Force = Force due to electric field + force due to magnetic field

$$\mathbf{F} = q\mathbf{E} + q\mathbf{v} \times \mathbf{B}$$

The **force** exerted on a charged particle q moving with velocity v through an electric field E and magnetic field B .

Induction: Charges of opposite nature are induced on the opposite body without actual contact



Electricity from Magnetism

Whenever there is a change in Magnetic flux (field/area) around a conductor, an emf is induced in the conductor. This induction of electrical energy from magnetic energy is called Electro Magnetic Induction [EMI]

If the conductor is in the form of closed circuit, current flows through it and it is known as induced current

NOTE:

Current always flows in closed circuit only, never in open circuit.

Magnetic flux [ϕ]: It is the total number of magnetic field lines of force crossing a surface normally.

Where $\phi = \vec{B} \cdot \vec{A} = BA \cos \theta$

i.e. Dot produce of magnetic field and area vector

Unit of magnetic flux $\Rightarrow$ Weber = SI unit

1 Weber = 1 Tesla $\times$ 1m²

C.g.s. unit $\Rightarrow$ Maxwell (Mx)

Where, 1 weber = 10⁸maxwe

Here is a change in Magnetic flux (field/area) around a conductor, an emf is induced in the conductor. This induction of electrical energy from magnetic energy is called Electro Magnetic Induction [EMI]

If the conductor is in the form of closed circuit, current flows through it and it is known as induced current

Magnetic flux through a plane surface is the product of the magnetic flux density normal to the surface and area of the surface.

(SSC CGL 19.01.2017)

Magnetic Flux Density

It is defined as the force acting per unit current per unit length when wire placed at right angle in the magnetic field.

Unit of magnetic flux density is Tesla.

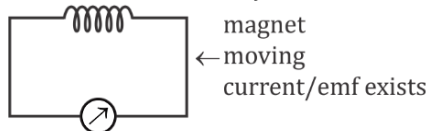
It is a vector quantity.

$$B = \frac{\phi}{A} = \frac{\text{weber}}{\text{meter}^2} = \text{Tesla}$$

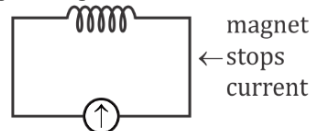
Faraday's Laws of Electro Magnetic Induction

(RRB NTPC 28.04.2016)

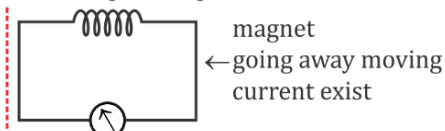
- E.M.F. is induced only when there is a change in magnetic flux. The induced emf lasts as long as change continuous.



Phase - 1

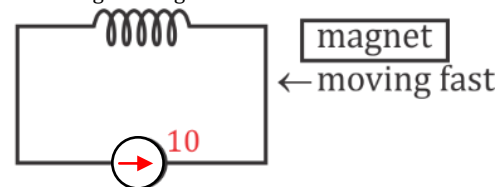
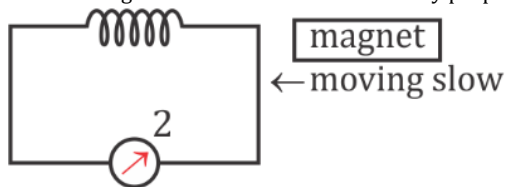


Phase - 2



Phase - 2

- The magnitude of emf induced is directly proportional to the rate of change of magnetic flux linked with the circuit.



Phase - 2

induced emf $e = -\frac{d\phi}{dt}$ = rate of change of

Magnetic flux.

This -ve sign is due to lenz's Law.

Lenz's Law: It states that the direction of induced current is such that it always opposes the change in magnetic flux, responsible for its production.

Explanation: -



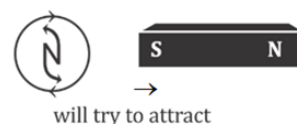
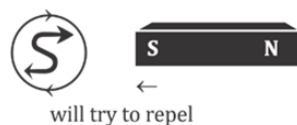
If North pole is coming towards it, coil tends to oppose it. So, make North pole on this side of coil.

If North pole is going away from the coil, it tries to oppose the motion by creating South pole on its side

If South pole is coming towards it, coil tends to oppose it. So, make South pole on this side of coil.

If South pole is going away from the coil, it tries to oppose the motion by creating North pole on its side

By convention



Law of Energy Conservation in EMI and Lenz Law

Mechanical energy used in moving a magnet

$\xrightarrow[\text{to}]{\text{Converted}}$ electrical energy of coil

If there is no movement, no work is done so no conversion of energy hence induced EMF = 0 (Zero)

NOTE:

- Changes in magnetic field is produced induced current.

(SSC JE 23.01.2018)

- The Induced Current Is Highest When The Direction Of Motion Of The Coil Is 90.

(RRB GROUP- D 18.09.2018)

- When direction of coil is perpendicular to magnetic field, then the value of induced current maximum

(SSC JE 27.01.2018)

- Speed of proton cannot change while it moves freely in magnetic field.

(SSC JE 25.01.2018)

- Moving from one end to another end inside a solenoid, its magnetic field remains same.

(SSC JE 24.01.2018)

- Magnetic keepers are pieces of soft iron that are placed across the poles of bar magnet or Horseshoe magnet.

- They are used to protect magnet from self- demagnetization.

(SSC MTS 16.02.2014 & 10.03.2013)



James Maxwell

He was a mathematician and physical scientist from Scotland. He proposed the electromagnetic theory in 1856, which led to the invention of radio and television. He demonstrated that light is an electromagnetic wave by combining electricity, magnetism and light

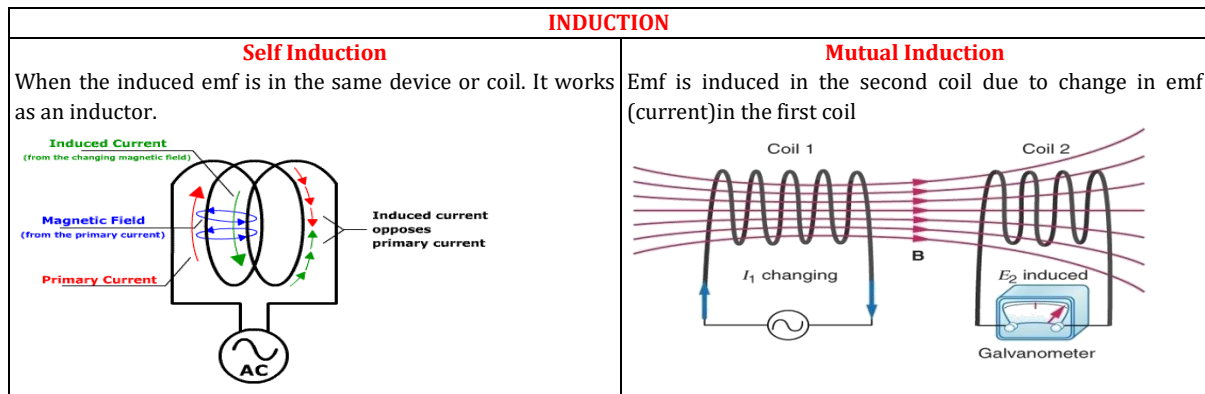
(RRB GROUP-D 05.10.2018)

Electromagnetic induction

Whenever the magnetic lines of force or magnetic field passing through a closed circuit change, an induced electromotive force is produced and hence a induced current is produced in it this generation of electric current due to the relative motion

between the coil and the magnetic field. This phenomenon is called as electromagnetic induction. It was discovered by Michael Faraday.

(SSC JE 24.01.2018 & RRB GROUP-D 16.10.2018)

**Meissner Effect**

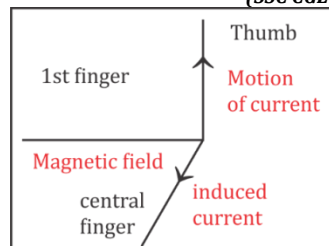
The Meissner effect states that at or below the transition temperature, there is no magnetic field or magnetic flux density inside the super-conductor when the specimen is placed inside a uniform magnetic field.

❖ **Fleming's Right Hand Rule:**

(RRB GROUP-D 17.09.2018)

It gives us the direction of induced emf/current in a conductor moving in a magnetic field.

(SSC CGL 19.10.2014)



First finger → Magnetic field (North to South)
Thumb → Motion of Conductor

(RRB JE 14.12.2014)

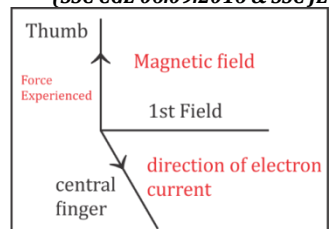
Middle finger → induced current

This concept is used in **Generator** [Mechanical Energy → Electrical Energy]

Fleming Left Hand Rule:

When a current carrying conductor is placed in external magnetic field, it experiences a force.

(SSC CGL 06.09.2016 & SSC JE 25.01.2018)



First finger → direction of magnetic field

Central finger → direction of electric current (current in conductor)

(SSC MTS 08.08.2019)

Thumb → Direction of force experienced by conductor

This is used in **Motor** [Electrical Energy → Mechanical Energy]

Eddy Currents or Foucault Currents

Eddy currents are the currents induced in the bulk pieces of conductors when the amount of magnetic flux linked with the conductor changes.

Their flow patterns resemble swirling eddies in water. That is why they are called eddy currents. These were discovered by Foucault in the year 1895 and hence they are called Foucault currents.

Note:

(i) Force applied on the conductor depends on the magnitude and direction of magnetic field strength.

(SSC JUNIOR ENGINEER 22.01.2018)

(ii) When a bar magnet is cut into two equal halves, the pole strength of each piece remains the same.

(SSC CPO 28.08.2011)

(iii) The method of magnetism is passing direct current through it.

FORMULA'S

1. E.F. due to charge

$$E = \frac{q}{4\pi\epsilon_0 r^2}$$

2. Force between charges/Coulomb's Law,

$$F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$$

3. Potential due to charge (V)

$$V = \frac{q}{4\pi\epsilon_0 r}$$

4. Potential energy between 2 charges (PE)

$$PE = \frac{q_1 q_2}{4\pi\epsilon_0 r}$$

$$5. F = qE, E = \frac{V}{l}$$

6. Capacitor

$$Q = CV, C = \frac{Q}{V} = 1$$

$$\text{Farad} = \frac{1 \text{Coulomb}}{1 \text{Volt}}, V = \frac{Q}{4\pi\epsilon_0 r}$$

To increase 1V, how much Q is required
⇒ 1 Farad

7. Gauss's Law for Magnetism

$$\oint_S \vec{B} \cdot d\vec{s} = 0$$

8. Gauss's law in electrostatics

$$\oint_S \vec{E} \cdot d\vec{s} = \frac{q}{\epsilon_0}$$

$$9. \text{Heat Produced} = H = I^2 R t \text{ joule} = \frac{I^2 R t}{4.2} (\text{Calorie})$$

10. Current I = Charge (Q)/ Time (t)

11. Voltage V = Current(I) × Resistance(R)

12. Current density J

$$J = \frac{I}{A} = \frac{q/t}{A}$$

$$I = JA \cos \theta = \vec{J} \cdot \vec{A}$$

I be the current

Cross-sectional area A

$$13. \text{Power } P = I^2 R = VI = \frac{V^2}{R}$$

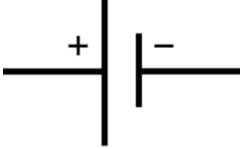
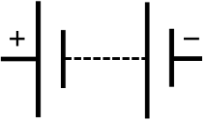
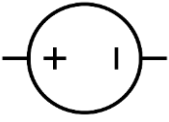
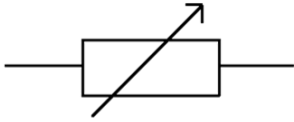
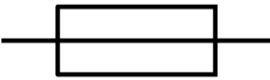
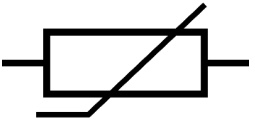
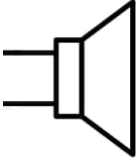
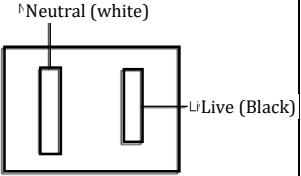
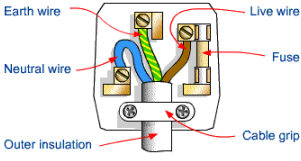
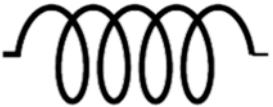
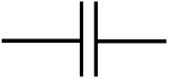
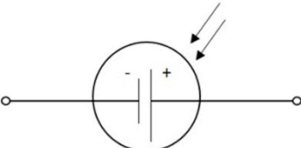
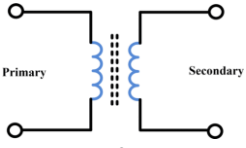
14. Dipole moment, p = (either charge) q × (distance between charges)

15. Lorentz Force = Force due to electric field + force due to magnetic field

$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$



06**Electrical Equipments****Symbols**

 Cell	 Battery	 DC Power Supply	 AC Power Supply
 Voltmeter	 Ammeter	 Motor	 Generator
 Filament Lamp	 Diode	 LED	 LDR
 Fixed Resistor	 Variable Resistor	 Fuse	 Thermistor
 Heater	 Loud Speaker	 Switch Open	 Switch Closed
 2 Pin Plug	 3 Pin Plug	 Resistor	 Inductor
 Capacitor	 Solar Cell	 Transformer	 Earthing



Laser:

It is an acronym for Light Amplification By stimulated Emission of radiation.

It is a device which **emits coherent light and monochromatic**. i.e a strong beam of light of same frequency.

It uses the concept of Population Inversion.

(SSC CHSL 10.11.2013)

Super conductivity:

As if Temperature $\uparrow$, resistance of conductors also increases and vice-versa i.e. Temp $\downarrow$, resistance $\downarrow$ and current $\uparrow$ or conductivity $\uparrow$.

The materials which **shows zero resistance at certain very low temperatures** shows Super conductivity (conductivity = very high at Resistance ≈ 0) are **Super conductors**.

Critical/Transition Temperature:

The temperature at which resistance becomes zero for a super conductor.

Ex: An alloy of

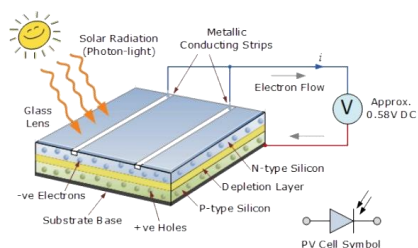
Plutonium	} Shows Superconductivity
Cobalt	
Gallium	

Applications of Super conductors

- To produce very high speed computer
- To make very strong electro magnets
- Used in medical research
- For transmission of high power.

Superconductors have been used to make digital circuits based on rapid single flux quantum technology, radio frequency and microwave filters for mobile phone base stations.

- Superconductor magnets are used in **Magnetic Resonance Imaging (MRI)** machines, mass spectrometers and the beam, steering magnets used in particle accelerators.
- The film of superconductor can be used in geophysics, meteorology, etc.

Solar Cell

Charles Fritts in 1883, built the first solar cell. He coated selenium with a very thin layer of gold to form junctions. It is basically a p-n junction device that converts solar energy into electric energy. The current generated is directly proportional to the

illumination (lumen/metre²) and on the size of the surface area that is illuminated.

Solar cells can be connected together in series to create solar panels. Solar cells are also widely used in producing electrical power in remote areas, in calculators, in empowering houses and offices with electricity.

Note:

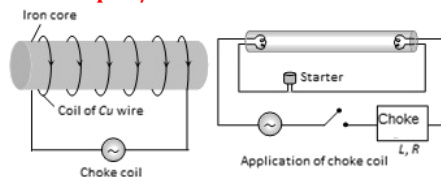
Solar thermal is a technology that utilizes the sun ray to generate heat which is further used in electricity generation process.

Choke Coil (Ballast)

Copper wire wound over an soft iron core makes a choke coil.

Device used to control current in AC Circuits

It is also used in Fluorescent Lamps

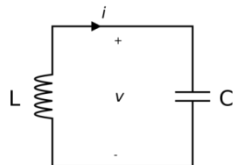
PhotoCopier/ Photo State Machine

- It is a device which makes the duplicate copies of a document.
- It works on the principle of electricity and photo conductivity.
- It contains a light sensitive photo receptor inside the machine which attracts the toner particles and than transfers them to a plain paper to make a copy of document.

Tape Recorder/ Tape Disk/ Tape Machine

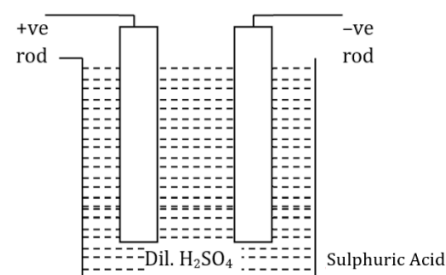
- It is a sound recording and reproduction device which records and plays back the sound.
- It uses magnetic tape for Storage.
- It records a fluctuating (audio) signal by moving a tape across a tape head that polarizes the magnetic domains in the tape in proportion to audio signal

[Take care, It should not be kept near a magnet]

Tank Circuit

An LC circuit, also called a **resonant circuit, tank circuit, or tuned circuit**, is an electric circuit consisting of an inductor, represented by the letter L, and a capacitor, represented

by the letter C, connected together in parallel. The main **function** of an **tank circuit** is to oscillate with minimum damping. It is used for producing signals or accepting a signal from a more composite signal at a particular frequency.

Electro-Chemical Cells

It is a device by which electric current energy is generated at the cost of chemical energy due to chemical action looking place in the cell.

❖ Lightning Conductor or Earthing

It is an instrument used to save big buildings from electrostatic discharge of clouds. Here a metal wire with sharp edge kept on the top of the building is wired whole along the length of building to its bottom under the earth. Due to induction, charges are transferred from clouds to metal wire and then through metal wire to ground. So, it saves big buildings from damage by the lightning flashed.

The lighting conductor should be made up of a good conductor like copper with sharp-pointed edges

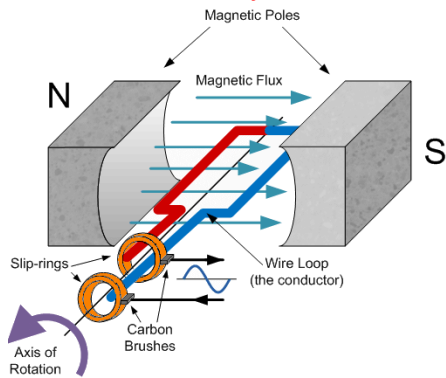
(SSC (10+2) 31.07.2018)

Thermo Couple

A thermocouple is an electrical device made up of two dissimilar wires joined to form a junction. It is used as a temperature sensor to detect temperature. Whenever a junction is heated, a certain temperature is observed and corresponding to it voltage is recorded

Sensors: These are the devices used to detect (sense) any physical quantity and gives us its value in terms of say current or voltage or any other measurable quantity.



A.C. Generator or A.C. Dynamo

It is a machine which produces alternating current (A.C.) from mechanical energy.

Uses **Fleming Right Hand Rule**

Principal: Based on Electro Magnetic induction

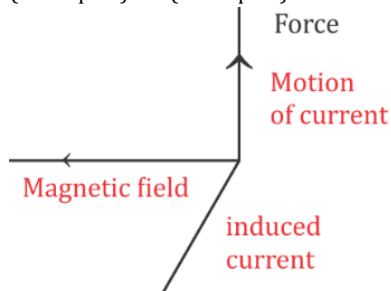
It was designed by **Nikola Tesla**

The word *Generator* is a misnomer

As nothing is generated by it Rather just converts

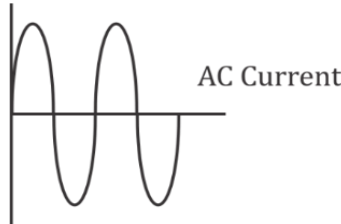
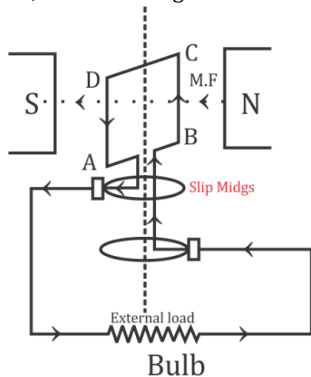
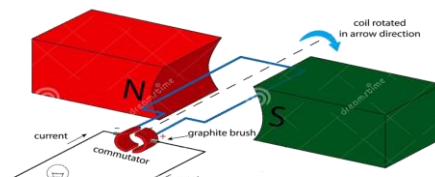
Mechanical Energy → Electrical Energy

- M.F.(Direction of magnetic field) → N (north pole) to S(south pole)

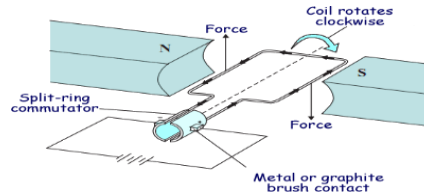


- As coil is rotated anticlockwise AD - out, BC in
- As per Fleming Right Hand Rule ,direction of current is from B to C
- So, Current flows in external circuit.
- As coil rotates further, direction of current is opposite.

So, AC current is generated.

**D.C. Generator**

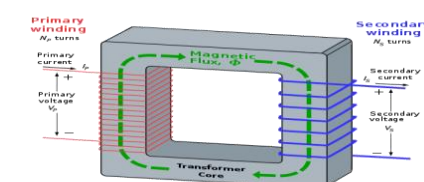
- Here *split rings* are used instead of slip rings.
- Output is DC in nature (i.e. either +ve or -ve)

DC Motor

- It converts electrical energy to mechanical energy.
- Principle: Current carrying conductor when placed in external magnetic field, experiences a force.

If coil is used, it experience Rotational force called Torque.

- A **split-ring** device called a **commutator** is used to reverse the current.
- Fleming left hand rule** is applied here.

Transformers

- A **transformer** is a device that changes voltage from one value to another.
- Power at the input end is equal to the power at the output end.
- Only the voltage will increase or decrease.

Principle:

- Transformers work on the principle of Mutual induction.
- Mutual Induction: Suppose there are 2 inductors if some current flows through

coil1, there will be change in the current
As a result there will be change in the magnetic flux in the coil 2 and because of which emf is induced in the coil 2.

Construction:

A Transformer consists of:

- Primary coil:**
Primary coil has ' n_p ' number of turns of wire over a piece of soft iron core.
It is the input end.
- Secondary coil:**
Secondary coil has ' n_s ' number of turns of any wire (like copper etc.).
It is the output end as we receive output from this end.
- Soft iron core:**
The hysteresis curve for iron is extremely thin because of which it covers minimum possible area.

As the area of the hysteresis loop of soft iron is very less therefore the energy lost by the transformer will be very less.

Permanent magnet is not suitable for use in transformers because the energy lost will be huge.

Types of transformer :

Here we consider two types of transformer that is:

- Step up transformer
- Step down transformer

Step up transformer-

The transformer that is used to convert low voltage into high voltage.

In this type of transformer, the voltage is high and the current is low.

Primary coil have less no. of coil as compare to secondary coil.

Step down transformer

The transformer that convert high voltage into low voltage.

In this type of transformer, the voltage is low and the current is high.

Primary coil have high number of coils as compare to secondary coil.

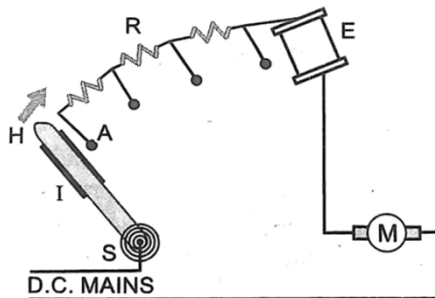
Applications of Transformers

- Transmission of power over long distances:**
Suppose there is a main power station, from there power is send to different sub area power stations and from there it is supplied to different houses. At the main power station there is step-up transformer, it will amplify the voltage and current is reduced.

When the current is reduced therefore heating will be reduced to a great extent. The power loss is minimized to a great extent till it reaches the area sub stations. At the area substation step-down transformer is used. This transformer will reduce the voltage and then supply to the houses. The line power loss will be not very much as the distance between the houses and area power substation is not very large.

- Transformers are used to regulate the voltage. Many appliances use voltage stabilizers which regulate the voltage so that the electronic devices are not harmed when there is fluctuation in the voltage.

Motor Starter



It is a device used to start a D.C. motor safely, by introducing high resistance in the motor circuit.

Normally, the resistance of motor is kept low to reduce copper loss and as R is low, current flowing through the motor is very high as per ohm's law.

$$V = IR$$

$$\frac{V}{I} = R$$

$$\text{or } R \propto \frac{1}{I}$$

Current and Resistance are inversely proportional to each other.

So, if at the starting phase, initial high voltage is supplied to motor, current in motor will be very high due to low resistance and As per Joule's law of Heating

$$H = I^2RT$$

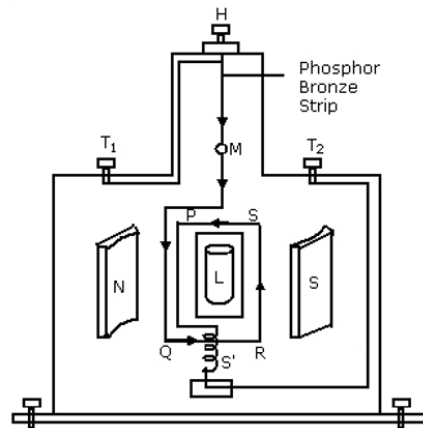
A lot of heat will be produced which may burn the motor. To avoid this condition a high resistance is added to the motor circuit so that current developed in the initial phase may be small to avoid heating effect.

Galvanometer

It is a device used to detect and measure electric current in a circuit. It can measure current up to 10^{-6} A. A galvanometer can be

converted into a voltmeter by connecting a very high resistance in its series.

Ammeter



It is a device used to measure current and is always **connected in series in an electric circuit**. Its measured value is always less than the actual value of current to be measured.

Voltmeter

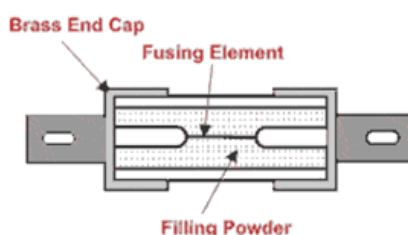
It is a device used to measure potential difference between two points in an electric circuit. It is **connected in parallel in an electrical circuit**. Its value is always lesser than the true value.

Shunt

A **low resistor** connected in parallel with a circuit or device that reduces the amount of electric current flowing through it

Ammeter	Voltmeter
low Resistance	High Resistance
- To measure current - Low Resistance Galvanometer	- To measure voltage - High Resistance Galvanometer
Low R is connected in parallel to decrease resistance	High R is connected in series to ↑ (increase) Resistance

Fuse

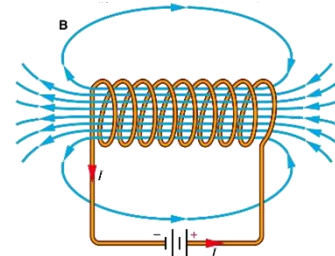


It consists of a low-resistance metal or **wire** that is used to close a circuit. *When too much current flows through the low resistance element of the fuse, the element melts and breaks the circuit following the Joule's Law of heating*

Gold Leaf Electro Scope (GLE)

It is an instrument used for detecting the presence of charge and the Polarity (sign $\pm$) of charge.

Solenoid/Temporary Magnet:



It is a long insulating wire closely wound in the form of a helix.

Its length >>> diameter

Concept: Current carrying conductor behaves as a magnet.

When we switch it ON, current flows, Magnetism appears, Acts as magnet

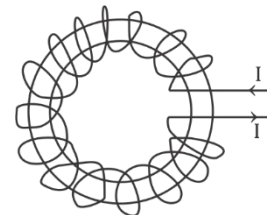
When we switch it OFF, current = 0, Magnetism Vanishes.

So, it is an electro magnet

Where,

$$\text{Electrical Energy} \xrightarrow{\text{converted to}} \text{Magnetic Energy}$$

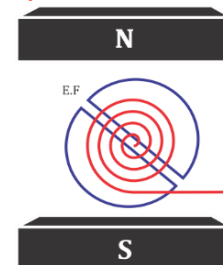
Toroid:



Similar to Solenoid, just it is an Endless Solenoid in the form of a ring.

It is a hollow circular ring on which a large number of insulated turns of a metallic wire are closely wound.

Cyclotron

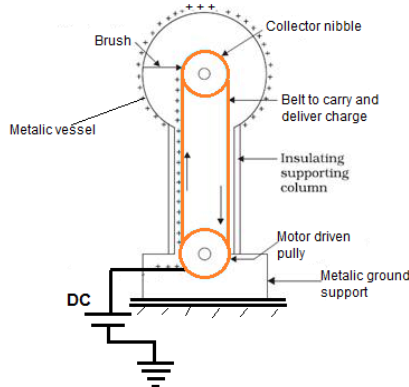


- Developed by Ernest O Lawrence



- It is an equipment used for accelerating positively charged particles like Proton, Deuterons & Alpha Particles
- Functioning: Here charged particle is allowed to move in perpendicular E.F. and M.F. due to which it moves in a helical path, each time gaining velocity and finally striking the target at very high velocity (speed).

Vande Graaff Generator



A device used to build up charges of very high potential difference of order of few million volts.

Use of vande Graaff

- To accelerate charged particles like e, p, ions.
- Used in experiments of Nuclear Physics.

Limitation

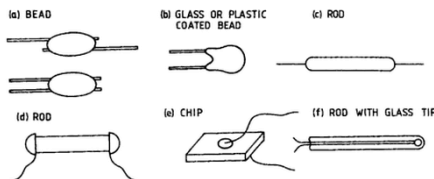
It cannot accelerate uncharged particles like neutrons.

Thermistor

It is a heat sensitive device whose resistivity changes very rapidly with change in Temperature

Use:

It is used to measure small temperature changes. It is available in various forms such as :



Miniature Circuit Breakers (MCBs)

In present time, the fuses are replaced by MCBs (Miniature Circuit Breakers) which is an automatically operated electrical switch designed to protect an electrical circuit from the damage caused by overload or short-circuit.



The tin-lead alloy is also used as soldering material for joining metals in electronic circuit. **Earth pin of the plug is always made thicker and longer.**

Inverter

It is a device used in offices, homes and designed to

- Charge the battery by converting AC to DC.
- Convert DC from a battery to AC.

It is fitted in main power line. In case of failure of power, it is automatically switch ON and provide power to the domestic wiring in the homes.

When the main supply is restored, the inverter automatically switches to a mode in which it starts charging the battery depleted due to use during the period of power failure.

Incandescent Lamp or Filament Lamp



It has tungsten filament connected between two lead wires. When there is a current through it, it gets heated up and emits light. The melting point of tungsten is about

3400°C. The electric bulb contains gas to prevent the evaporation of tungsten.

Argon is a commonly used gas used to fill incandescent light bulbs. It increases bulb life by preventing the tungsten filaments from deteriorating too quickly. Other gases such as helium, neon, nitrogen and krypton are also used in lighting. The gases used in light bulbs are known as inert gases. Most of the power consumed appears as fluorescent light. (SSC (10+2) 27.10.2013)

Fluorescent Tubes

It contains mercury vapors at low pressure which emits invisible ultraviolet rays when tube is switched on. These ultraviolet rays fall on the fluorescent coating inside the tube and emits visible light.

(SSC STENOGRAPHER 11.09.2017)

Since, there is a little amount of heat produced in a tube, i.e. almost all electrical energy is converted into light energy. The tubes are more cheaper and efficient.

Compact Fluorescent Lamps

An incandescent light bulb wastes a lot of electricity in the form of heat while no electric energy is wasted as heat in a fluorescent lamp. A CFL (Compact Fluorescent Lamp) is



miniature fluorescent tube and works on the same principle.

(SSC (10+2) 28.10.2013)

It is 4 to 6 times more efficient than an incandescent bulb. That's why one can buy a 15 W fluorescent lamp that produces the same amount of light as a 60 W incandescent bulb.

Although, initial cost for CFL is more but its lasting is 15 times longer than that of other bulbs. (Fluorescent lamp contains mercury which is a hazardous substance).

LCD stands for "liquid crystal display"

LCD, which stands for "light emitting diodes," LED differs from general LCD TVs in that LCDs use fluorescent lights while LEDs use those light emitting diodes.

NOTE:

Germanium is not suitable for LED structure.

(SSC CGL 12.04.2022)

Electric Iron/Heater/Heating Rod



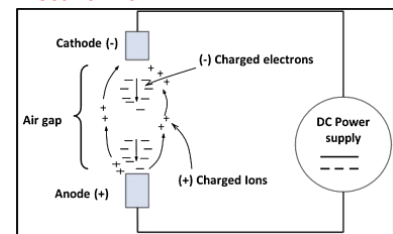
It is based on Heating effect of electric current

Heating Element used – Nichrome (an alloy of Ni + Cr)

(SSC CAPFS ASI & DELHI POLICE SI 05.07.2017)

Ni = Nickel, Cr = Chromium

Electric Arc



It consists of two carbon rods with a small suitable separation between them. When a high voltage (40 to 60 volt) is applied, a spark jumps across the gap and a very bright light is emitted in the gap.

Efficiency of an electric device (η)

Efficiency of an electric device is defined as the ratio of its output power to the input power, i.e.,

$$\eta = \frac{\text{output power}}{\text{input power}}$$

In case of an electric motor, efficiency = $\frac{\text{output mechanical power}}{\text{input electric power}}$

Sensitivity of a device:

It is the smallest value of a physical quantity that it can measure.

Ex: If a device A can measure current of 0.1 Ampere and Device B can measure current of 0.01 Ampere
than *Device B is more sensitive*

Air conditioner (AC)

Body comfort depends on temperature as well as humidity. The comfortable conditions for an average person are

- (i) Temperature between 23°C to 25°C and
- (ii) Relative humidity between 60 to 65 per cent.

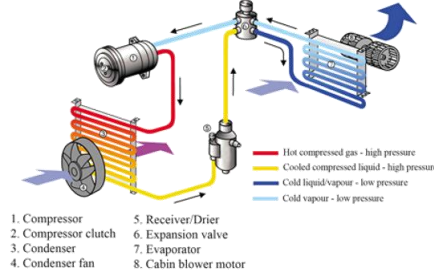
An air conditioner provides these conditions by regulating temperature and humidity.

The cooling capacity of an AC is expressed in tonnes, e.g. 1 tonne, 2 tonne, etc. A 1 tonne AC transfers 12000 BTU (*British Thermal Unit*) of heat from the room in an hour.

(1 BTU = 1055 joule).

An air conditioner (AC) in a room or a car works by collecting hot air from a given space, processing it to release cool air into the same space where the hot air had originally been collected. This processing is done using five components:

- ◆ Refrigerant: It is a coolant fluid
- ◆ Evaporator: These are coils
- ◆ Compressor: It compresses the gas to decrease its volume
- ◆ Condenser: Converts gas into liquid
- ◆ Expansion valve: To eject out the heat



The warm air is drawn in through a grille at the base of the indoor unit, which then flows over evaporator coils (pipes) through which the refrigerant (i.e., a coolant fluid) is flowing. The refrigerant liquid absorbs the

heat and becomes a hot gas itself. The coils also wring out moisture from the incoming air, which helps to dehumidify the room. This hot refrigerant gas is then passed on to the compressor, the compressor compresses the gas so that it becomes hot, since compressing a gas increases its temperature. This hot, high-pressure gas then travels to the third component – the condenser and it condenses the hot gas so that it becomes a liquid. The refrigerant reaches the condenser as a hot gas, but quickly becomes a cooler liquid because the heat of the 'hot gas' is dissipated to the surroundings through metal fins. So, as the refrigerant leaves the condenser, it loses its heat and becomes a cooler liquid. This flows through an expansion valve – a tiny hole in the system's copper tubing – which controls the flow of cool liquid refrigerant into the evaporator, so the refrigerant arrives at the point where its journey started.

A thermostat constantly monitors the temperature of the system so that it is maintained near a user's desired point.

07

Semiconductor Electronics

In terms of the electrical properties, materials can be classified into three groups: conductors, semiconductors, and insulators.

Conductor – Material that easily conduct electricity are called conductor.

Eg - copper, aluminium, zinc, gold, nichrome, silver

(RRB GROUP-D 02.11.18)

In this state, the number of electrons present for electrical conduction is greater. So the resistance of such materials is low and conductivity is high. If a low electric field is applied relative to the metal, then these free electrons start moving in the opposite direction of the electric field. (Because the electric field is from positive to negative and electrons move from negative to positive.

Due to this current flows and the metal behaves like a conductor.

(SSC CGL 19.05.2013)

Semi-conductor– materials that value falling between conductor and insulator.

Solids which conduct electricity at higher temperature but not at lower temperature are called semiconductor.

Ex- Germanium, Silicon and gallium arsenide etc.

(SSC CGL 21.04.2013 & SSC JE 24.01.2018)

Insulator – Materials that do not conduct electricity are known as insulator.

Eg -dry wood, bakelite, asbestos, ceramic, diamond, paper, mica and quartz, nitrogen, oxygen, sulphur.

(RRB JE 29.05.19, RRB ALP 29.08.18, RRB GROUP-D 16.11.18 & SSC CGL 27.08.2016).

Suspension type insulator are used for high voltage application.

(SSC STENOGRAPHER 14.09.2017)

Some Terms Are Related To The Band Theory

1. **Valence band**- valence electron are those electron that are present in outermost shell. they have different

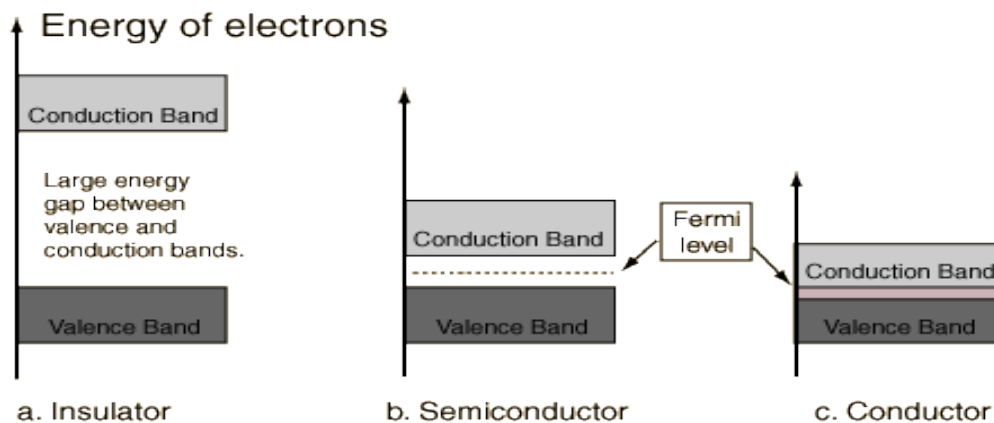
energy level and form an energy band known as valence band.

2. **Conduction band**- we know in the outermost orbit electrons are not tightly held to the nucleus and because of this they leave the outermost orbit at room temperature and become free electron orbit. these free Electron tend to conduct current in conductor.

3. **Fermi-level**-This is the energy level between the conduction band and the valence band where the probability of finding an electron is 50%.The state of the Fermi level changes due to impurity.

It is the energy level between Valence band and conduction where the probability of finding an electron is **50%**.

Fermi energy is the maximum possible energy possessed by free electrons of a material at absolute zero temperature (i.e., 0 K). The value of fermi energy for different materials is different.



Band Theory

It describes materials on the basis of presence or absence of electrons in valence band and conduction band.

Electrons conduct Electricity only when they are in conduction Band

Insulators	Semi-Conductor	Conductors
Due to large band gap between valence and conduction band, electrons are not available in conduction band so Poor conductors of electricity. Due to large band gap, electrons do not reach Conduction Band. Hence insulators do not conduct electricity.	A small band gap is present between conduction band and valence band. The energy to cover this gap can be easily provided so it serves as good conductors in Electronics Industry . Due to small gap between VB & CB, semiconductor conducts electricity to a lesser extend then conductors	There is no gap between valence band and conduction band so entire electrons of valence band lies in conduction band as well So it serves as Good conductors of electricity. (SSC CGL 20.07.2014) Due to overlapping of VB, CB, e ⁻ are present in CB so as external electric field is applied, current appears.



Examples of						
Insulator	Semi-Conductors					
	• Si (Silicon) Ge (Germanium) • Some doped elements of group 13, 14, 15 of periodic table.					
	Group 13		Group 14		Group 15	
• Wood • Rubber • Glass • Plastic • Mica • War • Ebonite • Paper	(Boron)	B	C(Carbon)	N	Nitrogen	
	(Aluminum)	Al	Si(silicon)	P	Phosphorous	
	(Gallium)	Ga	Ge(Germanium)	Ar	Arsenic	
	(Indium)	In	Sn (Tin)	Sb	Antimony	
	(Thallium)	Th	Pb (Lead)	Bi	Bismuth	
Conductors • Silver • Human Body • Earth • Copper, Iron, Aluminium • Coal • Mercury (Hg) • Salt, solutions, Acids, Alkali's						

A **hole** is considered as a seat of positive charge, having charge equal to that of an electron.

Doping is a process of addition of a desirable impurity atom to a pure semiconductor to modify its properties in a controlled manner. The impurity atoms added are called dopants.

(RRB JE 14.12.2014)

Conditions for Doping

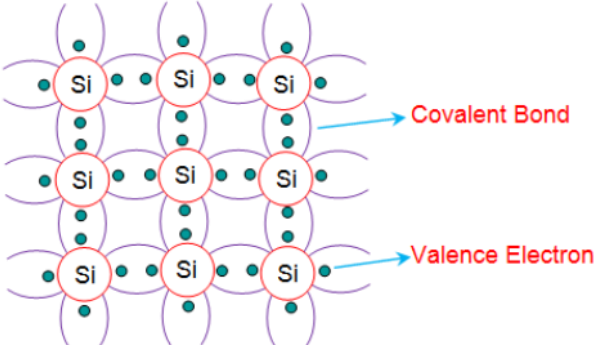
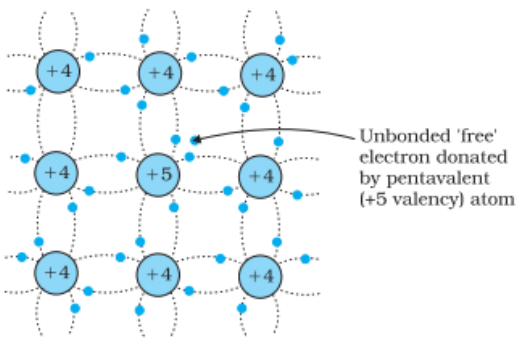
The impurity added may be ≈ 1 part per million (ppm).

Doping of a semiconductor increases its electrical conductivity to a great extent.

Methods of doping: Doping is achieved in many ways; for this, we can

1. Add the impurity atoms in the melt of the semiconductor
2. Implant dopant atoms or molecules by bombarding the semiconductor with them.

Doping of a semiconductor increases its electrical conductivity to a great extent.

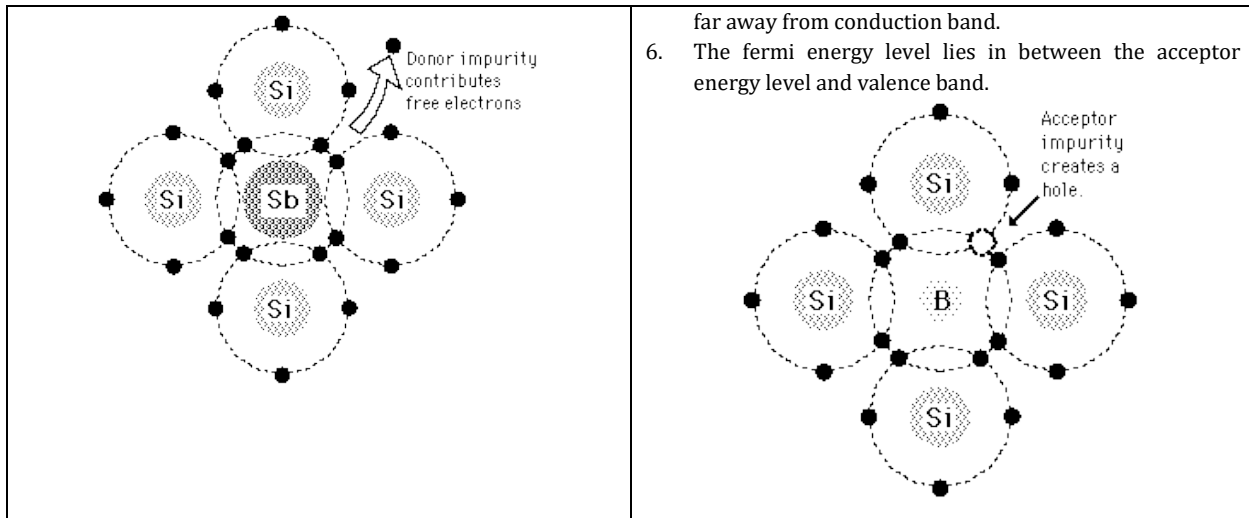
INTRINSIC SEMICONDUCTOR	EXTRINSIC SEMICONDUCTOR
1. It is pure semiconducting material and no impurity atoms are added to it. 2. Examples are crystalline forms of pure silicon and germanium. 3. No. of e^- = no. of holes 4. Its electrical conductivity is low. 5. Its electrical conductivity is a function of temperature alone. 	1. It is prepared by doping a small quantity of impurity atoms to the pure semiconducting material. 2. Examples are silicon and germanium crystals doped with phosphorous, indium, boron, aluminium etc. 3. Its electrical conductivity is high. 4. Its electrical conductivity depends upon the temperature as well as on the quantity of impurity atoms doped in the structure. 

Extrinsic semi-conductors are of two types:

- (i) n-type semiconductor (ii) p-type semiconductor

n-type semiconductor	p-type semiconductor
1. Group 5 + Group 4 2. The impurity atoms added, provide extra electrons in the structure, and are called donor atoms. (RRB SSE 21.12.2014) 3. The electrons are majority carriers and holes are minority carriers. 4. The electrons density (n_e) is much greater than the hole density (n_h). 5. The donor energy level is close to the conduction band and far away from valence band. 6. The fermi energy level lies in between the donor energy level and conduction band.	1. It is an extrinsic semiconductor which is obtained by doping the impurity atoms of III group of periodic table to the pure germanium or silicon semiconductor. Group 4 + Group 3 (RRB SSE 21.12.2014) 2. The impurity atom added, create vacancies of electrons (i.e., holes) in the structure and are called acceptor atoms. 3. The holes are majority carriers and electrons are minority carriers. 4. The hole density (n_h) is much greater than the electron density (n_e) 5. The acceptor energy level is close to valence band and is



**NOTE:**

Germanium (Eca-Silicon) is mainly used for semiconductor.

(RRB NTPC 19.1.2017, 17.01.2017 & 26.09.2018)

Germanium was later discovered and replaced with silicon.

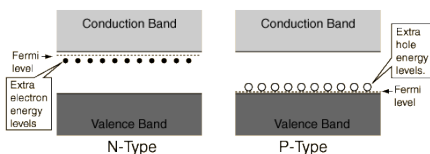
(RRB GROUP-D 05.10.2018)

When two semiconductors of p and n type are brought in contact, they form p-n junction which acts like rectifier.

(SSC (10+2) 10.11.2013)

Due to doping, the position of Fermi Level changes

As it moves towards valence band in P-type semiconductor and towards conduction band in N-type semiconductor



Effect of temperature on semiconductors

With the rise in temperature

- the resistance of a metallic conductor increases
- the conductivity of a metallic conductor decreases
- the resistance of a semiconductor decreases
- the conductivity of a semiconductor increases due to production of more number of electrons and holes.

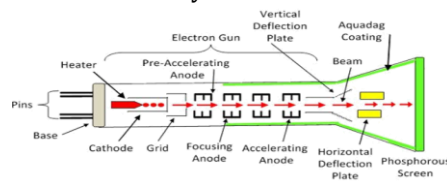
Vacuum Diode or CRT's

Vacuum tubes (also called **valves**) like the **diode valve** which has two electrodes (i.e. anode (called plate) and cathode). **Triode valve** which has three electrodes (i.e., plate, cathode and grid).

Tetrode valve having four electrodes (i.e., plate, cathode and two grids).

Pentode valve having five electrodes (i.e., plate, cathode and three grids).

In these vacuum tubes, the electrons are provided by heating the cathode using low tension battery. The controlled flow of electrons is achieved by varying the voltage between its different electrodes. The electrons strike the screen and give us a pictorial representation of data. A vacuum is created between inter-electrodes so that the moving electrons may not lose their energy on collision with air molecules in their way. In these vacuum tubes, the electrons can flow only in one direction (i.e., from cathode to anode), hence they are called as valves. The vacuum tube devices are bulky, operating at high voltages (more than 100 V), consume more power, having limited life and low reliability.



The PN Junction:

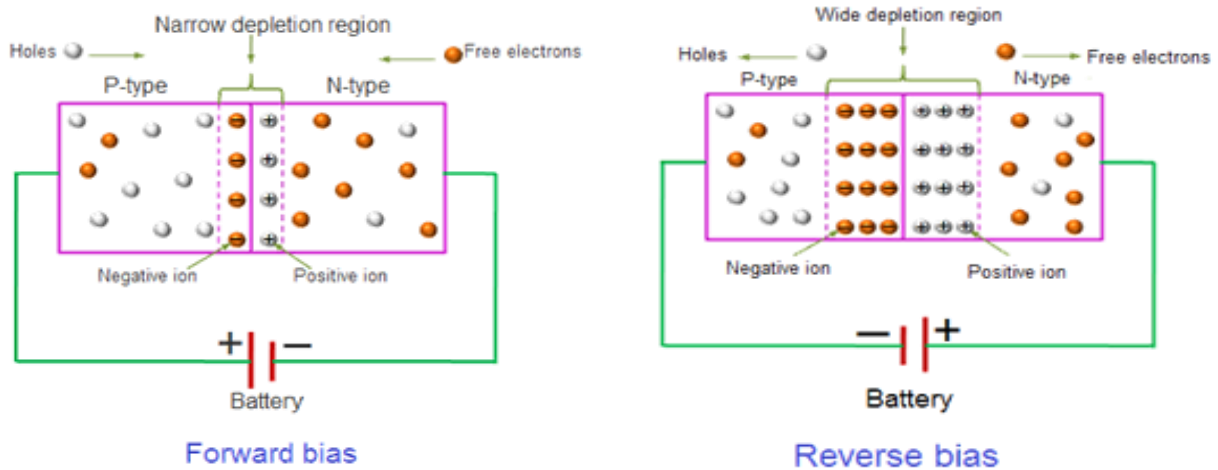
When you take a block of silicon and dope part of it with a trivalent impurity and the other part with a pentavalent impurity, a

boundary called the **pn junction** is formed between the resulting p-type and n-type portions. The pn junction is the basis for diodes, certain transistors, solar cells, and other devices. It is called a **DIODE or generic diode**.

A **p-type material** consists of silicon atoms and trivalent impurity atoms such as boron. The boron atom adds a hole when it bonds with the silicon atoms. However, since the number of protons and the number of electrons are equal throughout the material, **there is no net charge in the material and so it is neutral**.

An **n-type silicon material** consists of silicon atoms and pentavalent impurity atoms such as antimony. As we know, an impurity atom releases an electron when it bonds with four silicon atoms. Since there is still an equal number of protons and electrons (including the free electrons) throughout the material, there is no net charge in the material and **so it is neutral**.

If a piece of intrinsic silicon is doped so that part is n-type and the other part is p-type, a pn junction forms at the boundary between the two regions and a diode is created. The **p region** has many holes (majority carriers) from the impurity atoms and only a few thermally generated free electrons (minority carriers). The **n region** has many free electrons (majority carriers) from the impurity atoms and only a few thermally generated holes (minority carriers).



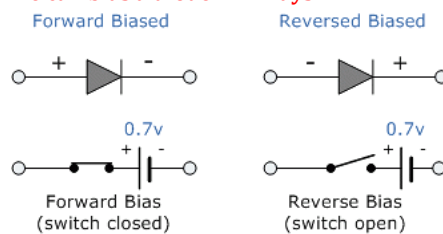
Formation of the Depletion Region: The free electrons in the n region are randomly drifting in all directions. At the instant of the pn junction formation, the free electrons near the junction in the n region begin to diffuse across the junction into the p region where they combine with holes near the junction, when the pn junction is formed; the n region loses free electrons as they diffuse across the junction. This creates a layer of positive charges (pentavalent ions) near the junction. As the electrons move across the junction, the p region loses holes as the electrons and holes combine. This creates a layer of negative charges (trivalent ions) near the junction. These two layers of positive and negative charges form the depletion region.

After the initial surge of free electrons across the pn junction, the depletion region has expanded to a point where equilibrium is established and there is no further diffusion of electrons across the junction. This occurs as follows: As electrons continue to diffuse across the junction, more and more positive and negative charges are created near the junction as the depletion region is formed. A point is reached where the total negative charge in the depletion region repels any further diffusion of electrons (negatively charged particles) into the p region (like charges repel) and the diffusion stops. In other words, the depletion region acts as a barrier to the further movement of electrons across the junction.

Barrier Potential: The potential difference required to move the electrons through the electric field is called the barrier potential.

Biasing: It is the method of connecting a power source to a device to make it functional.

Depending on the polarity of connections we can bias a diode in 2 ways:



- Forward Bias:** When positive terminal of the battery is connected to the p layer of the diode and negative terminal is connected to the n-layer of the diode. **Diode acts as a closed switch.** (RRB JE 14.12.2014)
- Reverse Bias:** When positive terminal of the battery is connected to the n layer of the diode and negative terminal of the battery is connected to the p layer of the diode. **Diode acts as an open switch.**

The p side is known as anode and the n side is known as cathode

Diffusion Current

The motion of charge carriers, due to difference in their concentration in the two regions of a p-n junction, gives rise to **diffusion current** across the junction.

Drift Current

The motion of these charge carriers due to electric field is called **drift**. As a result of it, a **drift current** starts, which is opposite in direction to the diffusion current.

Injection

The process of crossing of the depletion region by electrons and holes is known as **injection**.

Characteristics of a P-N Junction Diode

(i) Forward Characteristics

These are the graphical relations between forward bias voltage applied to p-n junction and the forward current through the p-n junction.

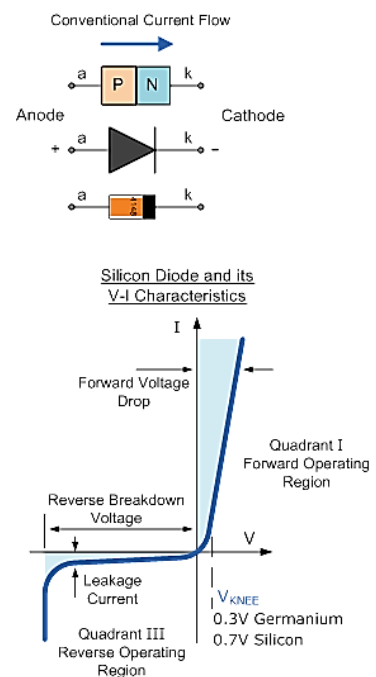
Knee Voltage

It is that **forward voltage beyond which the current** through the junction starts increasing rapidly with voltage, showing the **linear variation**. But **below the knee voltage the variation is non-linear**. The value of this voltage is 0.2 volt for germanium diode and 0.7 volt for silicon diode.

(ii) Reverse Characteristics

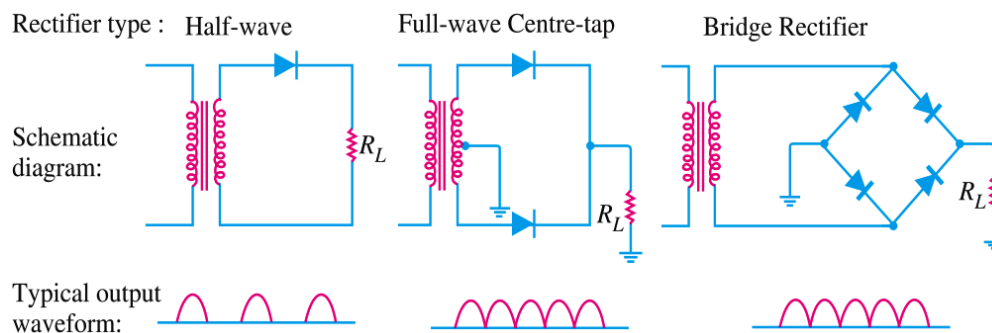
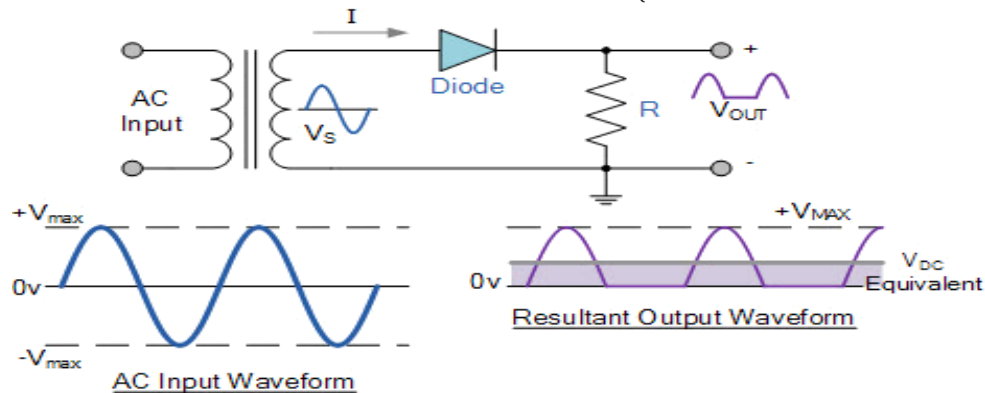
These are the graphical relations between the reverse bias voltage applied to the p-n junction and the reverse current across the p-n junction.

In reverse biasing of p-n junction diode, **the reverse current is very small ($\approx \mu A$)** and is voltage independent upto certain reverse bias voltage, known as **breakdown voltage**. It is called **reverse saturation current**.



Rectifier: It is an electrical device composed of one or more diodes that **converts alternating current (AC) to direct current (DC)**. A diode is like a one-way valve that allows an electrical current to flow in only one direction. This process is called rectification.

(RRB NTPC 29.04.2016 & SSC STENOGRAPHER 14.09.2017)



Special Purpose P-N Junction Diodes

(a) Zener Diode

It was invented by C-Zener. It is designed specially to operate in the reverse breakdown voltage region continuously without being damaged.

Zener diode is fabricated by heavy doping of both p-side and n-side of the p-n junction. As a result of it, the depletion region of Zener diode is very thin ($< 10^{-6}$ m) and the electric field set up across the junction is extremely high.

Zener Diode as Voltage Regulator

Its working is based on the fact that in reverse breakdown (zener) region, a very small change in voltage across the zener diode produces a very large change in current through the circuit but the voltage across the zener remains constant. So it provides constant output voltage.

(b) Photo Diode

Photodiode is a p-n junction which is an optoelectronic device in which current carriers are generated by photons through photo excitation, i.e., photoconduction by light.

When the photodiode is reverse biased with a voltage less than its breakdown voltage and no light is incident on its junction, the reverse current is extremely small (almost

negligible). This current is called **dark current**.

The photodiodes are used in reverse bias conditions because the change in reverse current through the photodiode due to change in light flux or light intensity can be measured easily as the reverse saturation current is directly proportional to the light flux or light intensity. But it is not so when photodiode is forward biased.

(c) Light Emitting Diode (LED)

Light emitting diode is a photo electronic device which converts electrical energy into light energy, under forward bias condition.

It is a heavily doped p-n junction diode which under forward bias emits spontaneous radiation. The diode is covered with a transparent cover so that the emitted light may come out.

LED's emit no light when reverse-biased.

LED is used in electronic devices, such as television emits radio waves.

(RRB NTPC 07.04.2016)

(d) Solar Cell

Solar cell is basically a solar energy converter. It is a special p-n junction device which converts solar energy into electric energy.

(e) Schottky diode

The Schottky diode (named after the German physicist Walter H. Schottky), also known

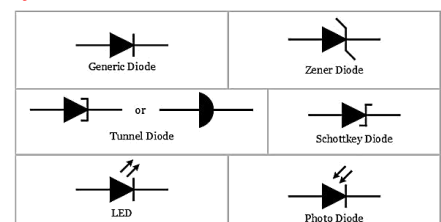
as **Schottky barrier diode** or **hot-carrier diode**, is a semiconductor diode formed by the junction of a semiconductor with a metal. It has a low forward voltage drop and a very fast switching action. In Schottky diode the junction is in between N type semiconductor to Metal plate. The schottky barrier diode has electrons as majority carriers on both sides of the junction. So it is a unipolar device

(f) Tunnel diode

A Tunnel diode is a heavily doped p-n junction diode in which the electric current decreases as the voltage increases. It is the P-N junction device that exhibits **negative resistance**. In tunnel diode, electric current is caused by "Tunneling". The tunnel diode is used as a very fast switching device in computers.

(RRB JE 14.12.2014)

Symbols of some common diodes



Transistor

A junction transistor is three terminal semiconductor device consisting of two p-n junctions formed by placing a thin layer of doped semiconductor (p-type or n-type) between two thick similar layers of opposite type. A transistor has three doped regions forming two p-n junction between them.

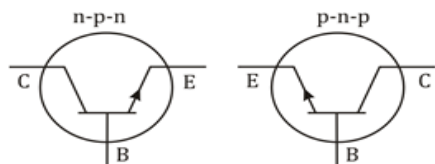
It is called as Bipolar Junction Transistor because it uses both holes and electrons as charge carriers.

Mostly transistor are found in hearing aid.

(SSC CGL 07.09.2016)

It is used as an amplifier in the circuits.

(SSC CGL 01.09.2016)

**Concept of an Amplifier**

An amplifier is a device which is used for increasing the amplitude of variation of alternating voltage or current or power.

(RRB JE 14.12.2014)

There are two input terminals for the signal to be amplified and two output terminals for

connecting the load; and a means of supplying power to the amplifier.

Advantages of Semiconductor Devices

1. Semiconductor devices are much smaller in size and weight as compared to vacuum tubes.
2. Semiconductor devices are not to be heated for emission of electrons. They start operating instantly. This saves a lot of electric power.
3. A transistorized equipment does not get heated, while operating. Therefore, no cooling arrangement is required.
4. The semiconductor devices are more rugged than the vacuum tubes. They can withstand rough handling.
5. Semiconductor device have much longer life as compared to the life of vacuum tubes.
6. Semiconductor devices are cheaper than vacuum tube devices.
7. Semiconductor devices are low power devices.

Disadvantages of Semiconductor Devices

1. Semiconductor devices are very sensitive to changes of temperature whereas the vacuum tubes are less sensitive.
2. It is difficult to produce semiconductor devices with exactly identical characteristics.

3. The noise level in semiconductor devices is higher than that of vacuum tubes.
4. Semiconductor devices cannot handle as much power as vacuum tubes.

In modern times, semiconductor devices are almost replacing vacuum tubes on account of their merits.

Logic Gate

A digital circuit which either allows a signal to pass through or stops it, is called a gate. Such gate allows the signal to pass through only when some logical conditions are satisfied. Hence they are called logic gate.

The logic gates are the building blocks of a digital system. Each logic gate follows a certain logical relationship between input and output voltages.

Each basic logic gate is represented by a symbol and its function is defined either by a truth table or by a Boolean expression.

In digital circuits, we mostly use junction diodes and transistors as switches to change from one voltage level to another. In the analysis of the digital circuits, we find out whether a voltage is low or high. In digital circuits low and high voltages are often represented by levels 0 and 1 respectively.

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A not gate can be implemented by single transistor.

(SSC CGL 21.04.2013))

INTEGRATED CIRCUIT

An **integrated circuit**, or IC, is small chip that can function as an amplifier, oscillator, timer, microprocessor, or even computer memory. An IC is a small wafer, usually made of silicon, that can hold anywhere from hundreds to millions of transistors, resistors, and capacitors.

IC is made up of silica.

(RRB NTPC 28.04.2016 & (SSC MTS 04.10.2017)

Transformer can not be developed within an **"INTREGRATED CIRCUIT"**

(SSC CGL 08.09.2016)

Types of Integrations of Integrated Circuits

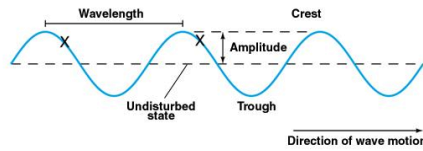
Name	Significa-tion	Year	Number of transis-tors	Number of logic gates
SSI	Small-scale integration	1964	1 to 10	1 to 12
MSI	Medium-scale integration	1968	10 to 500	13 to 99
LSI	large-scale integration	1971	500 to 20 000	100 to 9999
VLSI	Very large-scale integration	1980	20 000 to 1 000 000	10 000 to 99 999
ULSI	Ultra-large-scale integration	1984	1 000 000 and more	100 000 and more



08

Wave & Oscillations

A **wave** is a disturbance of a field in which a physical attribute oscillates repeatedly at each point or propagates from each point to neighboring points, or seems to move through space.

**Wave Motion**

A wave motion is a means of transferring energy and momentum from one point to another without any actual transportation of matter between these points.

Types of waves**Mechanical Waves**

These waves can be produced or propagated only in a material medium. These waves are governed by Newton's laws of motion. For example, waves on water surface, waves on strings, sound waves etc.

Electromagnetic Waves

These do not require a material medium for their production and propagation, they can pass through vacuum and any other material medium. Ultra-violet; radio waves; microwaves, X-rays, speed of all EM waves ,
 $c = 3 \times 10^8 \text{ m/s}$

**Matter Waves
(or de Broglie Waves)**

These waves are associated with moving particles of matter, like electrons, protons, neutrons, atoms, molecules, big physical bodies etc.

Transverse Wave Motion

In this, individual particles of the medium execute simple harmonic motion about their mean position in a **direction perpendicular to the direction of propagation of wave motion**. For example

- (i) movement of string of a sitar or violin,
- (ii) movement of the membrane of a Tabla or dholak,
- (iii) movement of a kink on a rope,
- (iv) light waves and all other electromagnetic waves are also transverse waves.

Longitudinal Wave Motion

A longitudinal wave motion is that wave motion in which individual particles of the medium execute simple harmonic motion about their mean position
(SSC CHSL (10+2) 25.03.2018)

. For example

- (i) Sound waves travel through air in the form of longitudinal waves,
- (ii) vibrations of air column in organ pipes are longitudinal,
- (iii) vibrations of air column above the surface of water in the tube of a resonance apparatus are longitudinal.

Crest

A crest is a portion of the medium, which is raised temporarily above the normal position of rest of the particles of the medium, when a transverse waves passes through it.

Trough

A trough is a portion of the medium, which is depressed temporarily below the normal position of rest of the particles of the medium, when transverse waves passes through it.

Compression

A compression is a region of the medium in which particles are compressed.



↑
 Compression
 High Pressure
 Low Velocity

Rarefaction

A Rarefaction is a region of the medium in which particles are farther apart.

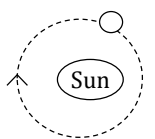


↑
 Rarefaction
 Low Pressure
 High Velocity

Waves and Oscillations

Periodic Motion

- In this, action repeats regularly after a fixed interval of time.

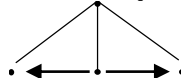


Earth revolves periodically around sun.

Oscillatory Motion

Body moves to and fro about a fixed point repeatedly.

- Action repeats after a fixed interval of time



But period of oscillation is small

Harmonic

Harmonic can be expressed in terms of single harmonic function (i.e., sine function or cosine function).

Non-Harmonic

Non-Harmonic oscillation is that oscillation which cannot be expressed in terms of single harmonic function.

A non-harmonic oscillation is a combination of two or more than two harmonic oscillations. Mathematically, non harmonic oscillation may be expressed as

$$\left. \begin{aligned} y &= a \sin \omega t + b \sin 2\omega t \\ y &= a \sin \frac{2\pi}{T} t + b \sin \frac{4\pi}{T} t \end{aligned} \right\}$$

Simple Harmonic Motion

$$F = -kx \quad \text{or} \quad \tau = -C\theta$$

If the restoring force/torque acting on the body in oscillatory motion is directly proportional to the displacement of body/particle and

$$\text{i.e. } F \propto x \quad \text{or} \quad \tau \propto \theta$$

& this force is always directed towards equilibrium position, then motion is called simple harmonic motion (HM)

A harmonic oscillation of constant amplitude and of single frequency is called simple harmonic oscillation.

Mathematically, a simple SHM be expressed as

$$y = a \sin \omega t = a \sin 2\pi t/T \quad \text{--- (1) or}$$

$$y = a \cos \omega t = a \cos 2\pi t/T \quad \text{--- (2)}$$

Here, y = displacement of body from mean position at any instant t .

a = maximum displacement or amplitude of displacement of the body.

$$\omega = \text{angular frequency} (= 2\pi\nu) = (2\pi/T)$$

ν = frequency and T = time period of harmonic oscillation.

SHM possess elasticity and as well as inertia.

(SSC CAPFS SI, CISF ASI & DELHI POLICE SI EXAM 22.06.2014)

Ex- A Simple Pendulum (SSC CPO SI, ASI 06.06.2021)

The Time period of a second pendulum is 2 second

(FCI ASSISTANT GRADE -II 22.01.2012)

Equation of SHM:

$$(a) F = -ky$$

$$(b) \frac{d^2y}{dt^2} + \omega^2 y = 0$$

Here $\omega = \sqrt{k/m}$ (k is force constant)

Some important terms

Displacement: The name displacement is given to a change in physical quantity under consideration with time in a periodic motion. Thus, displacement represent changes in physical quantities with time such as

position, angle, pressure, electric and magnetic fields etc.

Examples:

(i) **In a loaded spring:** When a body is oscillating under the action of a spring, the displacement variable is its deviation from the mean position of the oscillation, with time.

(ii) **In a simple pendulum:** The displacement variable is its angular

deviation from the vertical position during oscillations, with time.

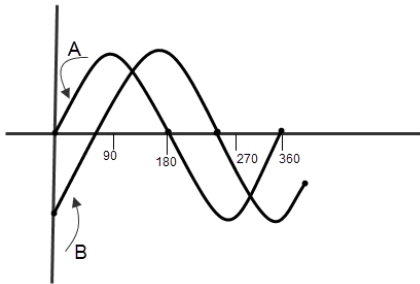
(iii) **During the propagation of sound wave in air:** The displacement variable is the local change in pressure, with time.

(iv) **During the propagation of electromagnetic waves:** The displacement variables are electric and magnetic fields which vary periodically, with time.



Initial Phase or Epoch

It is the phase of a vibrating particle corresponding to time $t = 0$. When $t = 0$, $\phi = \phi_0$. Its unit is **radian**.

Measurement of Phases

- (i) When the two vibrating particles cross their mean positions at the same time, moving in the same direction.

$$y_1 = a \sin \omega t \quad y_2 = b \sin \omega t$$

The phase difference between them is **zero**.

- (ii) When the two vibrating particles cross their mean position at the same time, moving in the opposite directions and the particle A is ahead of particle B by half vibration.

$$y_1 = a \sin (\omega t + \pi) \quad y_2 = a \sin \omega t$$

The phase difference between them is **π rad or 180°** .

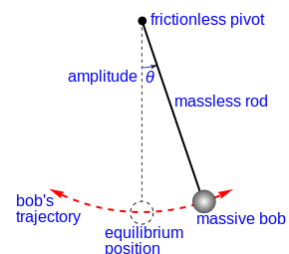
- (iii) When the particle A is passing from the extreme position with a further tendency to move towards left hand side and the particle B is passing from the mean position with a further tendency to move towards the right hand side.

$$y_1 = a \sin (\omega t + \pi/2) \quad y_2 = b \sin \omega t$$

- (iv) When the displacement of particle A is ahead of particle B by $1/8$ vibration. The motions of two particles can be represented by

$$y_1 = a \sin \omega t \quad y_2 = b \sin (\omega t - \pi/4)$$

$\pi/4$ rad or 45° .

Simple Pendulum

A simple pendulum is the most common example of bodies executing SHM.

An **ideal simple pendulum** consists of a heavy point mass body suspended by a weightless inextensible and perfectly flexible

string from a rigid support about which it is free to oscillate.

• Law's of simple pendulum:

Laws of isochronisms: It states that ($\theta \leq 4^\circ$), the time period of a simple pendulum is independent of its amplitude.

Laws of length: It states that time period of a simple pendulum varies directly as the square root of its length.

$$T \propto \sqrt{l}$$

Law of acceleration due to gravity: It states that, the time period of a simple pendulum varies inversely as the square root of acceleration due to gravity at that place.

$$T \propto 1/\sqrt{g}$$

So, Time period of simple pendulum,

$$T = 2\pi\sqrt{l/g}$$

- (a) When placed inside a lift being accelerated upwards, the effective value of g increases. Thus, the time period of pendulum decreases.

- (b) When placed inside a lift being accelerated downwards, the effective value of g decreases. Thus, the time period of pendulum increases.

- (c) Time period of the pendulum increases at higher altitudes due to decrease in g .

- (d) Time period of the pendulum at a place below the surface of earth decrease due to increasing g .

- (e) At the center of earth ($g=0$). So, the time period is infinite.

- (f) Time period is greater at equator than at poles.

- (g) Due to decrease in the value of g due to rotation of earth, the time period of the pendulum increases as the earth rotates about its axis.

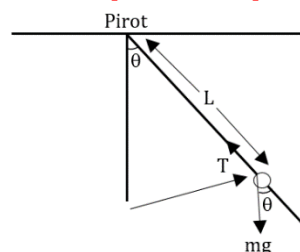
• Second Pendulum:

A second's pendulum is that pendulum whose time period is two second.

Time period of second pendulum,

$$dT = 2 \text{ sec}$$

$$\text{So, } l = 0.993 \text{ m}$$

• Time period of bar pendulum:

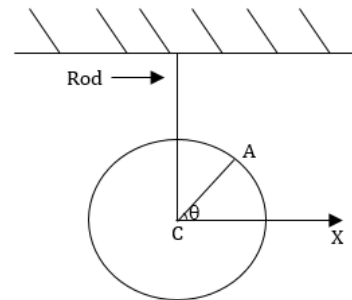
$$T = 2\pi\sqrt{I/mgl}$$

Here I is the rotational inertia of the pendulum.

and

$$T = 2\pi\sqrt{L/g}$$

$$\text{Here, } L = (k^2/l) + l$$

• Time period of torsion pendulum:

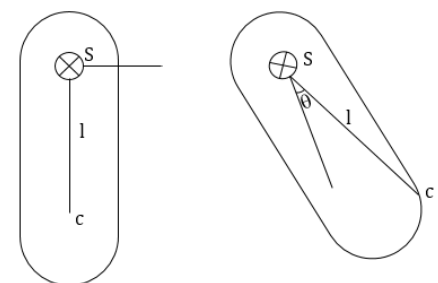
When disc is rotated in horizontal plane, wire gets twisted up and it produces an opposing force due to which disc moves in Oscillatory motion.

$$\therefore T = 2\pi\sqrt{\frac{I}{C}}$$

$I \rightarrow$ moment of inertia about point C.

$C \rightarrow$ constant opposing twisting motion

$T \rightarrow$ Torsional constant of wire.

Conical Pendulum:

Time period, $T = 2\pi\sqrt{(L \cos \theta / g)}$

Velocity, $v = \sqrt{(gR \tan \theta)}$

Compound Pendulum

$S \rightarrow$ point where solid object is pivoted

$C \rightarrow$ Center of mass of object.

$l \rightarrow$ distance between S and C

$$\text{So, } T = 2\pi\sqrt{\frac{I}{mgl}} \Rightarrow I = mL^2$$

$I \rightarrow$ moment of Inertia about points S.

- Resonance :** It is a phenomenon that only occurs when the frequency at which a force is periodically applied is equal or nearly equal to one of the natural frequencies of the system on which it acts. This causes **the system to oscillate with larger amplitude** than when the force is applied at other frequencies

- Frequencies at which the response amplitude is a relative maximum are known as **resonant frequencies** or **resonance frequencies** of the system. Near resonant frequencies, small periodic forces have the ability to



produce large amplitude oscillations, due to the storage of Vibrational energy.

Examples:

Swing

A playground swing is a familiar example of the resonance. When we push the swing, it swings forward and backwards. If a series of regular pushes are given to the swing, its motion can be built enormously. The man who is pushing the string has to match the timing of the swing. The pusher has to synchronize with the timing of the swing. This cause the motion of the swing to have increased amplitude and the swing will go higher. Once when the swing reaches its natural frequency of oscillation, a gentle push to the swing helps it maintain that amplitude of swing throughout due to resonance. We call this in-sync motion, as Resonance. But, if pushes are given irregular, the swing will hardly vibrate, and this out-of-sync motion will never lead



to resonance, and the swing will not go higher.

Bridge



A group of soldiers while marching on the bridge are asked to break their steps very often. Their rhythmic march can set extreme vibrations at the bridge's natural frequency. If their synchronized footsteps resonate with the natural frequency of the bridge, it can shake the bridge apart. So, When designing such structures, the engineers ensure that the resonant frequencies of components are different from that of other oscillating components. The biggest example of this is

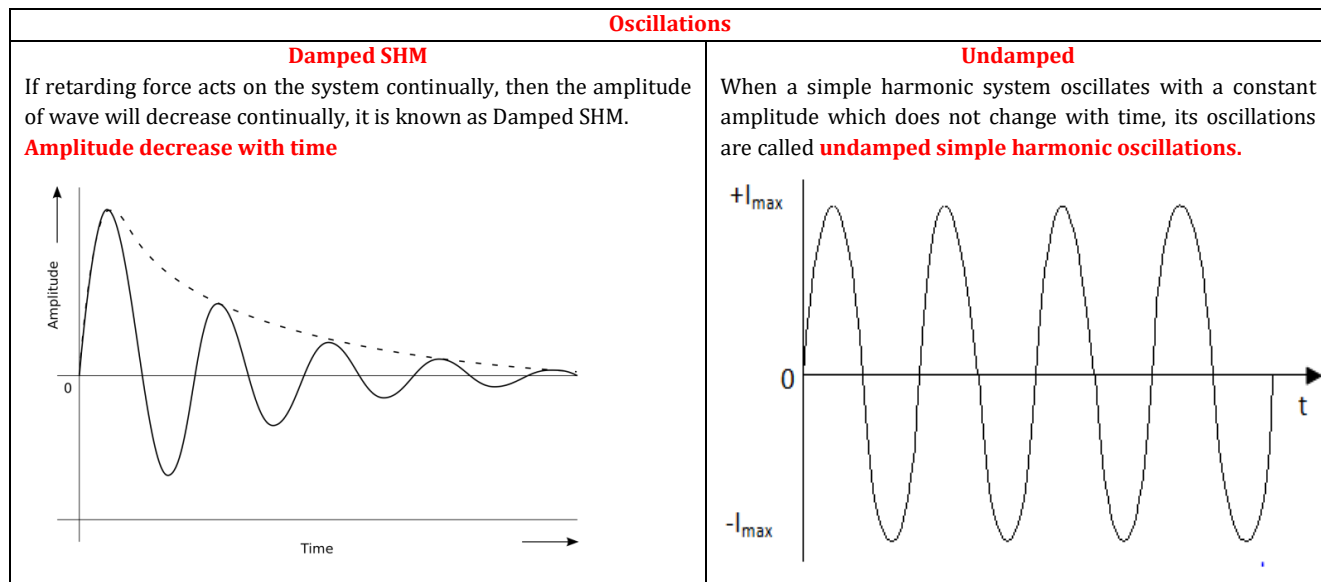
Tacoma Bridge Collapse, in which the frequency of the air matches with the frequency of the bridge, leading to its collapse.

Radio

When we turn the knob of the radio to our favorite channel, we are changing the natural frequency of the receiver. The natural frequency of the receiver then matches to the transmission frequency of the radio station. When two frequencies match, energy transfer occurs and we can listen to the selected channel.

Microwave Oven

The food is cooked very efficiently, evenly and quickly in a microwave because of resonance. The microwave oven has a certain wavelength and frequency. And like all other objects, Molecules of water and fat also have a resonant frequency. At a certain frequency, the molecules absorb wavelengths and start vibrating, causing cooking and heating up of food.



Damping is the process of continuous decrease in the amplitude of a signal under effect of an external retarding force.

Oscillations		
Free Oscillations If it vibrates with its own natural frequency without the help of any external periodic force. Examples: if you strike a tuning fork, it will begin to vibrate for some time after you struck it	Forced Oscillations When a body oscillates with the help of an external periodic force with a frequency different from the natural frequency of the body, its oscillations are called forced oscillations. Examples: when you push someone on a swing, you have to keep periodically pushing them so that the swing doesn't reduce.	Resonant Oscillations When a body oscillates with its own natural frequency ν_0, with the help of an external periodic force whose frequency ν is equal to the natural frequency of the body, the oscillations of the body are called resonant oscillations. Examples: singer breaking a wine glass



Condition required for Propagation of Transverse waves through a medium.

For the propagation of transverse waves, the material medium must possess the following four characteristics:

- (i) **Elasticity:** So that particles can return to their mean position, after having been disturbed.
- (ii) **Inertia:** So that particles can store energy and overshoot their mean position.
- (iii) **Minimum Friction:** amongst the particles of the medium ensures

minimum loss of energy so that waves can travel long distances.

(iv) **Uniform density of the medium.****Standing or Stationary Wave**

If two or more waves interfere which have slightly different frequencies, then the intensity of resulting wave will have alternate maxima and minima.

The number of minima or maxima in one second or number of beats heard per second is called Beat frequency.

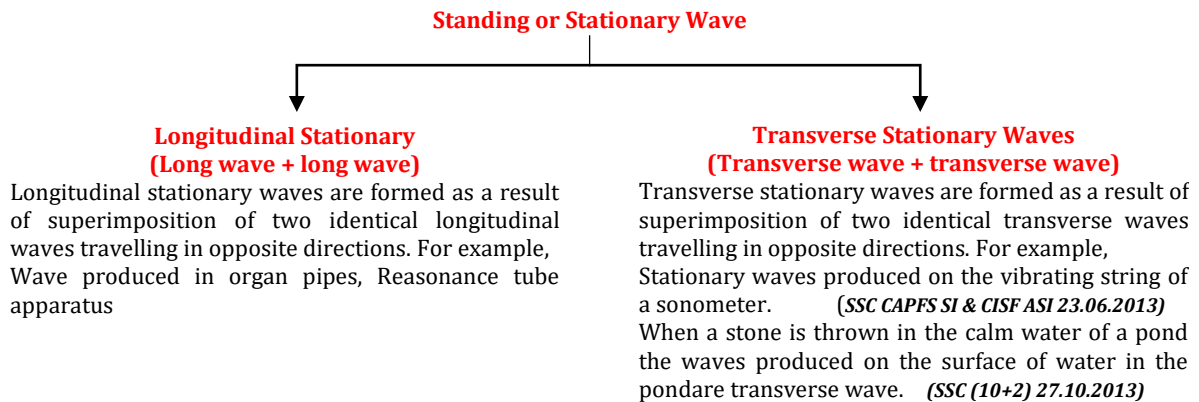
Beat frequency = $\nu = (f_1 - f_2)$ = Difference in frequency

Every point on the string vibrates in same phase with same frequency but different amplitudes which depend on position x of point along string.

This type of wave motion represented by equation is called **standing wave** because it appears to travel neither to left nor to right.

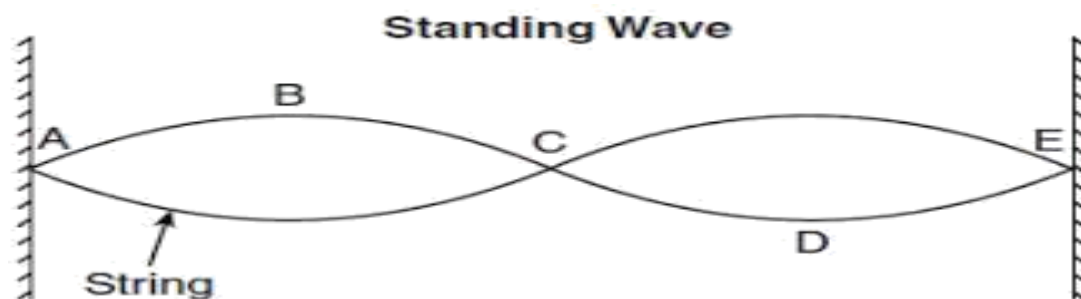
Nodes: The positions along the string for which the amplitude of oscillation is always zero. (Say at ends)

Antinodes: position along the string for which amplitude of oscillation is maximum.



Sound waves that propagate in solids is either longitudinal or transverse.

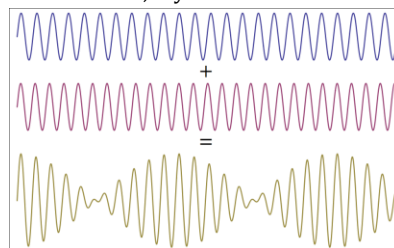
(SSC STENOGRAPHER 11.09.2017)

**Beats**

When two sound waves of equal amplitudes and nearly equal frequencies travelling in a medium along the same direction, superimpose on each other, the intensity of the resultant sound at a particular position rises and falls alternately with time.

If intensity of sound is maximum at time $t = 0$, one beat is said to be formed when intensity becomes maximum again, after becoming minimum once in between.

For the formation of distinct beats, difference in frequencies of two sources must be small, say less than 10.



09**Sound & Acoustics**

Sound is a form of energy, which produces the sensation of hearing.

- These are longitudinal mechanical waves.

(RRB NTPC 02.04.2017 & RRB GROUP-D 12.12.2018)

- It required medium to travel.
- Sound produce when vibration is occur.
- These waves cannot travel in vacuum.

(RRB NTPC 28.12.2021, 28.04.2016, ALP13.08.2018, 09.10.2018)

- Sound is measured in decibel.

(SSC JE 23.01.2018)

NOTE:

- If object have more density in the medium then through which sound travels creates pressure.

(SSC CHSL 27.03.2021)

- Sound does not effect by pressure.

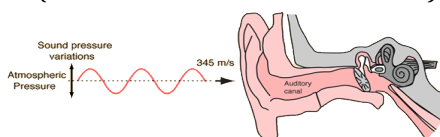
(RRB NTPC 07.04.2016)

- Sound is heard over longer distances on rainy days because sound travel fast in moist.

(SSC CGL 30.08.2015)

- 'Sound have following characteristics high density, regular shape and high rigidity.

(SSC CAPFS ASI & Delhi Police 04.07.2017)



Acoustics: The branch of physics concerned with the properties of sound.

Characteristics of a Wave**(i) Amplitude**

The maximum height of a wave is its amplitude.

Amplitude depend on the force required to vibrate an object.

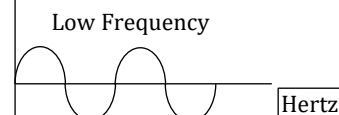
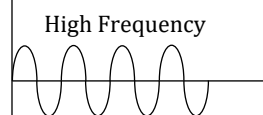
(RRB JE 24.05.2019)

Loudness or softness of sound is depend on amplitude

(SSC CHSL DEO & LDC 16.11.2014)

(RRB JE 24.05.2019)

(SSC STENOGRAPHER 11.09.2017)

(ii) Frequency (v)

Hertz

The number of waves passing through a point in one second.

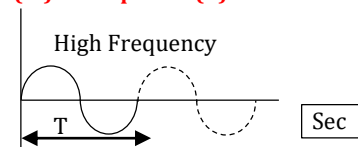
$$\text{Frequency} = \frac{1}{\text{time period}}$$

It is denoted by ν (new)

The SI unit of frequency is hertz.(Hz)

(SSC CGL 09.08.2017)

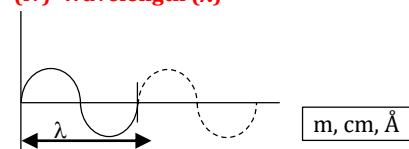
Sounds waves have low frequency and high wavelength.

(iii) Time period (T)

The time taken by a wave to complete one cycle.

(RRB JE 24.05.19)

Time period = $1/\text{Frequency}$

(iv) Wavelength (λ)

The horizontal distance covered by a wave in one cycle.

It is denoted by λ (lembda)

The sound is affected by change in air temperature by wavelength.

(SSC CHSL (10+2)01.11.2015)

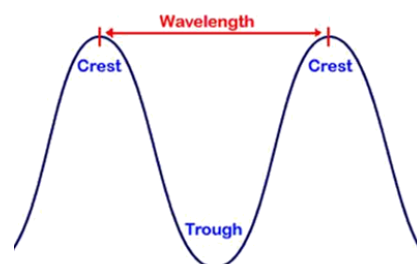
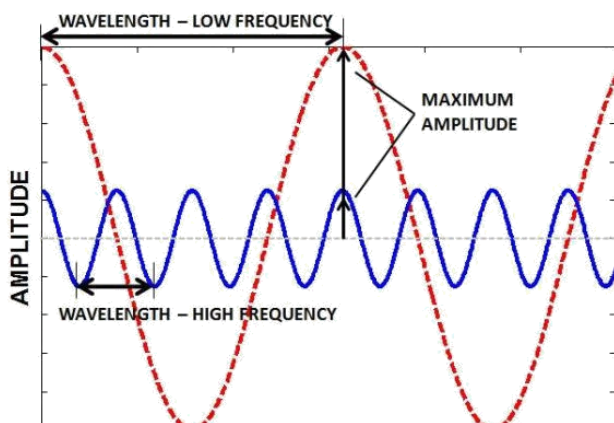
If frequency of sound wave is increased at a given velocity, its wavelength will decrease.

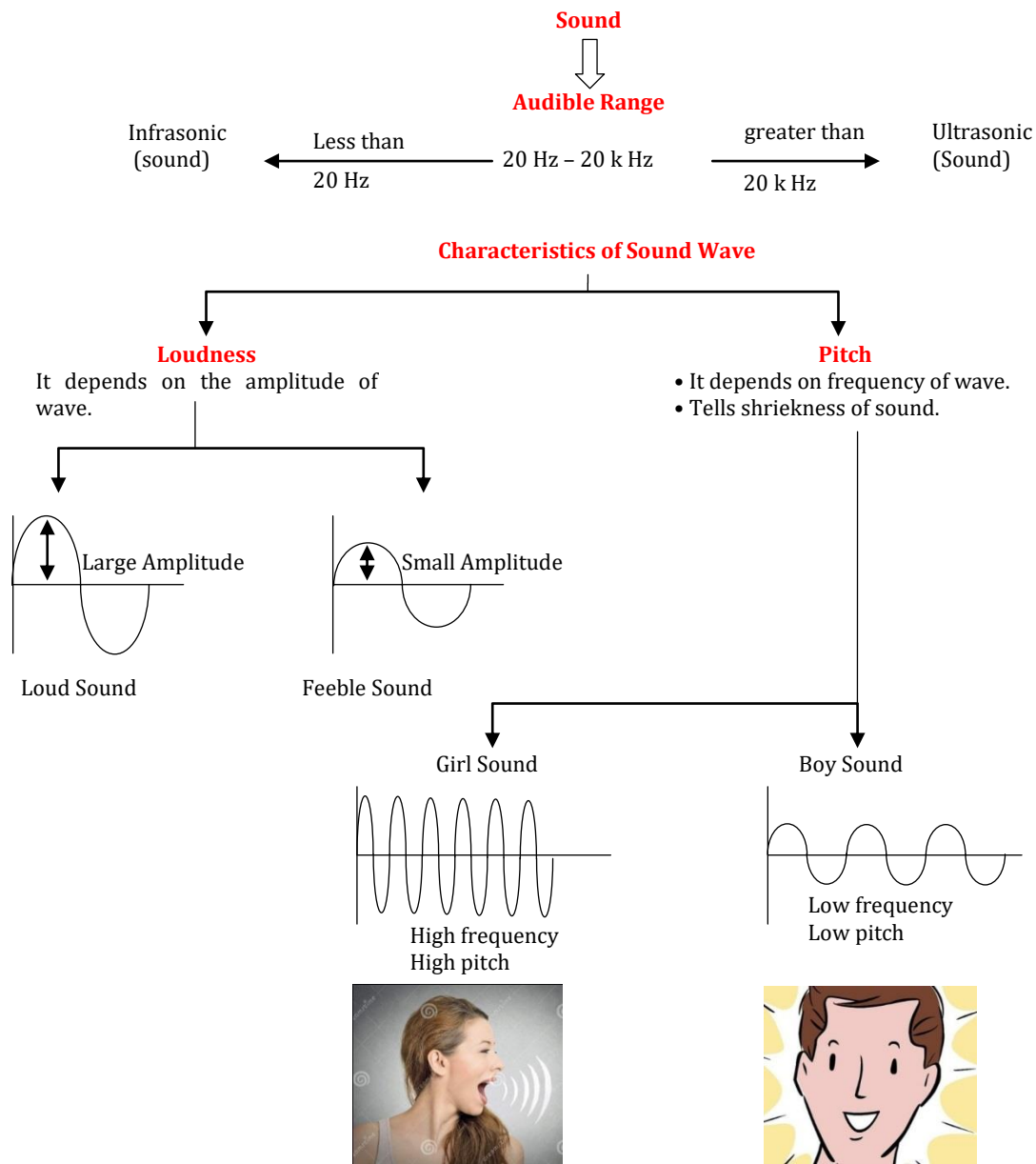
(RRB ALP 31.08.2018)

$$c = \lambda \nu$$

$$\text{Speed} = \text{wavelength} \times \text{frequency}$$

$$= \text{Wavelength}/\text{Time period}$$





According to their frequency range, waves are divided into the following categories

1. Audible Sound Waves

The longitudinal mechanical waves, which lie in the frequency range 20 Hz to 20000 Hz are called audible or sound waves. These waves are sensitive to human ear.

(FCI ASSISTANT 05.02.2012 & SSC MULTI TASKING 17.03.2013 SSC CSI IN DELHI POLICE, CAPFS & ASI 12.03.2019 & RRB NTPC 23.02.2021 & SSC CHSL 910+2) 10.07.2019)

Lowest frequency for human being is 20Hz.

(RRB NTPC 11.03.2021)

Highest frequency for human being is 20000Hz = 80db.

(RRB GROUP-D 08.10.2018 & 03.12.2018)

The ordinary and maximum tolerance limit of sound by human being is 60 db to 80 db.

(SSC CGL 21.04.2013)

2. Infrasonic Waves

The longitudinal mechanical waves having frequencies less than 20 Hz are called infrasonic waves. These waves are produced by sources of bigger size such as earthquakes, volcanic eruptions, ocean waves, elephants and whales.

(RRB GROUP-D 13.12.2018)

Frequency of infrasonic waves = less than 20Hz

(RRB GROUP-D 18.09.2018 & SSC CAPFS ASI & DELHI POLICE SI 06.07.2017)

3. Ultrasonic Waves

The longitudinal mechanical waves having frequencies greater than 20000 Hz are called ultrasonic waves. Human ear cannot detect these waves. But certain creatures like dog,

cat, bat, mosquito etc., can detect these waves

(SSC MTS 22.10.2017 & RRB NTPC 08.03.2021 & 05.04.2016 & SSC CHSL 910+2) 10.07.2019)

Note:

Bat not only detect but also produce ultrasonic waves

(RRB GROUP-D 09.10.2018 & 05.10.2018&)

(SSC CPO SI, ASI & INTELLIGENCE OFFICER 28.02.2011 & SSC COMBINED MATRIC LEVEL 16.06.2002)

Frequency of an ultrasonic wave is greater than 20000Hz.

(RRB JE 28.05.2019 & 16.10.2018)

Ultrasonic sound hear or produced by bats.

(SSC MTS 22.10.2017)

Applications of Ultrasonic waves

- For sending signals.
- For measuring the depth of sea.

- For cleaning clothes, aeroplanes and machinery parts of clocks.
- For removing lamp-shoot from the chimney of factories.
- In sterilizing of a liquid.
- In ultrasonography.

(SSC CHSL 16.11.2014)

- In SONAR
- Detects cracks and flaws in metal blocks.

(RRB NTPC 19.01.2021)

Characteristics of Sound**Intensity or Loudness**

Intensity of sound at any point in space is defined as the amount of energy passing normally per unit area held around that point per unit time. Its SI unit is watt/metre. Loudness depends on intensity of sound,

(RRB NTPC 27.03.2021)

Unit of loudness is **bel** and $1/10^{\text{th}}$ of bel is **decibel** (dB).

(RRB SSE 21.12.2014)

the intensity level of very low audio sound is 0 db.

(RRB GROUP-D 12.12.2018)

Intensity of sound wave is proportional to the square of amplitude.

(SSC CGL 07.09.2016)

Pitch or Frequency

The pitch of a sound is the characteristic which distinguishes between a shrillness or graveness of sound. Pitch depends upon frequency. A still and sharp sound has higher pitch and grave and dull sound has lower pitch.

(RRB ALP 10.08.2018 & SSC STENOGRAPHER 16.10.2011)

Frequency is measured in hertz (Hz).

(RRB GROUP-D 20.09.2018)

Quality or Timbre of Sound

Quality is that characteristic of sound, which enables us to distinguish between sound produced by two sources having the same intensity and pitch. It depends on harmonics and their relative order and intensity.

Quality of a musical note depends on harmonic present.

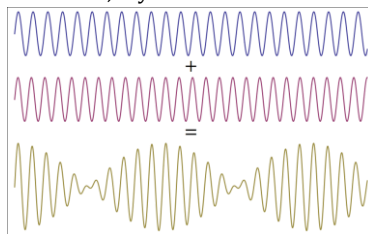
(SSC CGL 03.09.2016)

Beats

When two sound waves of equal amplitudes and nearly equal frequencies travelling in a medium along the same direction, superimpose on each other, the intensity of the resultant sound at a particular position rises and falls alternately with time.

If intensity of sound is maximum at time $t = 0$, one beat is said to be formed when intensity becomes maximum again, after becoming minimum once in between.

For the formation of distinct beats, difference in frequencies of two sources must be small, say less than 10.

**TONE or NOTE**

A sound produced due to single frequency is called tone.

(RRB ALP 17.08.2018,

RRB GROUP-D 04.10.2018)

A sound produced due to mixture of several frequencies is called a note.

The quality of tone of a musical sound produced by a stringed instrument depends on wave form of the sound.

(SSC CGL 09.09.2016)

Speed of Sound

The speed of sound basically depends upon elasticity and density of medium. Speed of sound in air is 332 m/s, in water is 1483 m/s and in iron is 5130 m/s.

AIR $\Rightarrow$ 343 m/s

(RRB NTPC 27.02.2021, RRB JE 14.12.2014 &

SSC CGL 07.03.2020)

Water $\Rightarrow$ 1483 m/sIron $\Rightarrow$ 5130 m/s

Seawater = 1531 m/s

(RRB GROUP-D 25.10.2018)

Speed of sound is fastest in solids as compare to other states of matter.

(SSC CGL 26.06.2011)

Speed of sound is maximum in solids then liquids and then in gases

(RRB ALP 20.08.2018, RRB GROUP-D

05.10.2018)

The speed of sound decreases, when it travels through solids to gas (RRB NTPC 23.01.2021, 28.12.2020, 28.04.2016, 09.10.2018)

When sound enters from one medium to another medium, its speed and wavelength changes but frequency remains unchanged.

Methods for determination of speed of sound in gas — **Kundt's tube** method

Methods for determination of speed of sound in air — **Resonance column** method

Note:

Liquids and solids generally have higher speed of sound than in gases

Effect of physical parameters on velocity of sound**Effect of Temperature**

If Temperature $\uparrow$ then velocity of sound $\uparrow$

Effect of Pressure

If temperature is constant, Pressure has NO effect on velocity of sound

Effect of Wind

If wind is blowing in the direction of sound then velocity of sound $\uparrow$.

Effect of Frequency

NO effect

Humidity

- Humid air $\rightarrow$ High velocity
 - Dry air $\rightarrow$ Low velocity
- ($\uparrow$ means Increase)

Velocity of sound depend on temperature and humidity.

(SSC MULTI TASKING 16.02.2014)

Velocity of sound in moist air is more than in dry air because the speed of sound is directly proportional to the square root of its density.

(SSC CGL 09.08.2015)

Reflection of sound

The rebounding back of sound, when it strikes a hard surface is called **reflection of sound**.

The repetition of sound due to reflection of sound wave is called an **echo**.

These cannot be heard on the surface of the moon and in outer space because there is no air on the moon.

(RRB JE 27.05.2019)

The flash of light is seen first and the sound of thunder is heard a little later.

Because the speed of sound in air is very slower as compared to the speed of light in air.

Speed of Light = 3×10^8 m/sec, Speed of sound = 332 m/sec

Echo:

It is a reflection of sound that arrives at the listener with a delay after the direct sound.

(RRB JE 24.05.2019)

To hear an echo we need minimum distance between listener and the source is 17.2m and the time taken by sound is 0.1s.



(RRB GROUP-D 26.11.2018, RRB ALP
13.08.2018)

(SSC CGL 05.08.2017 & SSC JE 27.01.2018)

Examples:

- Echo produced by the bottom of a well,
- by the walls of an enclosed room
- by the walls of an empty room.

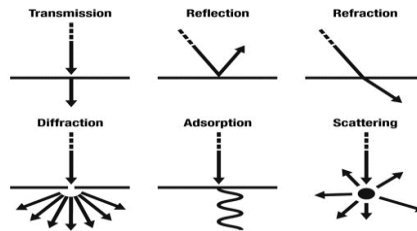
A true echo is a single reflection of the sound source.

(RRB GROUP-D 22.09.2018 & RRB ALP
21.08.2018)

To here an echo we use this formula:

$$\text{Velocity} = \frac{\text{Distance travelled}}{\text{time taken}} = \frac{2d}{t}$$

Different processes involved with waves



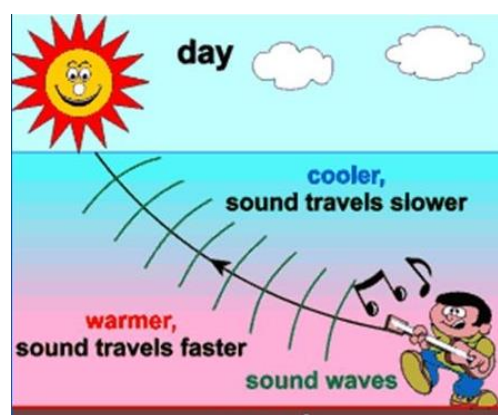
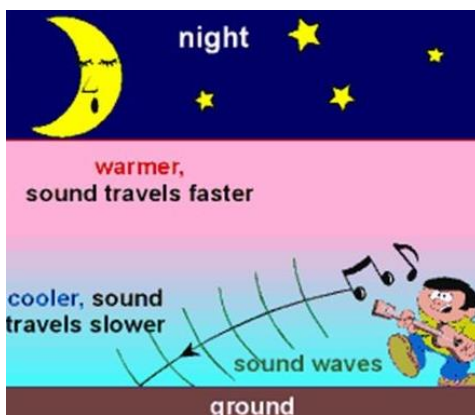
Refraction of Sound Waves

When a sound wave moves from one mechanical medium to another mechanical medium, then the waves are refracted or transmitted. This phenomenon is called refraction of sound.

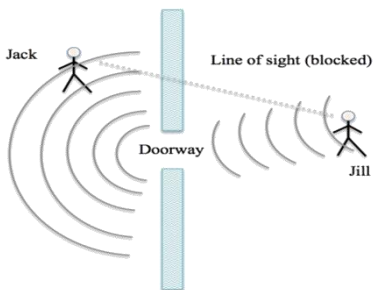
- The refracted waves deviates from the original path of the incident waves. The main reason for occurrence of

refraction in sound is difference inspeeds of sound, in different media at different temperatures. Range of sound and temperature depends on each other, in the following ways

- On a warm day, the air near the ground is warmer than the air above and so the speed of sound waves near the ground is higher. Thus, causes bending of the sound away from the ground.
- On a cold day or at night, the reverse happens and the sound waves bend towards the earth. Thus, on a cold day, sound can be heard over larger distance.



Diffraction of Sound Waves



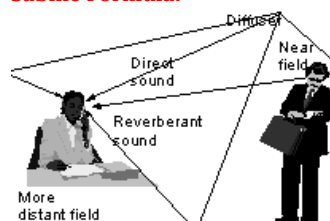
When sound waves are originated by a vibrating source, then they spread in the medium. If the medium is homogeneous, then these waves have spherical wave fronts from the point source. Far from the source, the wave fronts are nearly planes and the shape of the wave fronts is changed, when the sound waves meet an opening in its path. This leads to bending of sound waves around the edges. Such bending of sound waves from an opening is called diffraction. Since, the wavelength of the sound waves is approximately 1 m and of the same order as the doors and windows, etc., of our houses. Therefore, the sound waves diffracted broadly and one person easily hears the voice of the another person

(RRB NTPC 25.01.2021)

Reverberation Time (T): Persistence of sound even after sound has stopped.

(RRB NTPC 05.03.2021, 16.01.2021 RRB ALP
20.08.2018 & RRB JE 27.05.2019)

Sabine Formula:



Formula developed by Wallace Clement Sabine that allows designers to plan reverberation time in a room in advance of construction and occupancy

Formula: $T = 0.049(V/A)$ where T = reverberation time or time required (for sound to decay 60 dB after source has stopped) in seconds. V = Volume of room in cubic feet. A = Total square footage of absorption in sabines.

Part of it is absorbed and transmitted

Remaining is Reflected

Absorption Coefficient α

$$= \frac{\text{Sound energy absorbed by Surface}}{\text{Total incident energy on surface}}$$

Standard unit to measure α = OWU (Open window unit)

Total Absorption = α (Surface Area)

↑

Absorption coefficient

Doppler Effect

It is the phenomenon of change in apparent pitch of the sound due to relative motion between the source of sound and the listener.

According to Doppler's effect, whenever there is a relative motion between a source of sound and listener, the apparent frequency of sound heard by the listener is different from the actual frequency of sound emitted by the source.

Doppler effect is the motion related change in frequency of sound.

$$f = f_0 \left[\frac{v + v_o}{v + v_s} \right]$$

$f \rightarrow$ observed frequency

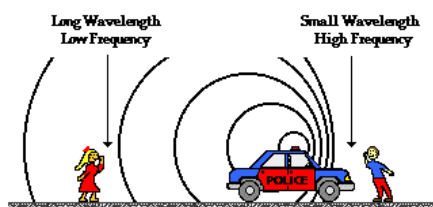
$f_0 \rightarrow$ original frequency

$v \rightarrow$ Speed of wave in medium (always +ve)

$v_o \rightarrow$ velocity of observer

$v_s \rightarrow$ velocity of source



The Doppler Effect for a Moving Sound Source**Applications of Doppler's Effect**

The change in frequency caused by a moving source/observer/listener is called **Doppler Shift**.

- By police to check over speeding of vehicles,
- At airports to guide the aircraft.
- In the military to detect enemy aircrafts.
- By astrophysicists to measure the velocities of planets and stars,
- To study heart beats and blood flow in different parts of the body.

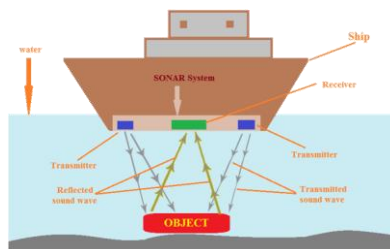
Sonar

The acronym SONAR stands for **Sound Navigation and Ranging**.

(RRB GROUP-D 26.11.2018, RRB NTPC 09.04.2016 & 16.012.2021)

It is a device, that uses the ultrasonic waves to measure the distance, direction and speed of objects under water.

(RRB NTPC 08.03.2021, RRB JE 31.05.2019 & 25.05.2019)



The ultrasonic sound pulse travel from the ship to the bottom of the sea, and back to the ship.

In other words, the SONAR measures the time taken by the echo to return to the ship.

The main component in a SONAR, that is used to detect the distance, direction and speed of an underwater body are transmitter and detector (RRB JE 29.05.2019)

Applications of Sonar

- Resource location for submarine.
- Submarine navigation.
- In aircraft.
- Remotely operated vehicles.
- Detecting the vehicle location.

MACH NUMBER

It is the ratio between the speed of object in medium to the speed of sound in medium. It is a dimensionless quantity.

$M = \text{speed of object in medium} / \text{speed of sound in medium}$

$M = v/c$

According to mach number various types of flow are classified;-

- SUB SONIC
- SONIC
- SUPER SONIC
- HYPERSONIC

- SUB SONIC** - speed of object that is lower than that of speed of sound. For this Mach number is less than 1.
- SONIC** - speed of sound that is equal to Mach number 1.

(SSC CAPFS ASI & SI Delhi Police SI 05.07.2017)

- SUPER SONIC**- speed greater than the speed of sound

(RRB GROUP-D 08.10.18, 04.10.18, RRB NTPC 17.01.17)

For this Mach number is more than 1.

- HYPER SONIC** - for this Mach number is 05 to 10.

Speed of Sound in Different Medium at 25°C

State	Substance	Speed (in m\s)
Gases	Hydrogen	1284
	helium	965
	Air	346
	Oxygen	316
	Sulphur dioxide	213
Liquids	Water	1498
	Seawater	1531
Solids	Aluminium	6420
	Nickel	6040
	Steel	5960
	Iron	5950
	Brass	4700
	Glass	3980

NOTE:

- The technique used to absorb noise by using soft and porous surface is called sound protection (RRB Group-D 10.12.2018)
- Vibration cause sound (RRB Group-D 08.10.2018 & 16.10.2018)



10

Light

Light is a type of energy.

Light is a transverse and electromagnetic wave.

(SSC JE 24.01.2018)

Like all electromagnetic waves light can travel through vacuum.

Transparent/Translucent/Opaque:

Transparent – the materials through which objects can be seen clearly are known as transparent objects.

Ex- glass, water, air etc.

(RRB NTPC 16.04.2016)

Translucent- the materials through which objects can be seen but not clearly seen, are known as translucent.

Ex- butter paper, sunglasses, vegetable oil etc.

(RRB NTPC 08.03.2021)

Opaque- the materials through which objects cannot be seen are known as opaque objects.

Ex- wood, metal etc.

Speed of light in different mediums:-

MEDIUM	SPEED OF LIGHT (m/s)
VACUUM	3×10^8 (RRB ALP 10.08.2018, RRB GROUP-D 03.12.2018 & RRB JE 24.05.2019) (SSC CONSTABLE 12.05.2013)
WATER	2.25×10^8
GLASS	2×10^8

Speed of sound is maximum in gas then in liquid and then in solid.

(RRB ALP 31.08.2018)

& RRB Group-D 01.10.2018)

GAS > LIQUID > SOLID

Luminous Object/ Non-Luminous Objects:

Luminous Object- objects that have their own light are luminous object

(RRB GROUP-D 26.09.2018)

(SSC Delhi Police Constable 05.12.2017)

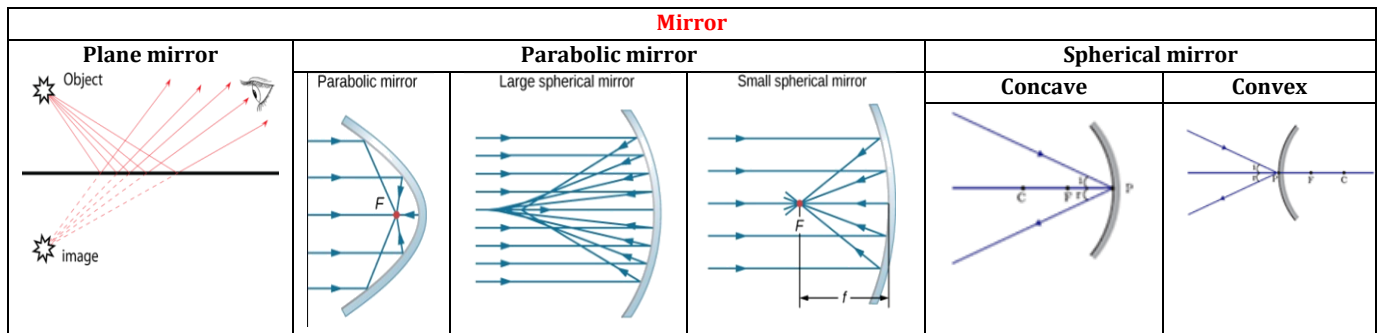
Ex-sun, moon, light etc.

Non-Luminous Object- objects that do not have their own light are non-luminous objects.

(RRB GROUP-D 25.09.2018)

Ex-bulb, torch etc.

Mirror



Mirror

It is a polished surface like glass, which reflects almost all the light. The two types of mirror are as follows

1. Plane mirror
2. Spherical mirror

Plane Mirror

In the plane mirror, the size of image is always equal to the size of the object and it is of virtual nature. The image in a plane mirror appears as far behind the mirror as the object is in front of it.

Image formed by plane mirror is virtual and laterally inverted.

(RRB GROUP-D 31.10.2018, 10.10.2018, 26.09.2018, 24.09.2018, 05.10.2018 & DELHI POLICE 03.12.2020)

- If the object is displaced by a distance towards or away from the mirror, then its image will be displaced by a distance towards or away from the mirror.
- The minimum size of the mirror required to see the full image of an observer is half of the height of the observer.

- If the plane mirror is rotated in the plane of incidence by an angle θ , then the reflected ray rotates by an angle 2θ .
- Focal length of plane mirror is infinity, i.e. power is zero. Linear magnification produced by plane mirror is 1.
- The size of the image formed is always equal to the size of the object.

(SSC JE 22.01.2018)

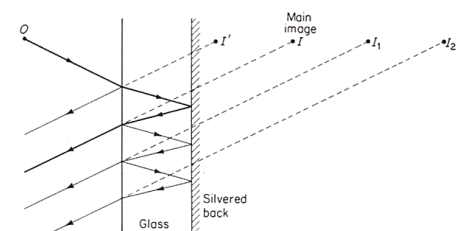
- When two plane mirrors are kept facing each other at an angle θ and an object is placed between them, then

$$\text{Number of images, } n = \left(\frac{360^\circ}{\theta} - 1 \right), \text{ if}$$

$\frac{360^\circ}{\theta}$ is even or the object lies symmetrically.

$$\text{Number of images, } n = \left(\frac{360^\circ}{\theta} \right) \text{ if}$$

$\frac{360^\circ}{\theta}$ is odd or the object lies asymmetrically.



- When two plane mirrors are parallel to each other the number of images are infinity.

(SSC CAPFS ASI 7 Delhi Police SI 03.07.2017)



Note: The plane mirror is utilized in the formation of kaleidoscope, periscope and looking glass, etc.

A **kaleidoscope** is a toy that uses light and mirrors to reflect objects and create beautiful, fascinating repeating patterns. There are many different types of kaleidoscopes that create different patterns



Spherical Mirror

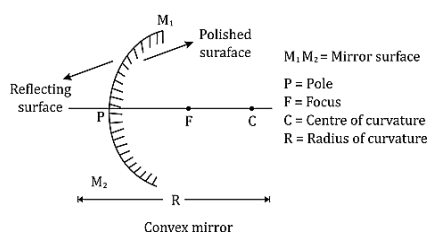
The spherical mirror is a highly polished curved surface, whose reflecting surface is a cut part of a hollow sphere. And it used the concept of reflection of light. There are two types of spherical mirrors given as below

(RRB JE 26.05.2019)

1. Convex Mirror

The spherical mirror whose reflecting surface is outwardly leaned, called convex mirror. It is also called diverging mirror. It formed virtual, erect and diminished image.

(SSC JE 22.01.2018 & RRB JE 28.08.2019, RRB GROUP-D 30.10.2018 & 10.10.2018)

**Focal Length**

- The distance of principal focus from the pole of mirror is called focal length.
- The distance of focus from the optical center of lens.

Optical center: It is the center of the lens**Pole:** It is the center of the mirror through which principal axis pass.

(RRB ALP 31.08.2021 & 10.08.2018)

(RRB GROUP-D 27.09.2018,

RRB NTPC 12.01.2021)

Centre of curvature: The centers of the two imaginary spheres of which, the lens is a part are called centers of curvature of the lens. A lens has two centers of curvature with respect to its two curved surface.

Radii of curvature: The radii of the two imaginary spheres of which, the lens is a part are called radii of curvature of the lens. A lens has two radii of curvature. These may not be equal.

Principal axis: A line joining the centers of curvature of the two bounding surfaces of a lens, is called its principal axis

Aperture – the diameter of the reflective surface of a spherical mirror is called aperture. It is the apparent area of a mirror or lens through light can pass.

(RRB ALP 20.08.2018)

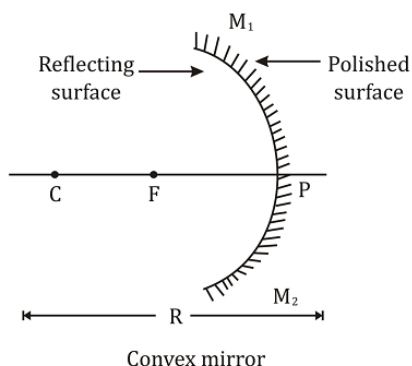
Formation of Image by Convex Mirror for Different Positions of Object

Position of object	Position of image	Nature and size of image	Ray Diagram
At infinity	At the focus, behind the mirror	- Virtual - Erect - Extremely diminished	
between infinity and the pole of the mirror (i.e. at finite distance)	Between the focus and the pole, behind the mirror	- Virtual - Erect - Diminished	

2. Concave Mirror

The spherical mirror whose reflecting surface is inwardly leaned, called concave mirror. It is also called converging mirror.

(RRB ALP 13.08.2018, 31.10.2018 & RRB GROUP-D 10.10.2018)



A concave mirror always form an image which is virtual and erect

(SSC CGL 16.05.2010 & 21.08.2017 &

SSC JE 29.01.2018)

Focus– the point at which all the rays meet.

(RRB GROUP-D 28.09.2018)

APERTURE – the diameter of a reflecting surface.

(RRB ALP 20.08.2018)

Focal Length

- The distance of principal focus from the pole of mirror is called focal length.
- The distance of focus from the optical center of lens.

Focal length of convex mirror is positive.

(RRB GROUP-D 16.10.2018)

The focal length increase if human eye lens becomes thin.

(SSC JE 29.01.2018)

Optical center: It is the center of the lens**Pole:** It is the center of the mirror through which principal axis pass.

Centre of curvature: The centers of the two imaginary spheres of which, the lens is a part are called centers of curvature of the lens. A lens has two centers of curvature with respect to its two curved surface.

(RRB ALP 17.08.2018)

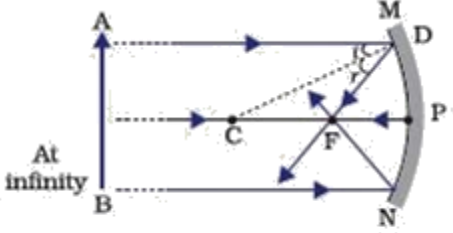
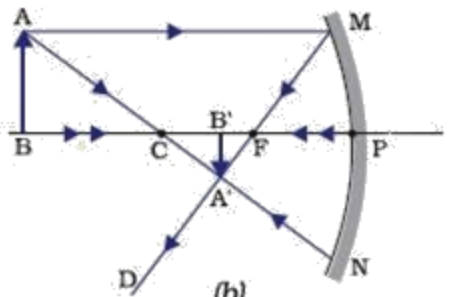
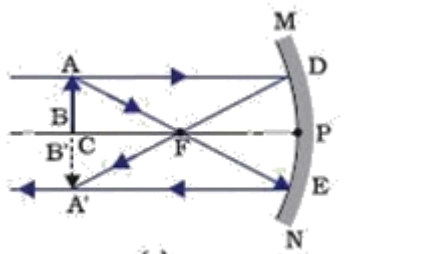
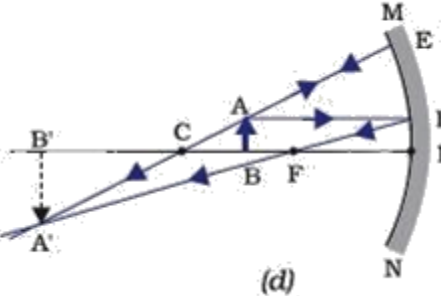
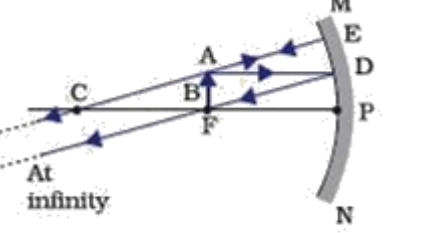
Radii of curvature: The radii of the two imaginary spheres of which, the lens is a part are called radii of curvature of the lens. A lens has two radii of curvature. These may not be equal.

Principal axis: A line joining the centers of curvature of the two bounding surfaces of a lens, is called its principal axis.

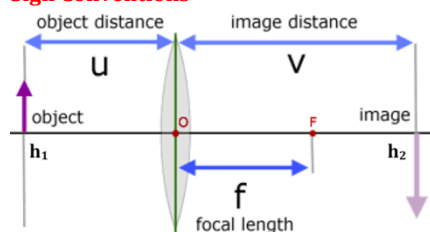
Relation between focal length and radius of curvature of a mirror is $R=2f$.



(RRB GROUP-D 22.10.2018 & 15.10.2018)**Formation of Image by Concave Mirror for Different Positions of Object**

Position of object	Position of image	Nature and size of image	Diagrams
At infinity (RRB GROUP-D 15.10.2018 & SSC CPO 2022, 10.11.2022 Shift-1)	At focus or in the focal plane	• Real • Inverted • Extremely diminished point size	 (a)
Beyond the centre of curvature but at finite distance	Between focus and the centre of curvature	• Real • Inverted • Diminished	 (b)
At the centre of curvature (RRB GROUP-D 20.09.2018) (RRB ALP 14.08.2018 & 20.09.2018) (SSC JE 23.01.2018)	At the centre of curvature	• Real • Inverted • Equal to the object size	 (c)
Between focus and centre of curvature. (RRB GROUP-D 03.12.2018, 19.09.2018, 03.12.2018, 19.09.2018 & RRB ALP 21.08.2018)	Beyond the centre of curvature	• Real • Inverted • Bigger than object	 (d)
At the focus (RRB GROUP-D 22.09.2018 29.08.2018, 22.09.2018 & RRB ALP 29.08.2018)	At infinity	• Real • Inverted • Extremely magnified	 (e)

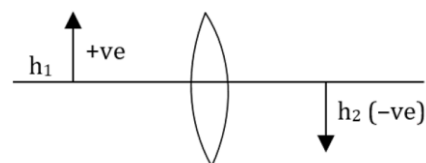
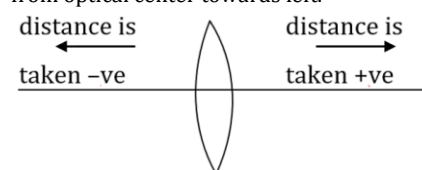
Between the pole and focus (RRB GROUP-D 11.12.2018, SSC MTS 07.08.2018)	Behind the mirror	• Virtual • Erect • Magnified	
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Sign Conventions

u = distance of object from center
 v = distance of image from center
 f = focal length
 h_1 = height of object
 h_2 = height of image

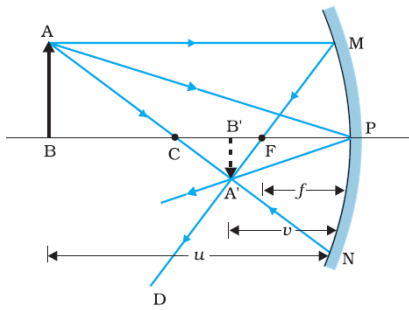
 $2f = R = \text{Radius of curvature}$
Rules for Image

The distance is taken positive if we move from optical center towards right.
 The distance is taken negative if we move from optical center towards left.



The height taken above the principal axis is considered as positive.
 The height taken below the principal axis is considered as negative.

Real Image If the rays actually meet to form an image. 	Virtual Image Here rays actually does not meet rather they are extended backwards so as to come from a point. The point when these extended rays meet gives us image.
Magnified Image Height of Image > Height of object 	Diminished Image Height of Image < Height of object
Erect Image If direction of image is same as that of object 	Inverted Image Direction of image is opposite to that of object.

Mirror Formula

All distance must be measured from the mirror pole.

(RRB GROUP-D 06.12.2018)

$$\text{It is given by, } \frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

(RRB GROUP-D 11.10.2018)

[valid in all situations for all spherical mirrors for all positions of the object.]

Where,

f = focal length of mirror,

u = distance of object from mirror

And v = distance of image from mirror

(RRB JE 30.08.2019)

• **Magnification:** Magnification is the ratio of size of the image formed by the mirror/lens to the size of the object.

It is represented by m

$$m = \frac{\text{size of image } (h_2)}{\text{size of object } (h_1)} = \frac{A'B'}{AB}$$

(RRB NTPC 17.01.2017)

Note 1:

- (i) $m > 1$, image formed is enlarged.
- (ii) When $m < 1$, image formed is diminished
- (iii) Again, when m is positive, image must be erect (i.e., virtual)

(RRB GROUP-D 19.09.2018)

- (iv) When m is negative, image must be inverted (i.e., real)
- (v) Obviously, in case of a concave mirror, magnification may be positive or negative, but in case of convex mirror, magnification is positive only.

Note 2:

1. When image formed is virtual (i.e., erect), magnification is positive. When image formed is real i.e., inverted, magnification is negative.

2. In a concave mirror, the image formed may be real or virtual depending on the position of the object. So magnification of a concave mirror can be negative as well as positive.
3. In a convex mirror, the image formed is always virtual. Therefore, magnification of a convex mirror can be positive only.
4. In case of a plane mirror, $|m| = |v|$. Therefore, $m = +1$. It implies that both, the object and image are upright and size of image = size of object

Practical Applications of Spherical Mirror:**(a) Convex Mirrors**

1. A convex mirror is used as a reflector in street lamps. As a result, the light from the lamp diverges covering a large area.
2. A convex mirror is used as a driver's mirror in all vehicles like cars and scooters etc., for looking at the traffic at the rear of the vehicle. Such a mirror has a much wider field of view as compared to a plane mirror or a concave mirror. The images formed are small and erect. (rear view) and virtual image.

(SSC (10+2) 28.10.2012, SSC CAPFS SI, CISF ASI & DELHI POLICE 21.06.2015, SSC CPO SI 16.12.2007, SSC Combined Matric Level 16.06.2002 & SSC Multi Tasking 27.02.2011 & SSC Multi Tasking Staff 17.03.2013 & RRB NTPC 03.03.2021 & 18.04.201, RRB GROUP-D 12.10.18 & 16.10.2018 & RRB JE 30.08.2019)

Note:

The mercury and sodium street lamps light up because of atomic emission.

(SSC CGL 16.08.2015)

(b) Concave Mirrors

1. A concave mirror is used as a reflector in search light, head lights of motor vehicles, telescopes, solar cookers etc.
2. A concave mirror is used in the ophthalmoscope, for reflecting light on to the retina of the eye.
3. A concave mirror is used as head mirror by ENT (Ear, Nose and Throat) specialists.

(SSC (10+2) 04.12.2011, SSC MTS 17.09.2017)

4. A concave mirror is also used as a shaving mirror/Make up mirror as it can form erect and magnified image.
5. A concave mirror is used by dentist to see big image of teeth.

(SSC CAPFS ASI & Delhi Police SI 06.07.2017 & NTPC 08.03.2021)

- 6 In solar cooker concave mirror is used because it concentrate the focus on one point.

(SSC JE 24.01.2018)

Important Notes:

1. Spherical mirrors can also be used as trick mirrors.
2. Parabolic mirrors are used by dish antennas to bring to focus microwave signals from satellites. These mirrors are also used in astronomical telescopes of large aperture for avoiding spherical aberration.
3. If object is appear enlarged and inverted in a rear view mirror, then concave mirror is used.
4. Ability to distinguish two closely placed objects is resolving power.

(SSC CGL 10.08.2017)

(SSC CAPFS ASI & SI DELHI POLICE 02.07.2017)

• **Parabolic Mirrors:** Parabolic mirror is such that all light rays falling on it in a direction parallel to the principal axis are reflected through a single image point, irrespective of their distance from the principal axis.

Applications of these mirrors are:

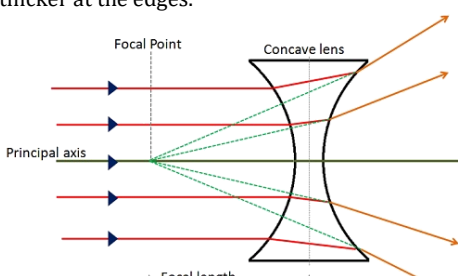
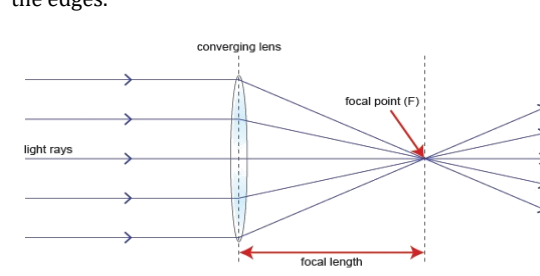
- (i) In solar-thermal electric plant, focused rays from the sun are used to generate steam, which drives a turbine connected to an electric generator.
- (ii) In automobile head lights, a high intensity light bulb is held at the focus of parabolic mirror, and strong light emerges in a direction parallel to the principal axis of the mirror.

Lens: A lens is a portion of a transparent refracting medium bound by two refracting surfaces out of which at least one is curved.

Lens are made up of flint glass.

(SSC CGL 19.06.2011)



TYPES OF LENS					
Concave Lens/Diverging Lens A concave lens is thinner in the middle and thicker at the edges. 			Convex Lens /Converging Lens Convex lens is that it is thicker in the middle and thin at the edges. 		
Bi Concave	Plano Concave	Convex Concave	Bi Convex	Plano Convex	Concave Convex
					

Terms Related to Lens

Aperture: It is the effective diameter of the light transmitting area of a lens.

Brightness of Image

(Depends on) → Intensity of light (image)

(Depends on) ↓
Aperture

Principal Focus

Lens has two principal focus

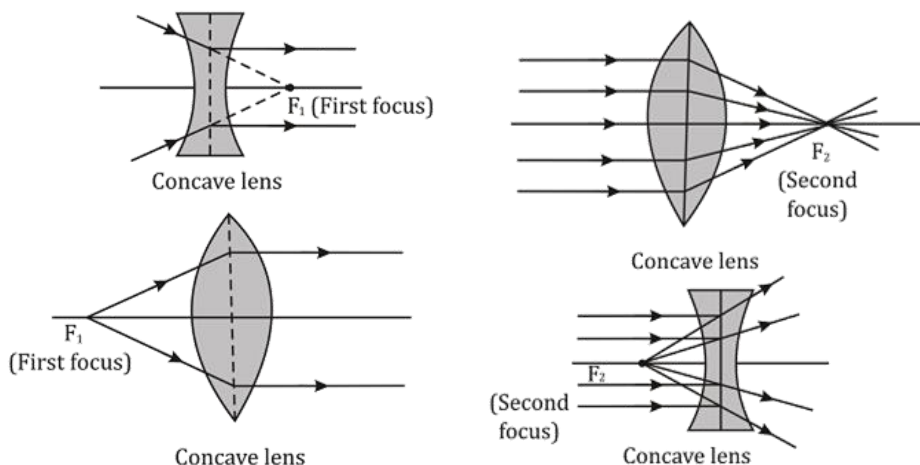
First Focus

First focus of the lens is a point on its principal axis.

The light rays coming or appear to come from it become parallel to the principal axis after refraction through the lens.

Second Focus

It is a point on principal axis, at which parallel beam of light rays to principal axis is incident on a lens, then light rays after refraction through it, meet or appear to meet at a point on principal axis, called second focus or principal focus (F_2) of the lens.



Images formed from Lens**Formation of Image by Concave lens for Different Positions of Object**

Position of object	Position of image	Nature and size of image	Ray Diagram
At infinity	At the focus	• Virtual • Erect • Extremely diminished	
between infinity and the pole of the mirror (i.e. at finite distance)	Between the focus and the pole	• Virtual • Erect • Diminished	

Formation of Image by Convex lens for Different Positions of Object

Position of object	Position of image	Nature and size of image	Ray Diagram
At infinity	At focus(F) or in the focal plane	• Real • Inverted • Extremely diminished point size	
Beyond the centre of curvature(2F) but at finite distance	Between focus(F) and the centre of curvature(2F)	• Real • Inverted • Diminished	
At the centre of curvature(2F)	At the centre of curvature(2F)	• Real • Inverted • Equal to the object size	
Between focus(F) and centre of curvature(2F)	Beyond the centre of curvature(2F)	• Real • Inverted • bigger than object(magnified)	

At the focus(F)	At infinity	• Real • Inverted • Extremely magnified	
Between the pole and focus(F)	Behind the object	• Virtual • Erect • Magnified	

NOTE:

(i) Magnifying glass are used in convex lens.

(SSC CAPFS ASI & SI Delhi Police 03.07.2017)

(ii) Black board appears black in color because it absorb all the colors.

(SSC CGL 05.08.2017)

Lens Formula

It is given by, $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$



Where,

f = focal length of the lens,

u = distance of the object from the lens

And v = distance of the image from the lens

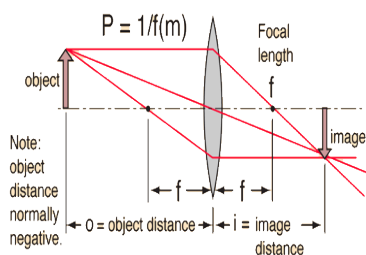
Linear magnification,

$$m = \frac{\text{Size of image}}{\text{Size of object}} = \frac{v}{u}$$

Lens Maker's Formula

$$\text{It is given by } \frac{1}{f} = (\mu - 1) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

Where, μ = refractive index of the material of the lens, R_1 and R_2 are radii of curvature of the surface of the lens. If lens is cut in two equal parts as shown in adjacent figure, then focal length of each new lens is double that of original lens.

Power of A Lens

The ability of the lens to converge or diverge the rays of light incident on it is called power of lens.

It is the reciprocal of its focal length. It is given as,

Power of a lens,

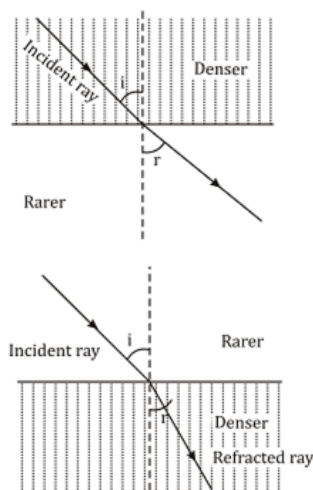
$$P = \frac{1}{f \text{ (metre)}}$$

Its unit is dioptre (D).

Refraction of Light

The phenomenon of deviation of light rays from its path, when it travels from one transparent medium to another transparent medium, is called refraction of light.

(RRB GROUP-D 27.09.2018)



When light passes from one medium to another, this phenomenon of change in its direction is called refraction.

(SSC CGL 16.08.2017)

When a light ray travels from a denser medium to a rarer medium, it deviates away from the normal then speed of light is also increase when light ray travels from a rarer medium to a denser medium, it deviates towards the normal and the speed of light is decrease. The cause of refraction is that, the speed of light is different in different media. The main reason for refraction is the varying velocity of light in different mediums.

(RRB GROUP-D 24.10.2018)

Ex-

- The apparent displacement of a pencil, partly immersed in water.
- Sun appears before the sunrise
- A pond of water appears less deep due to refraction.
- The spoon which looks bent in water.
- When we viewed a water tank from the top then it appear shallower from the top.

(SSC CGL 10.08.2017)

In refraction, the speed of light and its wavelength change but its frequency remains unchanged.

For a ray of light to suffer total internal reflection it has to pass from glass to water.

(SSC (10+2) 11.12.2011, SSC CCAPFS SI, CISF ASI & Delhi Police SI 21.06.2015)

Laws of Refraction

There are two laws of refraction given as below



1. The incident ray, the refracted ray and the normal at the point of incidence all three lie in the same plane.
2. The ratio of sin of angle of incidence to the sin of angle of refraction remains constant for a pair of media. This is denoted by ${}^1\mu_2$ and is called relative refractive index of medium 2 with respect to medium 1.

$$\text{i.e. } \frac{\sin i}{\sin r} = \text{constant } ({}^1\mu_2)$$

This law is also called Snell's law.

Refractive Index

The ratio of speed of light in vacuum (c) to the speed of light in any medium (v) is called refractive index of the medium. It has no unit

(RRB JE 28.08.2019)

Refractive index (μ) of a medium is given by

$$\mu = \frac{c}{v}$$

(RRB NTPC 22.04.2016)

When light rays travel from a denser medium to a rarer medium, it deviates away from the normal and the speed of light is also increased. Therefore, a pond appears shallower

(RRB ALP 10.08.2018)

When light travels from a rarer medium to a denser medium, then it bends

NOTE:

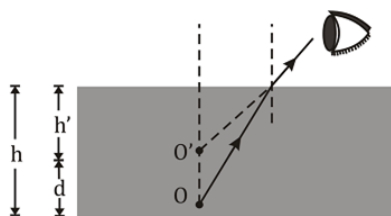
Refractive Index of Air is 1.003

(RRB ALP 17.08.2018)

Refractive Index of Water is 1.333

Refractive Index of Diamond is 2.417

(RRB GROUP-D 26.09.2018)



Refractive index

So, refractive index is given as,

$$\mu = \frac{\text{Real depth}}{\text{Apparent depth}} = \frac{h}{h'}$$

Note:

A coin appears at lesser depth in water. Writing on a paper appears lifted when a glass slab is placed over paper. This all happens due to refraction.

Relative Refractive Index

The Ratio between the speed of light in a medium to the vacuum.

(RRB NTPC 22.04.2016)

Refractive index = speed of light in medium / speed of light in vacuum

Absolute refractive index

The ratio between the speed of light in vacuum to the speed of light in medium.

Absolute refractive index = speed of light in vacuum / speed of light in medium.

The value of absolute refractive index is always greater than 1.

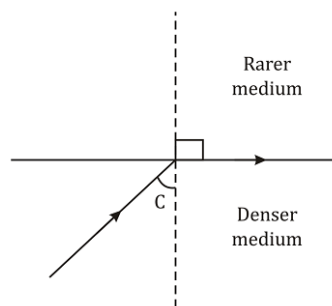
(RRB GROUP-D 03.10.2018)

Critical Angle

The angle of incidence in a denser medium for which the angle of refraction in rarer medium becomes 90° , is called critical angle (C).

Refractive angle is 90° and light ray goes from rarer to denser medium.

(SSC JE 27.01.2018)



Relation between Refractive index and Critical angle

$${}^a\mu_b = \frac{1}{\sin C}$$

Atmospheric Refraction

The density of the earth's atmosphere decreases with increasing altitude. When sunlight enters the earth's atmosphere, it gets refracted at different layers of different refractive index and therefore followed a curved path. This phenomenon is called atmospheric refraction.

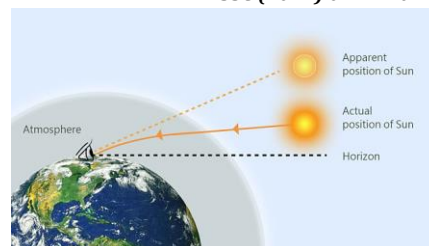
Due to atmospheric refraction, the sun appears two minutes before the actual sunrise and sets two minutes after the actual sunset. The twinkling of star is also due to atmospheric refraction.

(RRB NTPC 09.01.2021, 12.01.2021 &

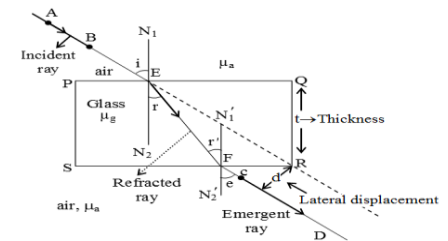
RRB JE 25.05.2019, SSC CPO SI 03.09.2006,

SSC Combined Matric Level 12.05.2002,

SSC (10+2) 04.11.2012)



Refraction of Light Through a Rectangular Glass Slab



In going from a rarer medium to a denser medium, the ray bends towards the normal, and in going from a denser to a rarer medium, the ray bends away from the normal.

According to the principle of reversibility of light, when the final path of a ray of light after any number of reflections and refractions is reversed, the ray retraces its entire path.

Lateral displacement/shift on passing through a parallel sided glass slab is the perpendicular distance between the directions of incident ray and the emergent ray.

A water tank appears shallower, i.e., less deep than what it actually is.

i.e., apparent depth is only $(3/4)$ th of the real depth of the tank of water

Prism

The prism divides sunlight into its constituent colors.

(RRB NTPC 29.03.2016)

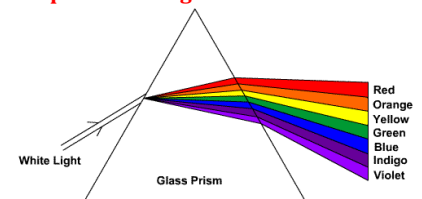
Prisms can be used to break or scatter the light into its constituent spectral colors.

(RRB NTPC 18.04.2016)

Angle of Deviation

The angle subtended between the directions of incident ray and emergent ray, is called angle of deviation (δ).

Dispersion of Light



When white light is incident on a glass prism, it splits into its seven colour components in the sequence of VIBGYOR. This phenomenon is called dispersion of white light.

(SSC CGL 04.07.1999 &

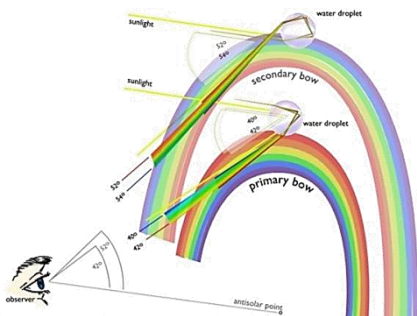
SSC TAX ASSISTANT 12.11.2006 &

SSC JUNIOR ENGINEER 23.01.2018)

The refractive index of glass is maximum for violet colour and minimum for red colour of light. Therefore, violet colour of white light (sunlight) deviated maximum and red colour of light deviated least.

Rainbow





Rainbow is formed due to the dispersion of light, suffering refraction and total internal reflection in the droplets present in the atmosphere. Observer should stand with its back towards sun to observe rainbow.

(RRB NTPC 31.03.2016)

A rainbow is formed due to refraction and reflection of light.

(SSC CHSL (10+2) DEO & LDC 09.11.2014,
SSC Combined Matric Level 05.05.2002,
SSC CGL 16.08.2015)

Rainbow constituent from 7 colors:-

VIBGYOR

Violet, Indigo, Blue, Green, Yellow, Orange, Red

Less	→	More
Wavelength		Wavelength
More	→	Less
Deviates		Deviates

Violet color of light has less wavelength while red color has more wavelength.

Violet color light deviates more while the red color deviates less.

(SSC CHSL (10+2) 21.12.2015)

Violet and red are extreme forms of colors.

(RRB NTPC 07.01.2021, RRB JE 01.06.2019)

Red light travel in glass with minimum velocity.

(SSC CHSL (10+2) LDC, DEO PA/SA
15.11.2015)

When red and green are mix then it makes yellow.

(SSC CGL 10.08.2017)

The primary colors in photography are red, blue, yellow.

(SSC (10+2) 04.12.2011)

There are two types of rainbow which are given below

1. Primary Rainbow

- Two refraction and one total internal reflection
- Innermost arc is violet and outermost is red.
- Subtends an angle of 42° at the eye of the observer.
- More bright.

2. Secondary Rainbow

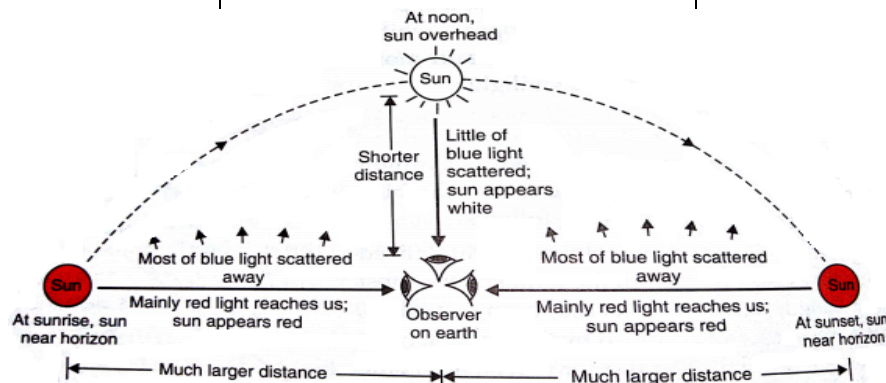
- Two refraction and two total internal reflection.
- Innermost arc is red and outermost is violet.
- It subtends an angle of 52.5° at the eye.
- Comparatively less bright.

Scattering of Light

When light passes through a medium, in which particles are suspended whose sizes are of the order of wavelength of light, then light on striking these particles, deviated in different directions. This phenomenon is called scattering of light.

According to Lord Rayleigh, the intensity of scattered light, $I \propto \frac{1}{\lambda^4}$

Therefore, red color of light is scattered least and violet color of light is scattered most. Some examples of scattering of light are as follows



Clouds appear white It is because cloud consists of a large size of droplets of water

and dust particles which scatter all colours of light equally. The mixture of all seven colours of sunlight is white. Therefore, clouds appear white.

(RRB GROUP-D 18.09.2018)

Danger signals are of red colors: It is because red colour of light scatters least and therefore, these signals can be seen from far away.



The sky appears blue because in sunlight, the blue color of light is scattered maximum and this scattered blue light enters our eyes and therefore sky appears blue.

(RRB NTPC 07.04.2021 & 03.02.2021,
RRB JE 23.05.2019, SSC Section Engineer
Officer 05.06.2005, SSC CGL 19.06.2011, SSC
(10+2) 04.12.2011, SSC CGL 19.10.2014, SSC
MATRIC LEVEL 05.05.2002, SSC CGL
28.08.2016, SSC SI in Delhi Police, CAPFS &
ASI 12.03.2019)

Sun appears reddish at the time of sunrise or sunset:

At the time of sunrise or sunset, the sun is near horizon and the sunlight travels maximum distance in earth's atmosphere. The blue colour of light which is scattered away due to maximum scattering and red colour of light reaches the earth which is scattered least. Therefore, sun appears reddish at the time of sunrise or sunset

(SSC CHSL (10+2) LDC, DEO & PA/SA
06.12.2015)

The time difference between the actual passing of the sun over the horizon and out being able to see the image of it on earth.

(RRB JE 28.08.2019)

The phenomenon of scattering of light by particles present in a colloidal solution is called Tyndall effect.

(RRB SSE 21.12.2014 & RRB NTPC
19.01.2017)

Note:



In the absence of earth's atmosphere, sky would appear black because there would be no particles to scatter the light.

(SSC CGL 30.08.2016)

the color of light emitted by sun is white. It can be broken into seven colours by using prism.

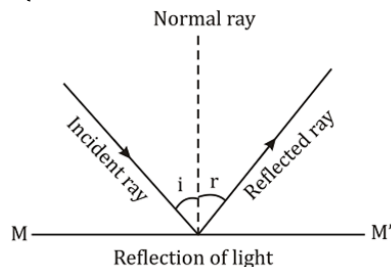
(SSC CGL 05.03.2020)

Reflection of Light

The phenomenon of bouncing back of light into the same medium, when it strikes on a smooth shining surface such as a plane mirror, is called reflection of light.

Kaleidoscope uses the phenomenon of reflection.

(SSC CAPFS ASI & SI Delhi Police 03.07.2017)



Laws of Reflection

(SSC CAPFS ASI & Delhi Police SI 06.07.2017)

There are two laws of reflection given as below

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

(RRB ALP 17.08.2018 & SSC JE 25.01.2018)

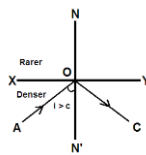
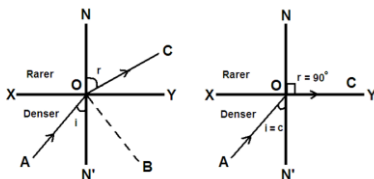
Total Internal Reflection

When a light ray travelling from a denser medium towards a rarer medium, is incident at the interface at an angle of incidence greater than critical angle, then light rays get reflected back into the denser medium. This phenomenon is called total internal reflection.

(SSC MTS 10.03.2013)

Two essential conditions for total internal reflection are:

- (i) Light should travel from a denser medium to a rarer medium.
- (ii) Angle of incidence in denser medium should be greater than the critical angle for the pair of media in contact.



A mirage occurs because of total internal reflection by layers of air.

(SSC TAX ASSISTANT 14.12.2008, SSC CGL 19.06.2011, SSC CHSL (10+2) 15.11.2015, SSC CGL 28.08.2016 & 30.08.2016 & 10.09.2016)

The glittering of air bubble rising through water is also processes responsible for total internal reflection of light.

(SSC CGL 01.09.2016)

Regular/Specular and Diffuse Reflection

- Reflection from a smooth surface is specular reflection.
E.g. Bathroom mirror, calm water on river etc. exhibits specular reflection.
(RRB GROUP-D 22.09.2018 & SSC CHSL 03.06.2022)
- Reflection from any rough (irregular) surface is known as diffuse reflection.
E.g. Ripple produced in water.

Application of reflection:

1. Reflection of light in mirror.
2. Reflection of light in spherical mirror.
3. Reflection of light in water pool.
4. Reflection of light on polished surface.
5. Object seen due to reflection of light.
6. Glowing of stars.
7. Lighting of moon at night.
8. Reflection from luminous object.
9. Reflection from non-luminous object.

PERSISTENCE

Persistence of vision is the phenomenon of the eye by which an afterimage persists for approximately one twenty – fifth of a second on the retina.

Persistence of vision is the principle behind the cinema.

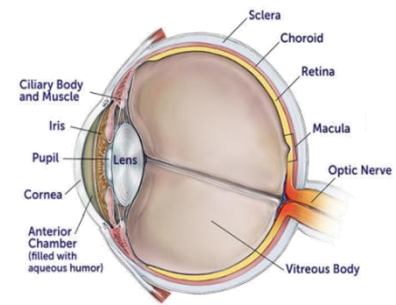
(SSC CGL 21.04.2013)

ALBEDO

It is the fraction of solar energy (shortwave radiation) reflected back from earth back into space. This is the measure of reflectivity of the earth's surface.

Ice, especially with snow on top of it land, has the highest albedo.

EYE



Anatomical features of the eye

The outer part, called the **eye ball** is nearly spherical with a diameter of about 25 mm. Light enters the eye through a transparent white membrane, called **cornea**. It covers a clear liquid called **aqueous humor**, behind which there is a diaphragm, called iris with a circular aperture, called the **pupil** of the eye. Behind the iris, is a **crystalline lens** held in position by the **ciliary muscles**. The region behind the crystalline lens is filled with a jelly like substance, called the **vitreous humor** and finally a light sensitive part of the eye, called **retina** which covers the curved back surface of the eye. The retina is a film of nerve fibers consisting of millions of structures called **rods and cones**. The rods sense light intensity and cones sense the colours. When stimulated by light, these structures send electrical impulses to the brain via the optic nerve. The brain finally interprets the image on the retina.

The least sensitive spot on the retina is called the **blind spot**. There is another spot at about the centre of the retina, which is most sensitive to light. This is called **yellow spot**.

The line joining the centre of the crystalline lens to yellow spot is called **visual axis** of the eye, and the line joining the centre of crystalline lens to the centre of cornea is called the **optic axis** of the eye.

This property of the eye is called **accommodating power** or **accommodation** of the eye. The ability of the eye to observe distinctly the objects situated at widely different distances from the eye.

When the eye looks at a very far off object, the ciliary muscle is not tensed. The crystalline lens has its least thickness and longest focal length. The eye is said to be **fully relaxed**. Focal length of the lens is about 2.5 cm.

When the object moves closer to the eye, the ciliary muscle tenses automatically, thereby increasing the thickness and decreasing the focal length of eye lens. The most distant point which an eye can observe clearly is called **Far Point (F)** of the eye. For normal eye, F lies at infinity.

The closest distance for which lens can focus light on the retina is called the least distance of distinct vision or the distance of Near point (N) of the eye. For a normal eye, value of least distance of distinct vision, $d = 25$ cm. This Distance increase with age, because of decreasing effectiveness of the ciliary muscles and loss of flexibility of the eye lens. The distance between near point and far point of the eye is called **Range of vision**.

NOTE:-

The lens of the eye is behind the pupil.

(SSC MATRIC LEVEL 14.05.2017)

Iris control the size of the pupil in human eye.

(SSC JE 22.01.2018)

Iris control the amount of light entering the eye.

(SSC JE 25.01.2018 & SSC CGL 04.06.2019)

The eye lens forms inverted and real image of the object.

(SSC JE 27.01.2018)

Light entering the eye through the outer, transparent structure at the front of the eye called the cornea.

(SSC CHSL (10+2) 08.07.2019)

The eye lens focuses light on the retina.

(DELHI POLICE 13.12.2020)

when we see an object, the image formed on the retina is real and inverted.

(SSC CGL 02.09.2016)

The sensitivity of a human eye is maximum in the green region.

(SSC CONSTABLE 12.05.2013)

Defects of Vision**Myopia or short sightedness**

(RRB NTPC 08.04.2021, 18.01.2021,

11.04.2016, SSC CPO SI 03.09.2006,

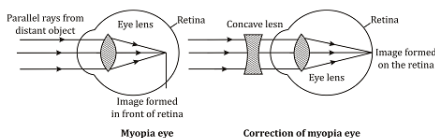
SSC Combined Matric Level 21.05.2000,

SSC STENOGRAPHER 26.09.2010,

SSC Constable (GD) & Rifleman 22.04.2012

& SSC CGL 02.09.2016)

It is a defect of eye due to which a person can see nearby objects clearly but cannot see far away objects clearly. In this defect focal length or radii of curvature of lens is reduced or power of lens increases or distance between eye lens and retina increases. So, image is formed at a point before retina.



Remedy this defect can be removed by using a concave lens of appropriate power.

(RRB GROUP-D 04/10/18)

Hypermetropia or long sightedness

It is a defect of eye due to which a person can see far away objects clearly but cannot see

nearby objects clearly. In this defect, the near point of eye shifts away from the least distance of distinct vision. In this defect focal length or radii of curvature of lens increases or power of lens decreases or distance between eye lens and retina decreases and image is formed behind the retina.

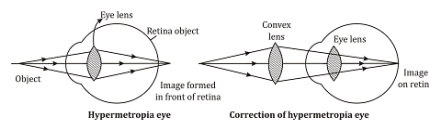
(RRB GROUP-D 11/10/18)

For a person having hypermetropia, the near point is greater than 25 cm.

(FCI ASSISTANT 22.01.2012)

The least distance of distinct vision is 25 cm.

(SSC CGL 02.09.2016 & 12.08.2017)



Remedy This defect can be removed by using a convex lens of appropriate power.

(RRB GROUP-D 05.10.2018 &

SSC Stenographer 16.10.2011)

Astigmatism

In this defect, a person cannot focus on horizontal and vertical lines at the same distance at the same time.

Remedy This defect can be removed by using suitable cylindrical lenses.

Colour blindness

In this defect, a person is unable to distinguish between few colours. The reason of this defect is the absence of cone cells which is sensitive for few colours. This defect cannot be removed.

Cataract

In this defect, an opaque, white membrane is developed on cornea due to which, a person loses power of vision partially or completely. This defect can be removed by removing this membrane through surgery.

Presbyopia (old sight)

With increasing age, the ciliary muscles holding the eye lens weaken and the lens loses some of its elasticity. Therefore, power of accommodation of the eye decreases with age. This defect is called presbyopia.

This defect can be corrected by using bifocal lens.

(SSC CHSL (10+2) 10.07.2019)

Accommodation

The ability of eye to focus on both, near and distant objects, by adjusting its focal length, is called the accommodation of the eye.

(RRB NTPC 11/01/21)

NOTE:

The person with color blind cannot distinguish between red and green.

(SSC CGL 11.09.2016)

The golden view of sea shell is due to polarization.

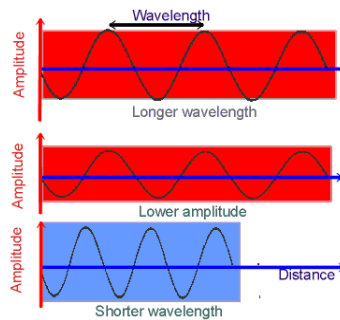
(SSC CHSL (10+2) DEO & LDC 09.11.2014)



Wave Optics / Physical Optics

- The wave nature of light was first put forward by Huygens.
Huygens studied the wave nature by assuming that entire space is filled with a hypothetical 'medium' called 'Luminiferous Ether'

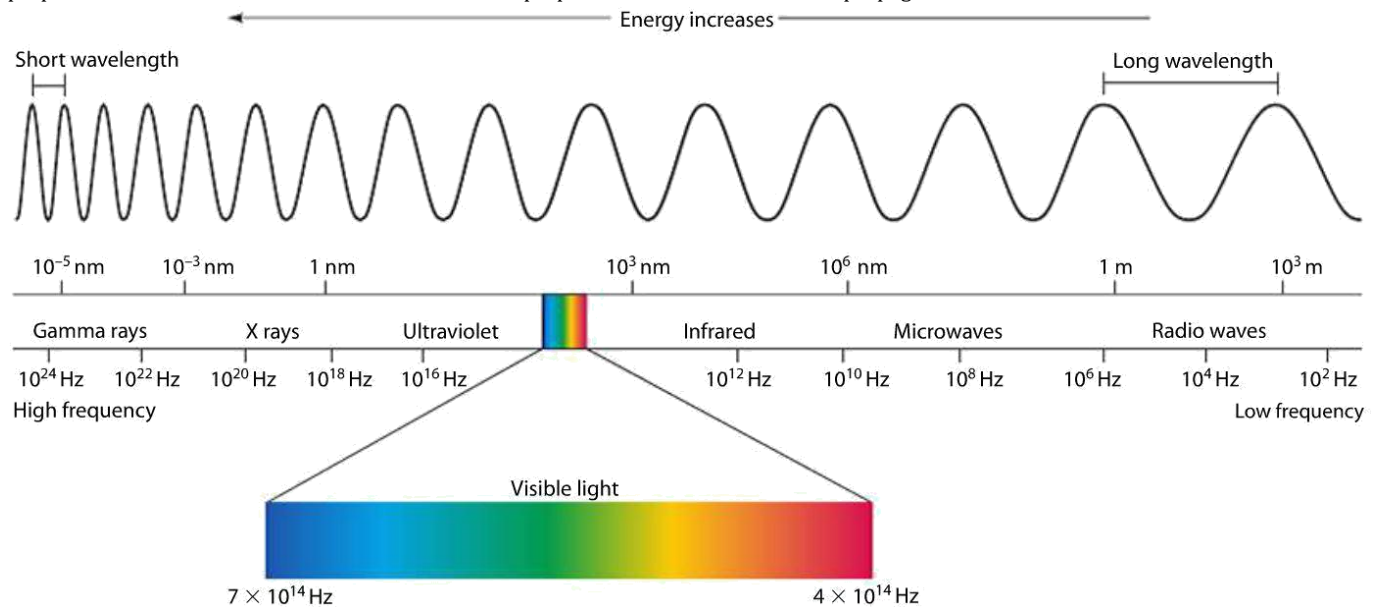
Characteristics of Luminiferous Ether



- Medium is massless
 - Possess Extremely high Elasticity
 - Very Low Density
- But Practically, Medium of such qualities cannot exist.
So, Further study was done by 'Fresnel'.*

Electromagnet Theory of Light

This theory was proposed by Maxwell. According to Maxwell, Light is an Electromagnetic wave having both electric and magnetic fields perpendicular to each other and these EF and MF are perpendicular to the direction of propagation.



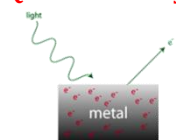
Phenomenon Explained by Electromagnetic Theory of Light

- Interference
- Diffraction
- Polarization

EM Theory failed to explain

- Photo Electric Effect
- Raman Effect
- Compton Effect

Quantum Theory of Light



Light is shown on a metal and after a certain binding energy is overcome, an electron is emitted from the metal.

- Proposed by Albert Einstein
- According to this, Light consists of packets of energy called photons
- Energy of a photon, E

by

$$E = h\nu$$

Where

h = Planck's constant = 6.6×10^{-34} JS

ν = Frequency of radiation

Where frequency = Number of waves passing through a point in one second. and

$$c = \lambda \nu$$

↑ Speed of light
 ↑ Wavelength
 ↑ Frequency

So, for a particular wave

If frequency is more, energy will be more and wavelength will be small.

Phenomenon Explained by Quantum Theory

- Photo Electric

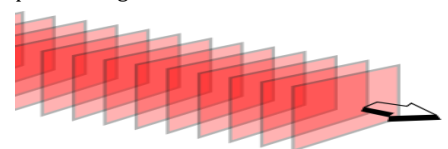
- Raman Effect
- Compton Effect

Quantum Theory failed to explain

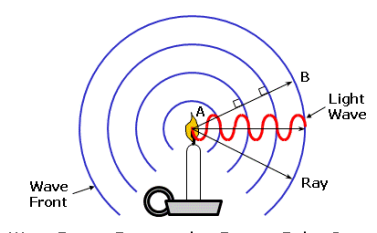
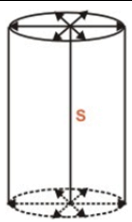
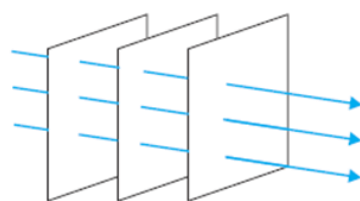
- Interference
- Diffraction
- Polarization

De-broglie's Dual Nature of Light Based on the fact 'That Nature loves Symmetry'.

Wave Front: A wave front is defined as the continuous locus of all the particles of a medium, which are vibrating in the same phase at a given instant.



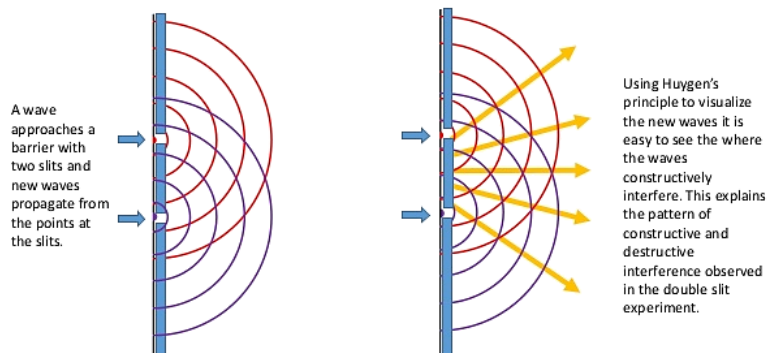
A Source of light Sends out distances in all directions.

Source of Light	Nature of Wave Front	
1. Point Source	Spherical Wave Front	 Wave Fronts Propagating From a Point Source
2. Linear	Cylindrical Wave Front	
3. Point source or Linear source but kept at very large distance	Plane Wave Front	

Huygen Principle: According to Huygen, we can draw straight lines perpendicular to the wave front. These straight rays are 'Rays of Light' and light energy flows along these rays and every point on the primary wave front acts as a fresh source for secondary wave front.

Note: Wave front propagates parallel to itself.

- Reflection and Refraction can be explained on the basis of wave theory also.

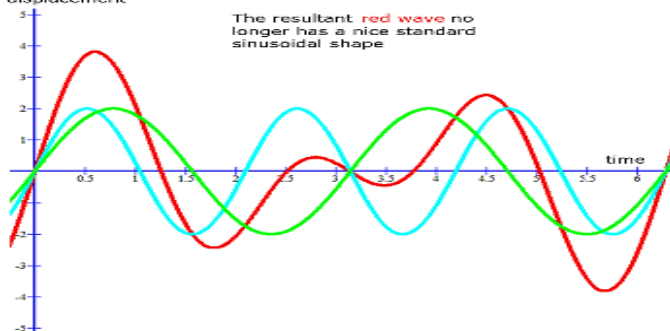


Superposition of Waves

According to this, two or more waves travelling in same medium superimpose one another to give a new resultant wave.

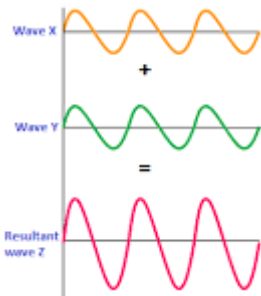
$$y = y_1 + y_2 + y_3 + \dots$$

displacement

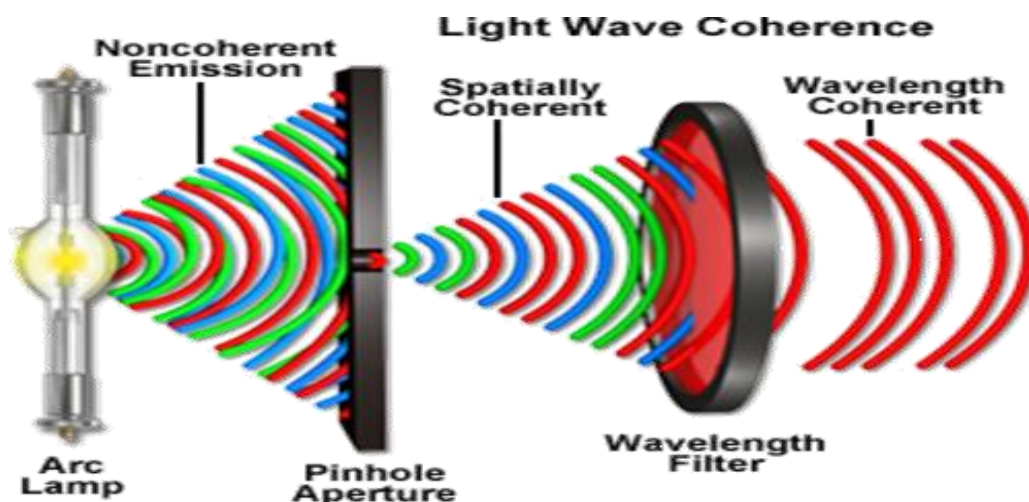


If the sources of 2 waves is coherent, the process is called



INTERFERENCE	
Constructive Interference When crest of one wave falls on crest of the other, the amplitude of the resultant wave is sum of the amplitudes of two waves, i.e., $\vec{y} = \vec{y}_1 + \vec{y}_2$ 	Destructive Interference When crest of one wave falls on trough of the other, the amplitude of resultant wave is difference of the amplitudes of the two waves, i.e., $\vec{y} = \vec{y}_1 - \vec{y}_2$ 

Sources of Light	
Coherent The sources of light, which emit continuous light waves of the same wavelength, same frequency and in same phase or having a constant phase difference are called coherent sources.	Non-Coherent A source that emits waves having random frequencies and phase differences. In such source, there is no relationship between the waves in terms of frequencies and phase difference. Examples include:-Electric bulb, night lamp



Two Independent Sources

Two independent sources of light cannot be coherent. This is because light is emitted from individual atoms of the source, when they return to ground state after being excited by heat or electric discharge. Even the smallest sources of light contains billions and billions of such atoms which obviously cannot emit light waves in the same phase. Two coherent light sources can be obtained from a single source of light by reflection, refraction.

In practice, coherence in interference is obtained by two methods:

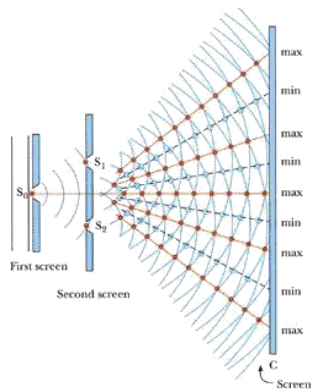
- By division of wavefront such as in Young's double slit experiment: Lloyd's mirror experiment and Fresnel's biprism experiment.
- By division of amplitude by partial reflection and refraction of waves such as in interference of light in thin films, Newton's Rings and Michelson's interferometer.

Conditions for Obtaining Two Coherent Sources of Light

- Coherent sources of light should be obtained from a single source by some device.
- The two sources should give monochromatic light.
- The path difference between light waves from two sources should be small.

Young's Double Slit Experiment





It explained the phenomenon of interference using two slits and one source of light and explaining the causes of light and dark patches obtained on the screen.

At the points, where the resultant intensity of light is maximum, interference is said to be **constructive**.

At the points, where the resultant intensity of light is minimum, the interference is said to be **destructive**.

In a moving car, radio signals are interrupted sometimes. Why?

While we are in moving car, there are periodic interruptions in a radio signal that we hear. It occurs an account of interfering radio waves. This is a common form of interference, called multipath interference between a radio wave and its reflection.

Why two independent light bulbs fail to produce interference?

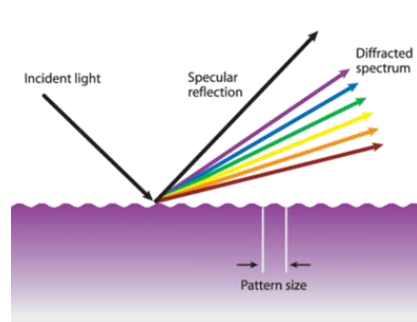
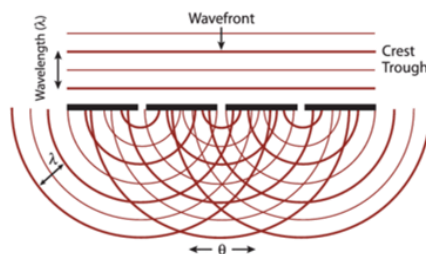
The light from an ordinary electric lamp undergoes about 100 million (10^8) random changes every second. Therefore, light from two independent light bulbs, the given set of interference conditions last for only about 10^{-8} second. As human eye cannot follow such a rapid change, therefore, no interference effects are observed from two independent light bulbs.

What is responsible for streaks of coloured light from a compact disc?

The streaks of colored light reflected from a compact disc (CD) resemble the colors that appear when white light passes through a prism. However, a CD does not separate colors on account of refraction. Instead, the light waves undergo interference here.

Diffraction of light

It is the phenomenon of bending of light around corners of an obstacle or aperture in the path of light. On account of this bending, light penetrates into the geometrical shadow of the obstacle or aperture.



Diffraction occurs on account of mutual interference of secondary wavelets starting from portions of the wavefront which are not blocked by the obstacle or from portions of the wavefront which are allowed to pass through the aperture.

Examples

Although this principle applies to all types of waves it is easier – to explain using sound waves since sound waves have longer wavelengths. If someone is playing music in their room with the door closed you might not be able to hear it while walking past the room however. If that person were to open their door while playing music you could hear it not only when directly in front of the door opening but also on a considerable distance down the hall to either side is a direct effect of diffraction. When light passes through much smaller openings called slits Huygens's principle shows that light bends similar to the way sound does just on a much smaller.

Diffraction	
Fresnel Diffraction The source of light or the screen or both are at finite distance from the obstacle/aperture. Diffraction at a straight edge, diffraction at a thin wire, diffraction at a small opaque disc.	Fraunhofer Diffraction The source of light and the screen are effectively at infinite distance from the obstacle/aperture. Light from the source at infinity, after diffraction is focused on the screen using a convex lens. Diffraction at a single slit, diffraction at a double slit and diffraction at a diffraction grating.

Diffraction Types

Fresnel/Near field
 → Circular Aperture/opening
 → At Straight edge
 → At Circular obstacle/disc

Fraunhofer/Far Field
 → Single Slit
 → Double Slit/Double Grating
 → Diffraction Grating (N-slits)
 → At circular aperture (Airy's Disc)
 → At Rectangular aperture

(Δt) **Coherence Time:** Time for which phase remains constant

(ΔL) **Coherence Length:** Distance travelled by pulses during coherence time

Resolving Power: It is the ability of the instrument to resolve or to see as separate, the images of two closely spaced objects.

Limit of Resolution:

The minimum distance between two objects which can just be seen as separate by the optical instrument is called the Limit of Resolution of the instrument. Obviously smaller the limit of resolution of the optical

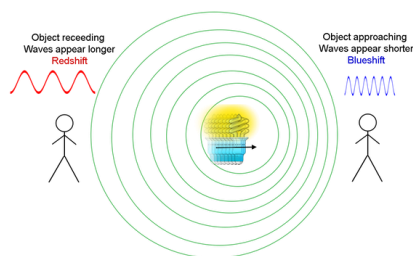


instrument, greater is its Resolving Power and vice-versa.

1. Resolving power of a microscope depends upon wavelength of light and the refractive index of the medium between the object and objective lens of the microscope.
2. Resolving power of a telescope increases with the increase in the diameter of objective lens and also with the decrease in wavelength of incident light.

Doppler's Effect

According to Doppler's Effect, whenever there is a relative motion between a source of light and observer, the apparent frequency of light received by observer is different from the true frequency of light emitted actually from the source of light.



Blue Shift

When source and observer approach each other, Δv is +, i.e., apparent frequency increases or apparent wavelength decreases. This is called **Blue shift**. ($\because \lambda_b < \lambda_r$)

Red Shift

When source and observer recede away from each other, Δv is negative i.e. apparent frequency decreases or apparent wavelength increases. This is called **Red shift**. ($\because \lambda_r > \lambda_b$)

Applications

Some important applications of Doppler's effect in light are in

- (i) measuring the speed of a star and speed of galaxies,
- (ii) measuring speed of rotation of the sun, about its own axis which is about 2 km/s.
- (iii) measurement of plasma temperatures in thermo-nuclear reactions,
- (iv) Doppler's effect is used in RADAR (Radio Detection and Ranging) to estimate the speed of aeroplanes, rockets, etc.
- (v) Doppler's effect is used in SONAR (Sound Navigation and Ranging) to estimate the velocity of submarines,

ships, etc. and in estimating the depth of sea.

- (vi) Doppler's effect confirms the hypothesis that universe is expanding.

Polarisation

The phenomenon of reconstructing of electric vectors of light into a single direction is called polarization. Ordinary light has electric vectors in all possible directions in a plane, perpendicular to the direction of propagation of light.

When ordinary light is passed through a tourmaline, calcite or quartz crystal, the transmitted light have electric vectors in a particular direction parallel to the axis of crystal. This light is plane polarised light. A plane containing the vibrations of polarised light is called plane of vibration. A plane perpendicular to the plane of vibration is called **plane of polarisation**. Polarisation can take place only in transverse waves.

$$S = \frac{100}{IC}$$

$l \rightarrow$ length of tube

$\theta \rightarrow$ Optical Rotation

$C \rightarrow$ Concentration = g/cc or % = 20% = 0.2 g/cc
5% = 0.05 g/cc

$S \rightarrow$ Specific Rotation

Polaroids

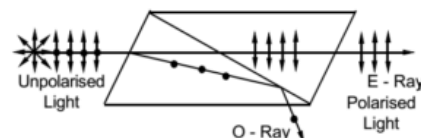
Polaroids are thin and large sheets of crystalline polarising materials (made artificially) capable of producing plane polarised beams of large cross-section. In 1852, Herapath discovered that the synthetic small needle-shaped crystals of iodosulphate of quinine possess the property of polarising the light.

Applications of Polaroids

- Polaroids are used in sun glasses. Such goggles are more efficient than those made of coloured glasses. They protect the eyes from the glare.
- The wind shield of an automobile is made of polaroid. Such a wind shield protects the eyes of the driver of the automobile from the dazzling light of the approaching vehicles. For the same reasons, the covers of head lights are made of polaroids.
- The polaroids are used in window panes of a train and especially of an aeroplane. They help to control the light entering through the windows.
- The pictures taken by a stereoscopic camera, when seen with the help of

polaroid spectacles, create three-dimensional effect.

Nicol Prism



A Nicol prism is an optical device, which is used for producing plane polarized light and analysing the same.

Detection of Polarized Light

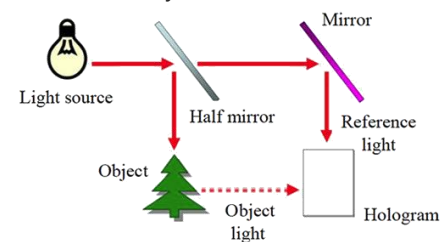
A naked eye cannot distinguish between polarized and unpolarized light. A crystal can be used for making this distinction. A calcite crystal, quartz crystal a Nicol prism (made from calcite (CaCO_3) crystal) can be used as polarizer as well as analyser of polarized light.

Applications

1. Clear photographs of white clouds are obtained by fitting polaroids in front of the camera lens.
2. Polaroids are useful in three dimensional motion pictures, i.e., in holography.
3. Polaroids are used to improve colour contrast in old oil paintings.
4. In calculators, watches, T.V., computers, etc. letters and numbers formed by liquid crystal display (LCD) through polarization of light.
5. Polarization of scattered sunlight is used for navigation in solar compass in polar regions.
6. To study asymmetries in crystals and molecules.

Holography is the science and practice of making **holograms**

A **hologram** is an image that appears to be three dimensional and which can be seen with the naked eye.



11

Heat

Heat

Heat is a form of energy, which produces the sensation of warmth. It is responsible for the change in thermal condition of the body. Its SI unit is 'joule' and CGS unit is 'calorie' which is also, widely used. When a body gets heated, various types of change occurs such as expansion, contraction, change of state, change of electrical properties, etc. The heat energy that is transferred from one body to another, can change into mechanical energy, electrical energy, etc.

(RRB ALP 22.01.2019)

Conductor or Insulator of heat

- Conductor (good conductor)** – Materials that allow heat to pass easily are known as conductor. Conductors have good presence of electron because of this they easily conduct electricity.

(RRB NTPC 17.01.2017)

Ex. silver, iron, copper, lead, aluminium, graphite, tungsten, gold

(RRB NTPC 18.04.2016, 17.01.2017, 05.04.2016 & 30.03.16)

Metal pots have wooden handles because wood is a bad conductor of heat.

(SSC (10+2) 04.12.2011)

MICA is a good conductor of heat but bad conductor of electricity.

(SSC (10+2) 21.10.2012)

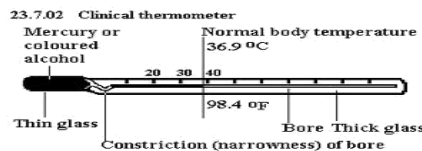
- Insulator (bad conductor)** – Materials that do not allow heat to pass are known as non-conductor. Non-conductors are not conduct electricity

Ex. wood, borosilicate, ceramic, glass, paper, water, woolen, Rubber etc.

(RRB NTPC 11.04.2016 & (SSC CGL Pre. 2022, 06.12.2022 Shift-1)

Temperature

Temperature is a quantity, that expresses the degree of hotness or coldness of a body. The flow of heat from one body to another body is due to their temperature difference, e.g., if on dropping a very hot spoon in water container, containing cool water, heat flows from spoon to the water. So, it is clear that temperature and heat are different things. It is measured in several arbitrary scale: like Celsius, Fahrenheit, Kelvin, Reaumur.

Measurement of Temperature

The device which measures the temperature of the body is called **thermometer**. It was developed by **Galileo**, who found that the gases expand on heating. As temperature is a variable quantity in different conditions. Therefore, different scales are provided to measure it.

A gas thermometer is more sensitive than a liquid thermometer because a gas does not change state easily.

(SSC CGL 08.02.2004)

A thermometer is used to measure temperature.

(SSC MTS 21.10.2017)

The working principle of thermometer is expansion of matter on heating.

(SSC CAPFS ASI & DELHI POLICE SI 03.07.2017)

Temperature Scales

To measure temperature, two fixed points are taken. One of them is the freezing point of water, known as **ice point** and other fixed point is boiling point of water, known as **steam point**.

Note:

- At a boiling point of liquids, its temperature remains constant. (SSC CGL 27.08.2016)
- Boiling point of water is depend on atmospheric pressure. (SSC CGL 27.08.2016)
- Vegetable are cooked in lesser time by adding a pinch of salt while cooking because boiling point of water increases. (SSC MTS 30.04.2017)
- The temperature of boiling water in a steam engine may be high because their is low pressure inside the boiler. (SSC (10+2) 04.12.2011)

Celsius Scale (°C)

In this scale, temperature is fixed from 0 (zero). Scale is divided into 100 equal parts called **degrees**. Ice point and steam point are taken as 0°C and 100°C. This scale was designed by **Anders Celsius** in 1710.

(RRB NTPC 16.04.2016)

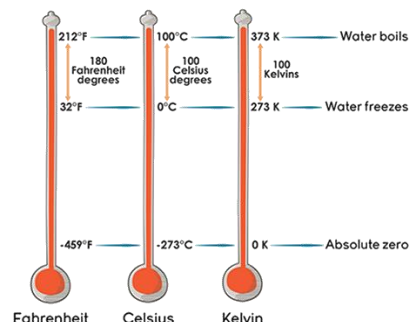
Fahrenheit Scale (°F)

In this scale, ice point and steam point are taken as 32° F and 212° F respectively. This

scale is divided into 180 equal parts. It was designed by **Gabriel Fahrenheit** in 1717.

Kelvin Scale (K)

In this scale, ice point and steam point are taken as 273 K and 373 K, respectively. This scale is divided into 100 equal parts. It was introduced by **Kelvin** in 1724.

**Reaumur Scale (R)**

In this scale, ice point and steam point are taken as 0 R and 80 R.

This scale was introduced by **RA Reaumur** in 1730.

Rankine Scale (Ra)

In this scale, ice point and steam point are taken as 460 Ra and 672 Ra. It was introduced by **JM Ranking** in 1859.

Relations between various temperature scales are as follow

$$\frac{C}{100} = \frac{F - 32}{180} = \frac{R}{80} = \frac{K - 273}{100} = \frac{Ra - 460}{212}$$

Note:

- Freezing point of water is = 273.15K = 32°F = 0°C
(RRB JE 19.09.2018, RRB NTPC 30.12.2020 & SSC CGL 27.04.2014)
- The density of water is maximum at 277K = 4°C
(SSC CGL 28.08.2016)
- Absolute zero temperature/pressure is = -273°C = 0°C
(RRB NTPC 22.04.2016 & 18.01.2017)
- Measure of room temperature on kelvin scale = 273K
(SSC CGL 29.08.2016)
- Celsius and farhenhit show same temperature at = -40C
(RRB JE 14.12.2014 & SSC JE 27.01.2018)
- The color of the star depend on their temperature.
(SSC CGL 19.10.2014)
- A black surface absorb more heat when it is black and rough.



(SSC STENOGRAPHER 09.01.2011)

(viii) The hand pump of water is warm in winter because the temperature inside the earth warms up the water.

(SSC (10+2) 1.12.2011)

(ix) Thermopile is a device that is used to detect radiant heat.

(SSC CGL 19.10.2014)

(x) Direction of heat flow depends on temperature.

(SSC CAPFS ASI & DELHI POLICE SI ONLINE EXAM 03.07.2017 & SSC JE 22.01.2018)

Surface area of a lake is about to freeze. Then the temperature of water at the bottom of the lake is 4°C

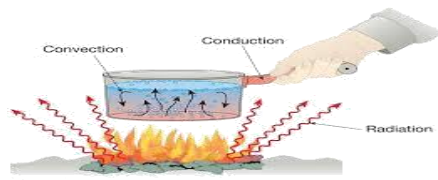
(SSC CAPFS ASI & SI DELHI POLICE 04.07.2017)

Transmission of Heat

Transfer of heat from one place to other place is called transmission of heat. There are three processes by which transmission of heat takes place.

Transmission of heat can be done by three methods are

1. Conduction,
2. Convection,
3. Radiation.



1. Conduction

Energy is transferred by direct contact.



It is the process of transmission of heat, in which heat goes from one particle to another particle of substance but no particle leaves its position. In solids, transmission of heat takes place by conduction process.

In metals, thermal conduction is due to vibration of atoms and free electrons.

It is a method of heat transfer.

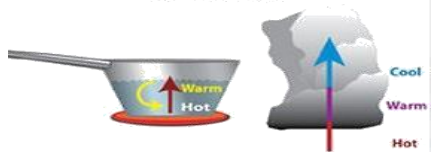
(SSC CPO SI, ASI 06.06.2016)

It depends on density of material, material dimension, electronic configuration.

(RRB NTPC 19.04.2016)

2. Convection

Energy is transferred by the mass motion of molecules.



It is the process of transmission of heat, in which particles of substance go to another place after taking heat from the source and other particles come to their place. In liquids and gases, transmission of heat takes place by convection process. Principle of chimney used in the kitchen or a factory is based on convection and sea breezes are due to the convection.

(SSC CGL 13.08.2021)

It is a method on which molecules of a fluid transmit the heat from one place to another.

(RRB JE 14.12.2014)

3. Radiation

Energy is transferred by electromagnetic radiation.



It is the process of transmission of heat, in which there is no need of medium for transfer of heat. It is the quickest way of transmission of heat. Heat from the sun comes to the earth by radiation. Dark colored objects absorb radiation better than the light-colored object.

The amount of radiation depends upon the nature of body, temperature of the body, type of the surface body.

(RRB JE 2014, 14.12.2014)

Heat from the sun reaches the earth by radiation.

(SSC CGL 01.09.2016)**(SSC CPO 05.09.2004, SSC TAX ASSISTANT 11.12.2005, SSC COMBINED MATRIC LEVEL 21.05.2000 & 31.08.2016)**

The word "ISOLATION" means incoming solar radiation.

(SSC CHSL(10+2) DEO & LDC 02.11.2014)

NOTE:

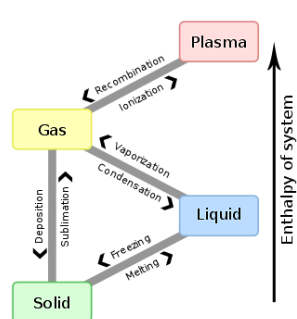
Within an environment, advection is a horizontal heat transfer.

(SSC JE 27.01.2018)

The damage of human body due to radiation, is measured in rems.

(SSC CGL 27.04.2014)

Transformation of Phase



When matter changes from one state to another it is called a phase transition.

Various processes involved in this are:

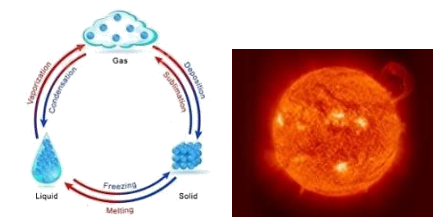
- Gas to solid phase transitions are known as "deposition."
- Gas to liquid phase transitions are known as "condensation."
- Liquid to gas phase transitions are known as "vaporization."
- Liquid to solid phase transitions are known as "freezing."

(RRB NTPC 03.12.2016)

- Solid to liquid phase transitions are known as "melting."
- Solid to gas phase transitions are known as "sublimation."

(SSC CHSL 31.05.2022)

- Gas to plasma phase transition is known as Ionization
- Plasma to gas phase transition is known as Recombination.



Dry Ice - Solid carbon dioxide is known as "dry ice" and sublimates at room temperature.

AT 257°C the physical state of water is gaseous.

Boiling point of water is $100^{\circ}\text{C} = 212^{\circ}\text{F} = 373^{\circ}\text{K}$

Freezing point of water is $0^{\circ}\text{C} = 32^{\circ}\text{F} = 273^{\circ}\text{K}$

Plasma is the fourth state of matter which does not have a fixed shape or volume and are less dense than solids and liquids but unlike ordinary gases, they are made up of atoms in which few or all the electrons have been stripped out and the ions move freely.

If a gas of very low density is cooled at very low temperature and it acquires the state of Bose-Einstein condensation.

(SSC MTS 13.08.2019)

Triple point:

The triple point of a substance is the temperature and pressure at which the three phases of that substance (Solid, liquid and gas) exist together in thermodynamic equilibrium.

Or it is that temperature and pressure at which the sublimation curve, fusion curve and the vaporization curve meet.

Triple point of water is 0.01°C

Specific Heat

The amount of heat required to raise the temperature of 1 g of a substance by 1°C is called the specific heat of gas.

It is represented by s . Its unit is cal/g°C or joule/g°C.

$$s = \frac{Q}{m \Delta t}$$

where,

Q = amount of heat given to the substance

m = mass of the substance

Δt = rise in temperature

There are two types of specific heat of gases

1. Specific Heat at constant volume (C_v)

At constant volume, the amount of heat required to raise the temperature of 1 g of a gas by 1°C is called specific heat at constant volume (C_v). Its unit is cal/g°C.

2. Specific Heat at Constant Pressure (C_p)

At constant pressure, the amount of heat required to raise the temperature of 1 g of a gas by 1°C is called specific heat at constant pressure (C_p). Its unit is cal/g°C.

Water is used in hot water bags because it has high specific heat.

(SSC (10+2) 11.12.2011)

Latent Heat

At constant temperature, the amount of heat taken by 1 g of a substance to change its state is called latent heat of substance. It is represented by L , its unit is cal/g.

(RRB ALP 22.01.2019)

Latent heat of vaporization is inversely proportional to the temperature and is maximum at 0°C. Variation of latent heat of water vapor with temperature is negative.

Heat, $Q = m(\text{mass}) \times L(\text{Specific latent heat})$
it happens at constant temperature

Burns caused by steam are much severer than those caused by boiling water because steam has latent heat.

(SSC CGL 16.08.2015)

Calorific Value:

The amount of heat obtained by 1 g of a fuel is known as its **calorific value**. Out of all the substances, hydrogen has maximum calorific value.

Note: If a pendulum designed at certain temperature is allowed to move/work at different temp. Then time difference is observed or correct time is not shown.

Time is lost or gained by pendulum per second.

Calorimetry

It is the science of measuring the changes in the state variables of a body due to transfer of heat in order to calculate the effect of heat

transfer on obtained changes. This is performed using Calorimeter.

Water is not suitable as a calorimeter substance because it has high specific heat.

(SSC MULTI TASKING STAFF 10.03.2013)

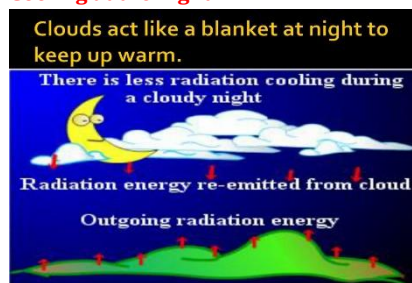
Entropy

It is the degree of order or randomness in the system and is thermodynamic function which depends only on the temperature of system only.

$$\text{Entropy } (\delta S) = \frac{\text{Heat absorbed } (\delta Q)}{\text{Absolute temperature } (T)}$$

$$\delta Q = T \delta S$$

Entropy of a substance is zero at absolute zero temperature. Water at 0°C is assumed to have zero entropy, and changes in its entropy are reckoned from this temperature.

Cooling at the night

The earth and other objects on it, receive solar radiation during the day and become warm. But at night they start emitting radiant energy and become cool. Cloudy nights are warmer than clear nights, because clouds reflect the radiations emitted by the earth at night and keep it warm. Thus, clouds acts like a blanket.

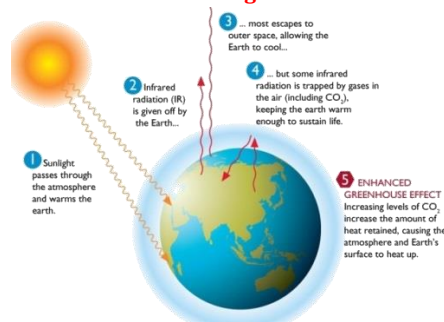
Greenhouse effect

The radiation from the sun when reaches to the earth surface is of shorter wavelength, some part of it is absorbed by the earth surface and some part is reflected back. The reflected radiation is of larger wavelength. So, it is trapped by the layer CO_2 molecules present in the atmosphere. So, the trapped radiations are reflected back towards the earth surface, thereby rising the temperature of entire earth. This effect is known as Green house effect and the CO_2 is known as Green house gas.

(SSC MULTI TASKING STAFF EXAM 23.02.2014 & SSC CGL 20.07.2014)

Ultra violet rays of sun do not reach the earth because earth atmosphere is surrounded by ozone.

(SSC SECTION OFFICER 09.09.2001 & 05.06.2005, FCI ASSISTANT 05.02.2012, SSC (10+2) 04.12.2011)

Newton's law of cooling

If a body is at higher temperature than its surroundings then it loses heat to the surroundings.

The rate of cooling of a body is directly proportional to the temperature difference of body and its surroundings.

e.g. hot water takes much less time in cooling from 100°C to 95°C than from 20°C to 15°C.

If hot water and fresh tap water are kept in a refrigerator, the rate of cooling of hot water will be faster than the tap water.

$$\text{Mathematically, } -\frac{dQ}{dt} \propto (T - T_0)$$

$$\Rightarrow \text{Rate of heat loss, } -\frac{dQ}{dt} = k(T - T_0)$$

$$\Rightarrow m s \frac{d\theta}{dt} = k(\theta - \theta_{\text{surroundings}})$$

When temperature difference between liquid and its surrounding is doubled, the rate of loss of heat will double.

(SSC CAPFS SI & ASI, DELHI POLICE SI EXAM 05.06.2016)

Black body

A perfectly black body is one, which absorbs completely all the radiations of whatever wavelength is incident upon it. Since, it neither reflects nor transmits any radiation, it appears black whatever the colour of the incident radiation may be.

Black body can absorb radiations of all wavelengths.

(SSC (10+2) 11.12.2011, 04.12.2011, 10.11.2013)

Emissive Power (e)

It is defined as the amount of heat radiated by unit area of the surface in one second at a given temperature and for given wavelengths. Its unit is $\text{J/m}^2 \text{ second}$.

Absorptive Power (a)

It is defined as the ratio of absorbed radiation to the total incident radiation. It has no unit.

The silvered surface of a thermo flask is a bad absorber. It does not absorb much heat from the surroundings. That is why ice inside the



flask does not melt. Also, the silver surface is a bad emitter/radiator, therefore hot liquids inside the flask do not cool quickly.

The earth is a good absorber and good radiator.

(SSC MULTI TASKING STAFF 17.03.2013)

Outside of cooking utensils are generally left black from below because black surface is a good absorber of heat.

(SSC CONSTABLE 12.05.2013)

Thermal Expansion

It is the tendency of matter to change its shape, area, density with change in temperature.

Example of thermal expansion

Provide a gap between the railway track for expand and contraction of track during summer and winter.

(RRB NTPC 16.04.2016)

In a railway track two rails are joined end to end with a gap in between them because expansion due to summer can be avoided.

(SSC MATRIC LEVEL 24.10.2003 & S12.05.2002, SSC (10+2) 21.10.2012, SSC CGL 30.08.2015 SSC Stenographer 16.10.2011)

Thermal expansion makes Eiffel tower taller during summers.

(SSC CGL 04.03.2021)

Thermal Conductivity

It is a measure of conduction of heat.

Thermal conductivity increase with increase in temperature of gas

Thermal conductivity decrease with increase in temperature of water.

Thermal conductivity decrease with increase in temperature of metal

(RRB JE 14.12.2014)

Any metal used as a cooking material has more thermal conductivity.

(SSC 910+2) 21.10.2012)

When hot liquid of is poured into a thick glass tumbler, it cracks because glass is a bad conductor of heat so only inner surface expands.

(SSC 910+2) 21.10.2012)

Silver has maximum thermal conductivity.

(SSC CGL 30.08.2016 & SSC CAPFS ASI & DELHI POLICE 05.07.2017)

Some materials arranged in decreasing order of thermal conductivity:

SILVER > COPPER > ALUMINIUM > STEEL.

(SSC CGL 05.05.2002, SSC MTS 20.02.2011)

Thermal Insulation

It is the reduction of heat transfer between objects in thermal contact.

Plastic, dry air, bakelite, paper, cotton, ebonite etc. are heat resistant

(RRB GROUP-D 16.10.2018)

NOTE:

Super cooling stands for cooling of a liquid at freezing point.

(SSC CGL 11.09.2016 & SSC CGL 16.08.2017)

Alcohol is more volatile than water because its boiling point is lower than water.

(SSC CGL 11.09.2016)

Kinetic Theory of Gases

The **kinetic theory of gases** describes a gas as a large number of submicroscopic particles (atoms or molecules), all of which are in constant, rapid, random motion. The randomness arises from the particles' many collisions with each other and with the walls of the container.

Kinetic theory of gases explains the macroscopic properties of gases, such as pressure, temperature, viscosity, thermal conductivity, and volume, by considering their molecular composition and motion. The theory posits that gas pressure results from particles' collisions with the walls of a container at different velocities.

The absolute temperature is achieved only when kinetic energy of molecules is zero.

(RRB ALP 29/08/18)

Assumptions of kinetic theory of gases

1. Every gas of extremely small particles known as molecules. The molecules of a given gas are all identical but are different from those of another gas.
2. The molecules of a gas are identical spherical, rigid and perfectly elastic point masses.
3. The molecular size is negligible in comparison to intermolecular distance (10^{-9} m).
4. The speed of gas molecules lies between zero and infinity very high speed.

5. The distance covered by the molecules between two successive collisions is known as free path and mean of all free paths is known as mean free path.
6. The number of collision per unit volume in a gas remains constant.
7. No attractive or repulsive force acts between gas molecules.
8. Gravitational forces on the molecules is ineffective due to small masses and very high speed of molecules.

Kinetic Theory of Matter

(a) **Solids:** It is the type of matter which has got fixed shape and volume. The force of attraction between any two molecules of a solid is very large. Solids have large molecular attraction as compare to all the state of matter.

(RRB JE 14/12/14)

(b) **Liquids:** It is the type of matter which has got fixed volume but no fixed shape. Force of attraction between any two molecules is not that large as in case of solids.

(c) **Gases:** It is the type of matter does not have any fixed shape or any fixed volume.

The kinetic energy of particle is maximum in gaseous state.

(RRB GROUP-D 19.09.2018 & 05.12.2018)

• **Ideal Gas:** A ideal gas is one which has a zero size of molecule and zero force of interaction between its molecules.

• **Ideal Gas Equation:** A relation between the pressure, volume and temperature of an ideal gas is called ideal gas equation.

$$PV/T = \text{Constant or } PV = nRT$$

Here, n is the number of moles and R is the universal gas constant

Real Gas: The gases which show deviation from the ideal gas behavior are called real gas.

• **Vander wall's equation of state for a real gas:**

$$[P + \{a/V^2\}][V - nb] = nRT$$

Here n is the number of moles of gas.

a and b are van der waals' constants.

Avogadro's number (N): Avogadro's number (N), is the number of carbon atoms contained in 12 gram of carbon-12.

$$N = 6.023 \times 10^{23}$$

(a) **To calculate the mass of an atom/molecule:**

Mass of one atom = atomic weight (in gram)/ N

Mass of one molecule = molecular weight (in gram)/ N

(b) **To calculate the number of atoms/molecules in a certain amount of substance:**



Number of atoms in m gram = $(N/\text{atomic weight}) \times m$
 Number of molecules in m gram = $(N/\text{molecular weight}) \times m$

(c) Size of an atom:

Volume of the atom, $V = (4/3)\pi r^3$
 Mass of the atom, $m = A/N$
 Here, A is the atomic weight and N is the Avogadro's number.
 Radius, $r = [3A/4\pi N\rho]^{1/3}$
 Here ρ is the density.

Gas laws

(a) Boyle's law: It states that the volume of a given amount of gas varies inversely as its pressure, provided its temperature is kept constant.

$$PV = \text{Constant}$$

(b) Charler's law or GayLussac's law: It states that volume of a given mass of a gas varies directly as its absolute temperature, provided its pressure is kept constant.

$$V/T = \text{Constant}$$

$$V - V_0/V_0t = 1/273 = \gamma_p$$

Here $\gamma_p (=1/273)$ is called volume coefficient of gas at constant pressure.

Volume coefficient of a gas, at constant pressure, is defined as the change in volume per unit volume per degree centigrade rise of temperature.

(c) Gay Lussac's law of pressure: It states that pressure of a given mass of a gas varies directly as its absolute temperature provided the volume of the gas is kept constant.

$$P/T = P_0/T_0 \text{ or } P - P_0/P_0t = 1/273 = \gamma_p$$

Here $\gamma_p (=1/273)$ is called pressure coefficient of the gas at constant volume.

Pressure coefficient of a gas, at constant volume, is defined as the change in pressure per unit pressure per degree centigrade rise of temperature.

(d) Dalton's law of partial pressures:

Partial pressure of a gas or of saturated

vapors is the pressure which it would exert if contained alone in the entire confined given space.

$$P = p_1 + p_2 + p_3 + \dots$$

$$nRT/V = p_1 + p_2 + p_3 + \dots$$

(e) Graham's law of diffusion: Graham's law of diffusion states that the rate of diffusion of gases varies inversely as the square root of the density of gases.

$$R \propto 1/\sqrt{\rho} \text{ or } R_1/R_2 = \sqrt{\rho_2/\rho_1}$$

So, a lighter gas gets diffused quickly.

(f) Avogadro's law: It states that under similar conditions of pressure and temperature, equal volume of all gases contain equal number of molecules.

(SSC CGL 05.03.2021)

$$\text{For } m \text{ gram of gas, } PV/T = nR = (m/M) R$$

Pressure of a gas (P):

$$P = 1/3 (M/V) C^2 = 1/3 (\rho) C^2$$

• **Root mean square (r.m.s) velocity of the gas:** Root mean square velocity of a gas is the square root of the mean of the squares of the velocities of individual molecules.

$$C = \sqrt{[c_1^2 + c_2^2 + c_3^2 + \dots + c_n^2]/n} = \sqrt{3P/\rho}$$

• **Pressure in terms of kinetic energy per unit volume:** The pressure of a gas is equal to two-third of kinetic energy per unit volume of the gas.

$$P = 2/3 E$$

• **Kinetic interpretation of temperature:** Root mean square velocity of the molecules of a gas is proportional to the square root of its absolute temperature.

$$C = \sqrt{3RT/M}$$

$$\text{At, } T=0, C=0$$

Thus, absolute zero is the temperature at which all molecular motion ceases.

• **Kinetic energy per mole of gas:**

K.E. per gram mol of gas

$$= \frac{1}{2} MC^2 = \frac{3}{2} RT$$

• **Kinetic energy per gram of gas:**

$$\frac{1}{2} C^2 = \frac{3}{2} rt$$

Here, $\frac{1}{2} C^2$ = kinetic energy per gram of the gas and r = gas constant for one gram of gas.

• **Kinetic energy per molecule of the gas:**

Kinetic energy per molecule

$$= \frac{1}{2} mC^2 = \frac{3}{2} kT$$

$$\text{Here, } k (\text{Boltzmann constant}) = R/N$$

Thus, K.E per molecule is independent of the mass of molecule. It only depends upon the absolute temperature of the gas.

(a) Most probable speed: It is the speed, possessed by the maximum number of molecules of a gas contained in an enclosure.

$$V_m = \sqrt{[2kT/m]}$$

(b) Average speed (V_{av}): Average speed of the molecules of a gas is the arithmetic mean so the speeds of all the molecules.

$$V_{av} = \sqrt{[8kT/\pi m]}$$

(c) Root mean square speed (V_{rms}): It is the square root of the mean of the squares of the individual speeds of the molecules of a gas.

$$V_{rms} = \sqrt{[3kT/m]}$$

$$V_{rms} > V_{av} > V_m$$

• **Degree of Freedom (n):** Degree of freedom, of a mechanical system, is defined as the number of possible independent ways, in which the position and configuration of the system may change.

In general, if N is the number of particles, not connected to each other, the degrees of freedom n of such a system will be,

$$n = 3N$$

If K is the number of constraints (restrictions), degree of freedom n of the system will be,

$$n = 3N - K$$



12

Thermodynamics

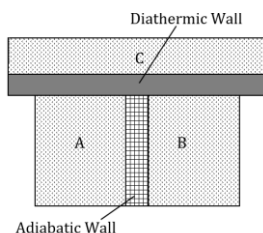
The branch of physics, which deals with the study of relation of heat energy with different types of energy is called thermodynamics.

Some Key Terms:**Thermal System**

An assembly of an extremely large number of particles (atoms or molecules) is called a thermodynamical system. Such a system may exist in the form of a solid, a liquid or a gas or a combination of two or more states.

Thermal Equilibrium

A thermodynamical system is said to be in **Thermodynamical equilibrium** when macroscopic variables (like pressure, volume, temperature, mass, composition etc.) that characterize the system do not change with time.

**Adiabatic Wall**

An insulating wall that does not allow flow of heat energy from one gas to the other.

Diathermic Wall

A conducting wall, which allows heat energy to flow from one gas to another.

Temperature

The physical quantity that determines whether or not given system A is in thermal equilibrium with another system B is called Temperature. It is a **scalar quantity**.

If temperature of 2 systems is same, they are in *Thermal equilibrium*.

Thermodynamic state variables

These are the parameters which describe equilibrium states of the system. For example, equilibrium state of a gas is completely specified by the values of pressure, volume, temperature, mass and composition.

The Equation of State

It represents the connection between the state variable of a system. The equation of state of an ideal gas is represented as

$$\begin{array}{c} \text{Pressure} \quad \text{Volume} \\ \uparrow \quad \quad \uparrow \\ PV = \mu RT \rightarrow \text{Temperature} \end{array}$$

μ is number of moles of the gas

R is gas constant

Internal Energy

The net energy contained by the molecules of the substance is called the internal energy. It is represented by U .

Hot water burns are less severe than that steam burns, because steam has high latent heat.

Ice at 0°C appears colder than that of water at 0°C because when phase changes from water to ice, it ejects out latent heat so, an additional amount of heat has been ejected out for ice at 0°C than water at 0°C .

For cyclic process, change in internal energy is zero.

Types of Thermodynamic Processes

Thermodynamic Processes			
Isothermal Temperature constant $P_1V_1 = P_2V_2$	Adiabatic No heat flow between the system and the surroundings, i.e., $\Delta Q = 0$ $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ $PV^r = \text{constant}$ $P_1V_1^r = P_2V_2^r$ $r = \frac{5}{3}$ monoatomic gas $r = \frac{7}{3}$ diatomic gas $r = \frac{C_p}{C_v}$	Isobaric Pressure constant $\frac{V_1}{T_1} = \frac{V_2}{T_2}$	Isochoric Volume constant $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

Isothermal

The two essential conditions for a perfect isothermal change are:

- The walls of the container must be perfectly conducting, to allow free exchange of heat between the gas and its surroundings.
- The process of compression or expansion should be slow so as to provide time for the exchange of heat.

Some Examples of isothermal changes:

- Melting process* is an isothermal change, because temperature of a substance remains constant during melting.
- Similarly, *boiling process* is also an isothermal operation.

$$PV = \text{constant}^*$$

Equation of an isothermal change.

In an isothermal change,
 $T = \text{constant}; \Delta T = 0$

$$\text{As } c = \frac{\Delta Q}{m(\Delta T)}$$

Therefore, $c = \infty$

i.e., during an isothermal change, *specific heat of gas is infinite*.

Adiabatic

The two essential conditions for a perfect adiabatic change are:

- The walls of the container must be perfectly non-conducting in order to prevent any exchange of heat between the gas and its surroundings, and

- The process of compression or expansion should be sudden so that there is no time for the exchange of heat.

Some Examples of isothermal changes:

- Sudden compression or expansion of a gas* in a container with perfectly non conducting walls.
- Sudden bursting of the tube of a bicycle tyre.*
- Propagation of sound waves in air and other gases.
- Expansion of steam in the cylinder of a steam engine.
- Expansion of hot gases in an internal combustion engine.

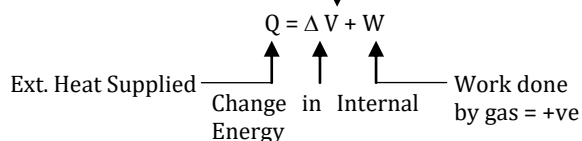


$PV^\gamma = K$, a constant

 γ = specific heat of the gas at constant pressure/ specific heat of the gas at constant volume
Isochoric

In an **isochoric process**, volume V is constant.
No work is done on or by the gas.
Heat absorbed by the gas goes entirely to change its internal energy and its temperature.

As temperature changes, so does the internal energy of the gas.
Where, Internal Energy = Kinetic energy + Potential energy

Laws of Thermo Dynamics**Zeroth Law****First Law****Second Law****Kelvin's Statement****Clausius Statement**

Explains Heat Engine

Explains Refrigerator

Application in 4 Processes**Isothermal Process**

In an isothermal process, temperature remains constant. So the internal energy shall remain constant, i.e., $dU = 0$
 $dQ = dU + dW$
 $= 0 + dW$
 $= dW$
 $dQ = dW$
 Heat supplied in an isothermal process is used entirely to do work against the external surroundings.

Adiabatic Process

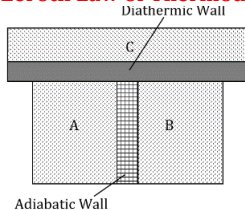
In an adiabatic process, no heat energy enters or leaves the system as it is well insulated i.e., $dQ = 0$
 $dQ = dU + dW$
 $0 = dU + dW$
 $dU = -dW$
 When a gas expands adiabatically, dW is positive. Therefore, dU must be negative, i.e., internal energy of the system would decrease and the gas will be cooled.

Isochoric Process

When volume of a system (such as a gas) is kept constant,
 $dW = P(dV) = 0$.
 $dQ = dU + dW$
 $dQ = dU$
 $\therefore$ If heat is absorbed by a system at constant volume, its internal energy increases by the same amount and vice-versa.
 $dW = 0$
 Work done is zero.

Cyclic Process

In such processes, the system returns to its initial state after any number of changes.
 In that case, no intrinsic property of the system would change
 $\therefore dU = 0$
 $dQ = dU + dW$
 $dQ = dW$
 $\therefore$ Net work done during a cyclic process exactly equals the amount of heat energy transferred.

Zeroth Law of Thermodynamics

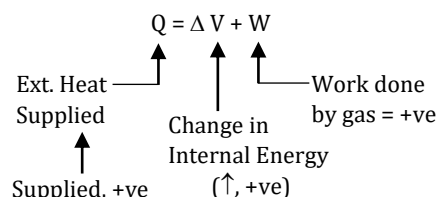
If two bodies A and B are separately in thermal equilibrium with the third body C, then A and B will be in thermal equilibrium with each other i.e.,

(RRB JE 14/12/14.)

If $T_A = T_C$ and $T_B = T_C$ then, $T_A = T_B$ **First Law of Thermodynamics**

The amount of heat given to a system (Q) is used up in two ways, first to increase the

internal energy (U) and second to do external work (W).
 i.e. $\delta Q = \delta U + \delta W$



It is based on the law of conservation of energy. It is the mathematical statement of first law of thermodynamics. Work done by a thermodynamically system is given by
 (SSC CAPFS SI, CISF ASI & Delhi Police SI EXAM 21.06.2014 & 05.07.2017, RRB SSE 21.21.2014)

$$W = P \Delta V$$

Where, P = Pressure
 ΔV = Change in volume

$$mc \Delta t = n \left(\frac{f}{2} R \right) \Delta T + \int p dV$$

$$\uparrow = nc_v \Delta T$$

Specific heat

 f = degree of freedom $f = 3 \rightarrow$ monoatomic gas $f = 5 \rightarrow$ for diatomic gas $f = 6 \rightarrow$ tri-atomic gas $f = 7$ for diatomic gas

William thomson modified the first law of thermodynamics and deduced that the absolute zero of temperature is -273.15°C . he



was honoured for this with then naming of the kelvin temperature scale.

(SSC CGL 07.06.2019)

Second Law of Thermodynamics

The second law of thermodynamics is the outcome of human experience under which, heat energy can be converted into mechanical energy. The second law defines the entropy.

(RRB SE 21.12.2014)

The following two forms are worth mentioning about this law

1. Kelvin's Statement

It is impossible for an engine operating in a cyclic process to extract heat from a

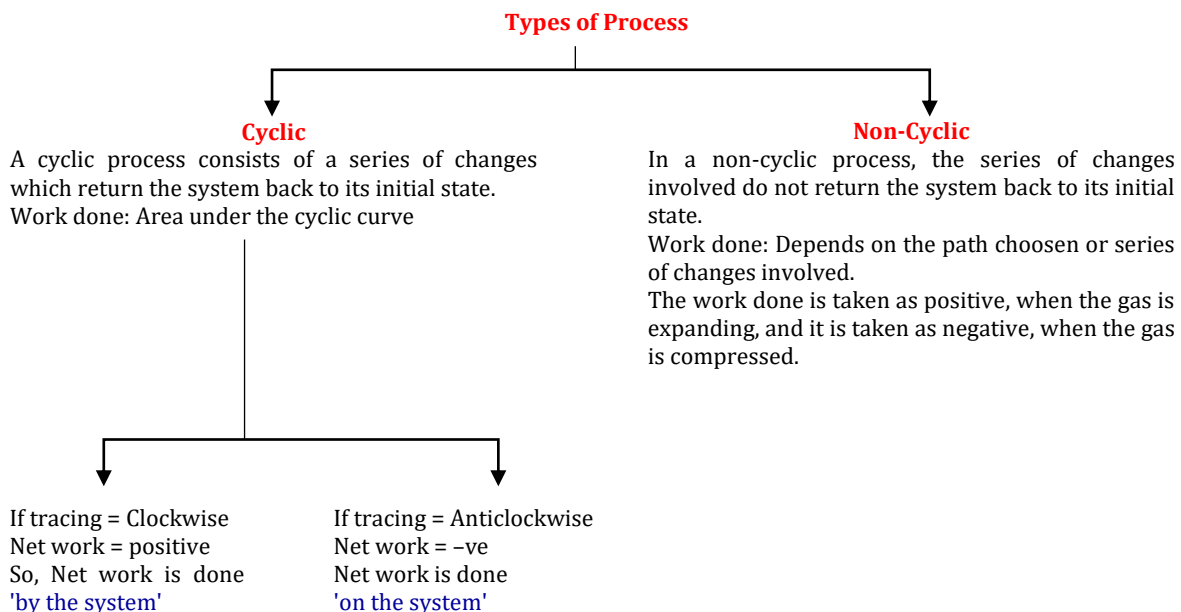
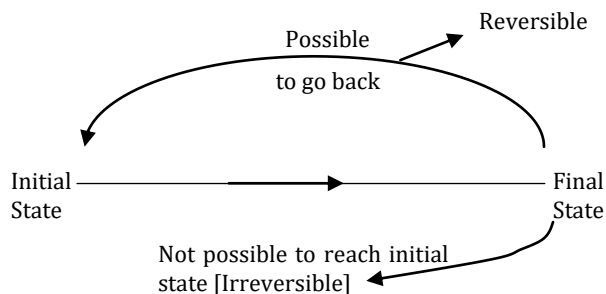
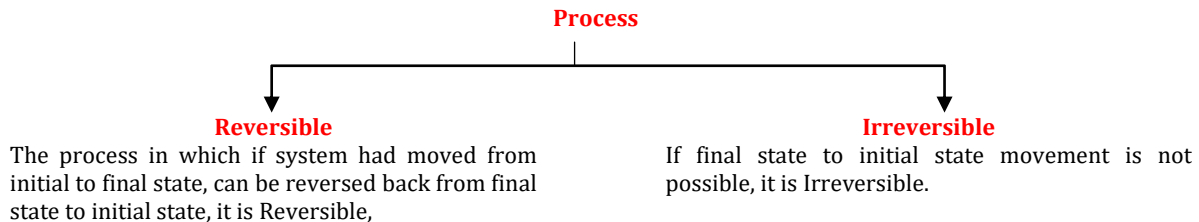
reservoir and convert it completely into work. In other words, **whole of heat cannot be converted into work**. Heat engine is based on this statement.

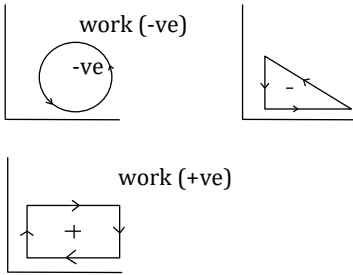
2. Clausius Statement

It is impossible for a self-acting machine, unaided by any external agency to transfer heat from a cold to hot reservoir. In other words, **heat by itself cannot pass from a colder to a hotter body**. Refrigerator is based on this statement.

Important Sign Conventions	
1. Work Done (dW)	
• gas expands	• gas is compressed

• Work is done by gas	• Work is done on the gas
• dW is +ve	• dW is -ve
2. External Energy (dQ)	
+ve Heat is Supplied to System	-ve Heat is Drawn from System
3. Internal Energy (dU)	
+ve Temperature of gas increase	-ve Temperature of gas decrease



Cyclic Process**P - V graph → Closed**

$$\therefore Q = W$$

Work = area enclosed in PV graph

Work = +ve if clockwise cycle

= -ve if anticlockwise cycle

Heat Engine

A heat engine is a device which converts heat energy into mechanical energy. For this, a system is made to undergo a cyclic process.

A heat engine essentially consists of three parts:

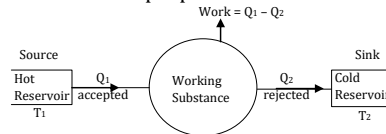
1. Source of heat at higher temperature
2. Working substance

Steam engine
→ Steam

Diesel engine
→ Mixture of fuel vapours and air

3. Sink of heat at lower temperature.

The working substance absorbs some heat from an external reservoir (the source) at some high temperature. It then undergoes cyclic change consisting of several processes. The work done by the working substance of the system in a cycle, is transferred to the environment via some arrangement. For example, when the working substance is in a cylinder with moving piston, the piston transfers mechanical energy to the wheels of a vehicle via a shaft. The cycle is repeated again and again to obtain the desired useful work for some purpose.



Suppose, Q_1 = amount of heat absorbed by the working substance from the source at T_1 K, in one complete cycle.

Q_2 = amount of heat rejected to the sink at T_2 K, in the cycle.

W = net amount of external work done by the working substance, on the environment in the cycle.

$\therefore$ Net amount of heat absorbed in one cycle, $dQ = Q_1 - Q_2$

As the working substance returns to its initial state, the change in its internal energy = 0

i.e. $dU = 0$

According to first law of thermodynamics, $dQ = dU + dW$

$$\therefore dQ = dW$$

i.e., net amount of heat absorbed = external work done by the engine

$$\text{or } Q_1 - Q_2 = W$$

Thermal efficiency (η)

$$= \frac{\text{Net work done / cycle (W)}}{\text{Total amount of heat absorbed / cycle (} Q_1 \text{)}}$$

$$\eta = \frac{\text{Work done}}{\text{Total Heat Supplied}} = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$$

$$= 1 - \frac{Q_2}{Q_1} = 1 - \frac{Q_{\text{rejected}}}{Q_{\text{Supplied}}} = 1 - \frac{T_2}{T_1}$$

As some heat is always rejected to the sink, $Q_2 \neq 0$. Therefore, efficiency is always less than 1, i.e., thermal efficiency of a heat engine is always less than 100%.

 $\eta < 1$ always

Practical experience shows that efficiency is less than 100% even if we eliminate all sorts of losses associated with actual heat engine.

Types of Engine**External Combustion Engine**

Heat is produced by burning the fuel in a chamber *outside the main body* (i.e., cylinder and piston arrangement) of the engine.

For example: Steam engine

Internal/Four Stroke Engine

Heat is produced by burning the fuel *inside the main body* of the engine.

Petrol engine and diesel engine

Petrol

As petrol engine is *light in weight* and small in size, it is used in aeroplanes, cars, scooters etc.

Diesel

A diesel is *heavy* and hence it is used in heavy vehicles like bus, truck, tractor, railway engine etc.

Refrigeration

The term 'refrigeration' may be defined as the **process of removing heat from a substance under controlled conditions**. The practical unit of refrigeration is expressed in terms of tonne of refrigeration. One tonne of refrigeration is taken as equivalent to 210 kJ/min or 3.5 kW. (i.e. 3.5 kJ/s).

Refrigerator

A refrigerator is a device used for cooling things. In a refrigerator, cooling is produced by the evaporation of a volatile liquid, **freon**, inside a copper coil (evaporator), which surrounds the freezer.

- A refrigerator is a reversed heat engine or a heat pump.

The quality that a refrigerant have are

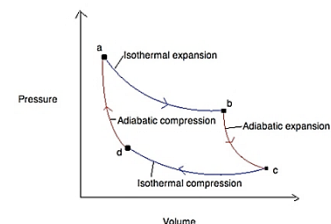
1. Latent heat is high
2. Freezing point should be less
3. The critical temperature should be high
4. Refrigerant temperature should be low

(RRB JE 14.12.2014)

Coefficient of Performance

$$Q = \frac{\text{Heat extracted from cold Reservoir}}{\text{Work done on system}}$$

$$= \frac{Q_2}{Q_1 - Q_2} = \frac{Q_2}{W}$$

Carnot Theorem

No engine can have efficiency more than that of the Carnot engine.

Carnot Cycle

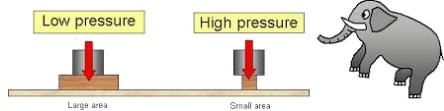
Isothermal Expansion
Adiabatic Expansion
Isothermal Compression
Adiabatic Compression



13

Properties of Matter

Pressure



The force acting per unit area on a surface is known as pressure.

(RRB GROUP-D 16.10.2018 & 05.12.2018)

$$\text{Pressure (p)} = \frac{\text{Force (F)}}{\text{Area (A)}}$$

(RRB NTPC 30.13.2016)

It is a scalar quantity having SI unit Nm^{-2} or Pascal (Pa)

(SSC CHSL 15.03.2021 & 04.07.2019, SSC CPO 2022, 09.11.2022 Shift-3)

The quantity pascal is named after Blaise Pascal.

(SSC MTS 05.08.2019)

The dimensional analysis of pressure is $\text{ML}^{-1}\text{T}^{-2}$.

Pressure is also defined as thrust per unit area.

(RRB GROUP-D 12.12.18 & 11.10.18)

If we increase the area then pressure decreases

(RRB GROUP-D 02.11.18)

Fluid is the name given to a substance which begins to flow when external force is applied on it.

If we want to calculate the pressure of the liquid at the bottom of a vessel, the quantity which is not required to determine it is, the surface area of the bottom of the vessel.

(SSC (10+2) 11.12.2011)

Examples:

- (i) A man standing close to the platform at a railway station experiences a pulling force towards a fast moving train because of pressure difference due to fast moving air.

(SSC CGL 02.09.2016)

- (ii) Water Boils At A Lower Temperature On The Hills Because There Is Decrease In Air Pressure On The Hills.

(SSC Data Entry Operator 02.08.2009, SSC CHSL (10+2) 20.10.2003 & 04.12.2011)

- (iii) The wall of a dam is made thicker at the bottom than at the top because the pressure exerted by the wall on the wall increases with height of the wall.

(SSC (10+2) 28.10.2012)

- (iv) Pressure cooker cooks faster because higher temperature is attained for cooking.

(SSC CGL 11.11.2012, SSC CAPFS SI, CISF ASI & Delhi Police 21.06.2015)

- (v) It is easy to burst a gas filled balloon with a needle, than with a nail, it is because needle exerts more pressure than nail on the balloon.

(SSC CGL 09.08.2015)

Pressure in Liquid

The pressure at any point inside the liquid acts in all directions. Pressure at a depth h in a liquid of density ρ is given by

$$P = \rho gh + P_0$$

Where,

g = acceleration due to gravity

ρ = density of liquid

h = height of liquid column

and P_0 = atmospheric pressure.

Floatation and swimming in sea water is easier due to its high density than fresh water.

At higher altitudes, atmospheric pressure is lower than that at sea level.

As depth increases from the free surface of a fluid then the pressure exerted by the liquid will increase.

(RRB GROUP-D 12/12/18)

As depth decreases from the free surface of a fluid then the pressure exerted by the liquid will decrease.

(RRB GROUP-D 10/12/18)

Archimedes' Principle

It states that when a body is immersed wholly or partly in a liquid at rest, it loses some of its weight. The loss in weight of the body in the liquid is equal to the weight of the liquid displaced by the immersed part of the body.

(RRB JE 14.12.14 & RRB GROUP-D 15.10.18 & SSC CAPFS ASI & Delhi Police SI 07.07.2021 & SSC Multi Tasking Staff 17.03.2013)

Note: The upward force exerted by a fluid on the immersed body is called buoyant force or buoyancy or upthrust

If there is no gravity, then upward thrust will not be there in fluid.

(SSC CGL 31.08.2016)

Lactometer, hydrometer, designing of ship and submarine etc are based on Archimedes principle.

(RRB NTPC 06.04.2021)

Purity of metal can be determined with the help of Archimedes principle.

(SSC CAPFS SI, CISF ASI & Delhi Police SI 22.06.2014)

It also states the buoyancy theory that ship floats in water.

(RRB NTPC 30.04.2016)

A boat of full iron nails is floating on water in a lake. When the iron nails are removed, the water level falls because we very well know that the weight displaced by a body is equal to the loss of weight of body.

(SSC MULTI TASKING 21.10.2017)

Buoyant force helps swimmers to float in water.

(SSC CHSL (10+2) 03.07.2019)

Density

The ratio of mass m to the volume V of a body is called its density (i.e. mass present in its unit volume). It is a scalar quantity having SI unit - kg/m^3 .

(RRB JE 14.12.2014)

The density of water is 1000 kg/m^3 (at 4°C)

(RRB JE 14.12.2014, RRB NTPC 18.04.2016 & SSC CHSL 16.1.2014, SSC CGL 21.04.2013)

$$\text{Density (p)} = \frac{\text{Mass (m)}}{\text{Volume (V)}}$$

Clouds float in sky because of low density.

(RRB NTPC 28.04.2016)

Examples :

- (i) A spherical ball made up of steel when dropped in mercury container will be on the surface of the mercury.

(FCI ASSISTANT 05.02.2012)

- (ii) If we removed cream from milk its density increases because the density of pure fresh milk is 1.032, while the density of fat globules is 0.86 but if we add water in milk then its density decreases

(SSC (10+2) 28.10.2012)

- (iii) It is easy for man to swim in sea water, than in river water because the density of the sea water is more than the density of river water.

(SSC DELHI POLICE SI 19.08.2012)

Relative Density

It is the ratio between the density of material to the density of water.

(RRB GROUP-D 22.10.2018 & RRB JE 26.06.2019, SSC Multi Tasking Staff 17.03.2013 & SSC CHSL 17.03.2018)

It is represented by S .

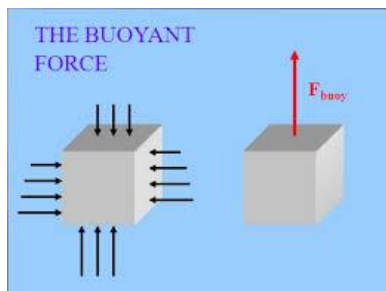
S = density of material / density of water

There is no unit of relative density.

The dimensional formula is $\text{M}^0\text{L}^0\text{T}^0$

Law of Floatation



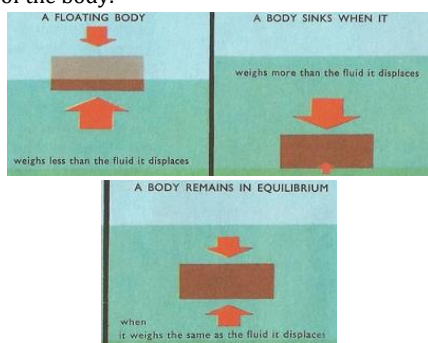


When a body of density ρ , volume V is immersed completely in a liquid of density σ , two forces are acting on it.

1. True weight $W (= V \rho g)$ of the body acting vertically downwards through the centre of gravity.
2. Buoyant force or upward thrust $w (= V \sigma g)$, equal to the weight of the liquid displaced, acting vertically upward through the centre of Buoyancy. It always act perpendicular to plan

(RRB GROUP-D 15.10.2018, 05.10.2018 & 28.08.19, RRB ALP 21.08.2018, RRB JE 31.05.2019)

Thus the **law of floatation** states that a body will float in a liquid, if weight of the liquid displaced by the immersed part of the body is atleast equal to or greater than the weight of the body.



There will be equilibrium of floating bodies if the following conditions are fulfilled.

- (i) A body can float if the weight of the liquid displaced by the immersed part of body must be equal to the weight of the body.
 - (ii) A body can be in equilibrium if the centre of gravity of the body and centre of buoyancy must be along the same vertical line.
 - (iii) The body will be in stable equilibrium if centre of gravity of body lies vertically below the centre of buoyancy and in the unstable equilibrium if centre of gravity lies vertically above the centre of buoyancy.
1. When an ice block is floating in water in a vessel, then the level of water in the

vessel will not change when the whole ice melts into water.

2. When an ice block is floating in a liquid in a vessel and ice completely melts, then the following cases may arise for the level of liquid in the vessel.
 - (i) If density of liquid is greater than that of water, i.e., $\rho_l > \rho_w$, the level of liquid plus water will rise.
 - (ii) If density of liquid is less than the density of water, i.e., $\rho_l < \rho_w$, the level of liquid plus water will decrease.
 - (iii) If density of liquid is equal to the density of water, i.e., $\rho_l = \rho_w$, the level liquid plus water will remain unchanged.

Atmospheric Pressure

The air that envelopes the earth is called atmosphere and the pressure exerted by it on a body on the earth is called atmospheric pressure.

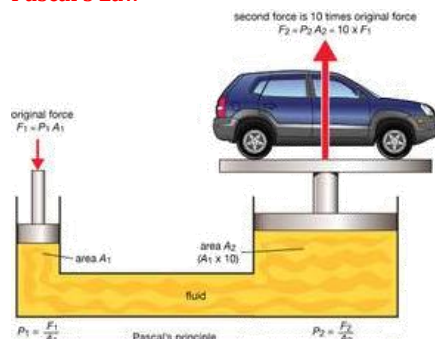
The atmospheric pressure is maximum at the surface of the earth and goes on decreasing as we move up into the earth's atmosphere. The measurement of atmospheric pressure is carried out by barometer.

Barometers are also used for weather forecasting. If the barometric height falls suddenly, it indicates the coming of a storm. A gradual fall and rise in barometric height indicate the possibility of rain and fair weather respectively.

1 atmospheric pressure = 1.01 bar
= $1.01 \times 10^5 \text{ N/m}^2$

A barometer is a device for measuring atmospheric pressure.

Pascal's Law



It states that if gravity of effect is neglected, the pressure at every point of liquid in equilibrium of rest is same.

This law also accounts for the principle of transmission of pressure in liquids or gases. In this form,

Pascal's law states that the increase in pressure at one point of the enclosed liquid in equilibrium of rest is transmitted equally to all other points of the liquid and also to

the walls of the container, provided the effect of gravity is neglected.

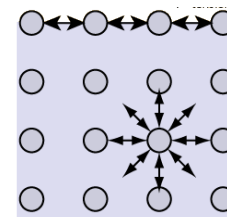
(SSC CHSL 03.07.2019)

i.e. $P_1 = P_2$

This applies to fluid at rest

Hydraulic brakes used in automobile vehicles is direct virtual application of pascal law.

Surface Tension



surface tension is the property of the liquid by virtue of which the free surface of liquid at rest tends to have minimum surface area and as such it behaves as if covered with a stretched membrane.

The surface tension of water on adding detergent to it decrease.

(SSC CGL 05.05.2002, SSC (10+2) 04.12.2011)

Water droplets cannot stick to the oily surface due to surface tension.

(SSC (10+2) 11.12.2011)

A solid needle placed horizontal on the surface of the water floats due to surface tension of water.

(SSC (10+2) 21.10.2012)

A drop of liquid is in spherical shape because a sphere has the least surface area for a given volume.

(SSC (10+2) 21.10.2012)

Materials for rain proof coats and tents owe their water proof properties to surface tension.

(SSC (10+2) 04.11.2012)

Bubbles from liquid are formed due to surface tension.

(SSC CGL 27.08.2016)

Measurement of Surface Tension

Surface tension of a liquid is measured as the force acting on unit length of a line imagined to be drawn tangentially anywhere on the free surface of the liquid at rest. It acts at right angles to this line on both the sides and along tangent to the liquid surface.

$$S = F/l$$

Units of surface tension are dyne/cm in cgs system and Nm^{-1} in SI.

The dimensional formula of surface tension is $[\text{ML}^2\text{T}^{-2}]$. Surface tension is a scalar quantity because it has no specific direction for a given liquid.

Illustrations of Surface Tension

1. Rain drops are spherical in shape because each drop tends to acquire

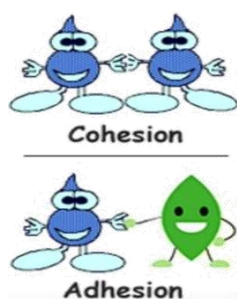


minimum surface area due to surface tension, and for a given volume, the surface area of sphere is minimum.

(RRB JE 14.12.2014)

- When mercury is split on a clean glass plate, it forms globules. Tiny globules are spherical on account of surface tension because force of gravity is negligible.
- A drop of fluid is combined because the attraction of its particle minimize its possible area.
- (RRB NTPC 17/01/17)
- An oil drop spreads over water because oil is lighter than that of water.

(SSC Tax Assistant 11.12.2005,
SSC Multi Tasking 16.02.2014)



Surface tension of a liquid decreases with an increase in temperature.

Surface Film

It is the top most layer of liquid at rest with thickness equal to the molecular range.

Inter-Molecular Forces

The forces between the molecules of the substances are called intermolecular forces.

Types of Intermolecular Forces

There are two types of intermolecular forces.

(i) Force of Adhesion or Adhesive Force

It is the force of attraction acting between the molecules of different substances.

While writing, graphite from lead pencil sticks to the paper on account of adhesive forces. Fevicol, cement etc are useful in glueing two surface.

(ii) Force of Cohesion or Cohesive Force

It is the force of attraction amongst the molecules of the same substance.

(RRB NTPC 11.02.2021)

Mercury does not wet the surface of a glass container because the force of cohesion amongst molecules of mercury is stronger than the force of adhesion between molecules of mercury and glass.

Soap bubble attains spherical shape due to surface tension.

(SSC SI Delhi Police, CAPFS & ASI 12.03.2019
& SSC CGL 09.08.2017)

On a clean glass plate a drop of water spreads to form a thin layer whereas a drop of

mercury remains almost spherical because cohesion of mercury is greater than its adhesion with glass.

(SSC CGL 27.08.2016)

Capillarity



A tube with a fine and uniform bore throughout its length is called a capillary tube.

The phenomenon of rise or fall of liquid in a capillary tube is called capillarity.

Rise or fall of a liquid in a capillary tube is caused by surface tension and depends on the relative magnitude of cohesion of the liquid and the adhesion of the liquid to the walls of the containing vessel.

Liquids rise in tubes if they wet (adhesion > cohesion)

Liquids fall in tubes that do not wet (cohesion > adhesion).

Applications of capillary action

- The fine pores of a blotting paper act like capillary tubes. Ink rise in them leaving the paper dry.
- Water from soil enters into the root hairs owing to capillary pressure.
(SSC Multi Tasking 20.02.2011, RRB NTPC 29.04.2016 & 30.13.16)
- Kerosene rises in the long narrow spaces between the threads of a wick, because they act as fine capillaries.
(RRB NTPC 11.01.2021, SSC Section Officer 05.06.2003, SSC CGL 12.05.2002 & SSC Multi Tasking 24.03.2013)
- Swelling of wood in rainy season, is due to rise of moisture from air, in the pores of wood.
- Ploughing of field is essential for preserving moisture in the soil. By ploughing, the fine capillaries in the soil are broken. Water from within the soil shall not rise and evaporate off.
- Sand is drier soil than clay. This is because holes between the sand particles are not so fine as compared to that of clay, as to draw up water by capillarity action.

Piezometer: For measuring pressure inside a vessel or pipe in which liquid is there, a tube may be attached to the walls

of the container (or pipe) in which the liquid resides so liquid can rise in the tube. By determining the height to which liquid rises and using the relation $P = \rho gh$, gauge pressure of the liquid can be determined. Such a device is known as piezometer. To avoid capillary effects, a piezometer's tube should be about 1/2 inch or greater.

Fluid

A fluid is a substance which deforms continuously under the action of shearing forces, however small they may be. Conversely, it follows that:

If a fluid is at rest, there can be no shearing forces acting and, therefore, all forces in the fluid must be perpendicular to the planes upon which they act.

Types of Fluids

1. Newtonian fluids:

Fluids which obey the Newton's law of viscosity are called as Newtonian fluids. Newton's law of viscosity is given by

$$\tau = \mu \frac{dv}{dy}$$

Where,

τ = shear stress

μ = viscosity of fluid

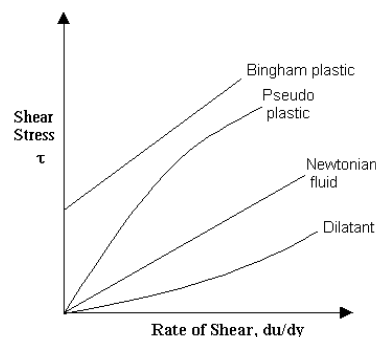
$\frac{dv}{dy}$ = shear rate, rate of strain or velocity gradient

All gases and most liquids which have simpler molecular formula and low molecular weight such as water, benzene, ethyl alcohol, CCl_4 , hexane and most solutions of simple molecules are Newtonian fluids.

2. Non-Newtonian fluids:

Fluids which do not obey the Newton's law of viscosity are called as non-Newtonian fluids.

Generally non-Newtonian fluids are complex mixtures: slurries, pastes, gels, polymer solutions etc.,



Various non-Newtonian Behaviors:

Time-Independent behaviors:

Properties are independent of time under shear.



Bingham-plastic: Resist a small shear stress but flow easily under larger shear stresses. e.g. tooth-paste, jellies, and some slurries.

Pseudo-plastic: Most non-Newtonian fluids fall into this group. Viscosity decreases with increasing velocity gradient. e.g. polymer solutions, blood. Pseudoplastic fluids are also called as Shear thinning fluids. At low shear rates (du/dy) the shear thinning fluid is more viscous than the Newtonian fluid, and at high shear rates it is less viscous.

Dilatant fluids: Viscosity increases with increasing velocity gradient. They are uncommon, but suspensions of starch and sand behave in this way. Dilatant fluids are also called as shear thickening fluids.

IDEAL FLUID – a fluid that is non – viscous, frictionless and incompressible. It does not have surface tension and bulk modulus. This type of fluid is not exist.

(RRB SSE 21.12.2014)

Physical properties of fluid

1. Viscosity:

(RRB NTPC 08.04.2021)

The viscosity is the resistance to deformation at a given rate.

It is represented by μ .

The SI unit of viscosity is N s m^{-2} (poiseuille)

Viscosity changes with the changes in temperature.

If we increase the temperature the gases viscosity is also increase

and if we decrease the temperature then liquid viscosity is decrease.

A liquid distributed by stirring comes to rest due to viscosity.

(SSC GRADUATE 19.05.2013)

2. VAPOUR PRESSURE

The pressure at which a liquid will boil is called its vapor pressure. This pressure is a function of temperature (vapor pressure increases with temperature). In this context we usually think about the temperature at which boiling occurs. For example, water boils at 100°C at sea-level atmospheric pressure (1 atm abs). However, in terms of vapor pressure, we can say that by increasing the temperature of water at sea level to 100°C , we increase the vapor pressure to the point at which it is equal to the atmospheric pressure (1 atm abs), so that boiling occurs. It is easy to visualize that boiling can also occur in water at temperatures much below 100°C if the pressure in the water is reduced to its vapor pressure. For example, the vapor pressure of water at 10°C is 0.01 atm. Therefore, if the pressure within water at that temperature is reduced to that value, the water boils. Such boiling often occurs in flowing liquids, such as on the suction side of a pump. When such boiling does occur in the flowing liquids, vapor bubbles start growing in local regions of very low pressure and then collapse in regions of high downstream pressure. This phenomenon is called as cavitation

3. Compressibility and the Bulk modulus

If we pressurize a body and their density will change while compressing then the body is said to be compressible.

Reciprocal of compressibility is bulk modulus

Bulk modulus (K) = (change in pressure) / (volumetric strain)

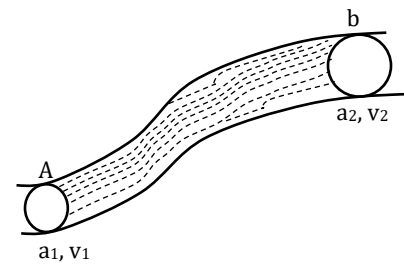
Volumetric strain is the change in volume divided by the original volume. Therefore, (change in volume) / (original volume) = (change in pressure) / (bulk modulus)

i.e., $-\delta V/V = \delta p/K$

Negative sign for δV indicates the volume decreases as pressure increases.

the concept of the bulk modulus is mainly applied to liquids, since for gases the compressibility is so great that the value of K is not a constant.

Equation of continuity



Cross-sectional view of a pipe through which incompressible liquid is passing,

Then Equation of continuity states that Volume of liquid entering = volume of liquid leaving

$$a_1 v_1 = a_2 v_2$$

a_1 → area of tube at point A

v_1 → velocity of liquid at point A

a_2 → area of tube at point B.

v_2 → velocity of liquid at point B.



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Mechanical Properties of Solids

Matter is anything that has mass and occupy space. It includes all the physical 'material' around us. Different matter have dissimilar properties such as elasticity, density, viscosity, etc., to distinguish them from each other.

Stress

The restoring force per unit area is called stress. Its units is N/m^2 or Pascal.

$$\text{Stress} = \frac{\text{Restoring force (F)}}{\text{Area (A)}}$$

Stress can be defined as vector quantity.

(SSC CPO 06.06.2016)

There are different types of stress given as below

Normal Stress/Longitudinal Stress

Stress produced normal to the axis of the body is called normal stress. It consists of two types.

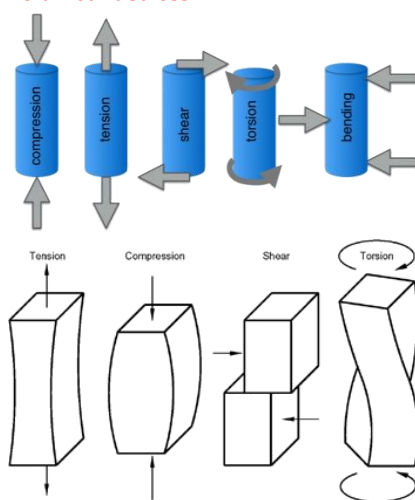
1. Compressive Stress: Stress produced in the body, which is responsible for the compression in the body is called compressive stress.

2. Tensile Stress: Stress produced in the body, which is responsible for the elongation in the body is called tensile stress.

Shearing Stress and Volumetric Stress

Stress produced along the axis of the body under the action of a force parallel to its axis, i.e. tangential force is called shearing stress. It is also called **tangential stress**.

Stress produced in the body under the action of the force, which is perpendicular to the surface and proportional to the area in case the body is immersed in fluid, is called **volumetric stress**.

**Strain**

When a system of forces acts on a body, it undergoes some deformation. This deformation per unit length is known as unit strain or simply a strain.

Strain is a ratio of change in dimension to the original dimension, it has *no units or dimensional formula*.

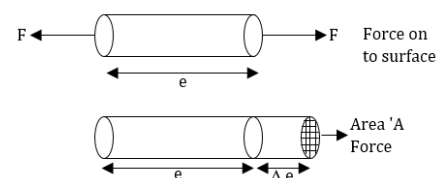
(SSC CONSTABLE GD 04.10.2015)

$$\text{Strain} = \frac{\text{Change in length}(\Delta l)}{\text{Original length (l)}}$$

There are three types of strain given as below

1. Longitudinal Strain

It is the ratio of change in length to that of initial length of the body (i.e. $\Delta L/L$).



Force perpendicular to Area A must be considered when equal & opposite force is applied on both ends. Then length increases.

$$\text{Longitudinal strain} = \frac{\Delta l}{l} = \frac{\text{change in length}}{\text{Original length}}$$

2. Shear Strain

The angle between the displaced state and initial state of the body is called shearing strain. (i.e. $\frac{\Delta x}{l}$)

3. Volumetric strain

It is the ratio of change in volume of the body to its initial volume (i.e. $\Delta V/V$).

$$\text{Volume Stress, } \Delta P \text{ (Extra Pressure)} = \frac{F}{\text{Area}}$$

$$\text{Volume Strain, } E = \frac{\Delta V}{V}$$

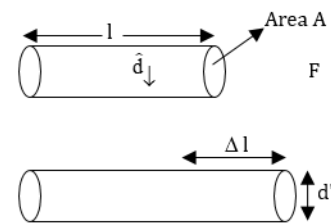
$$\text{Bulk Modulus, } B = \frac{\text{Normal stress}}{\text{volumetric strain}}$$

$$= \frac{F/a}{-\Delta V/V}$$

Negative Sign is used because volume decreases once volumetric stress is applied.

Poisson's Ratio

When an object is stretched, volume remains same so length $\uparrow$ but area $\downarrow$ (diameter $\downarrow$)



$$\text{Longitudinal strain} = \frac{\Delta l}{l} = \frac{\text{Change in length}}{\text{Original length}}$$

$$\text{Lateral strain} = \frac{\Delta d}{d} = \frac{\text{Change in diameter}}{\text{Original diameter}}$$

It is the ratio of lateral strain to the longitudinal strain in a stretched wire.

$$\text{Poisson's ration } (\mu) = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$$

$$= \frac{\Delta d / d}{\Delta l / l}$$

Length $\uparrow$, diameter $\downarrow$

It is a dimensionless quantity.

Poisson's ratio for steel is 0.30.

Elasticity

The property of matter by virtue of which a body tends to regain its original shape and size after the removal of deforming force is called elasticity.

If the body completely regains its original shape after removal of deforming force, the body is called **perfectly elastic body**.

Ex. "shock-absorber" are generally made up of steel because it has high elasticity.

(SSC CGL 26.06.2011)

Plasticity

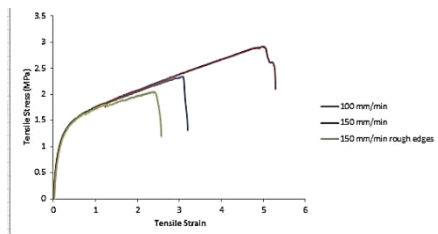
The property of matter by virtue of which it does not regain its original shape and size after removal of deforming force is called plasticity. If the body remains in deformed shape even after removal of the deforming force, it is called **perfectly inelastic** or **plastic body**.

Note: Steel is more elastic than rubber because the magnitude of stress for a given strain is much large in steel than rubber.

Perfectly Plastic: Putty, mud, Paraffin Wax

Perfectly Elastic: Quartz, Phosphor Bronze

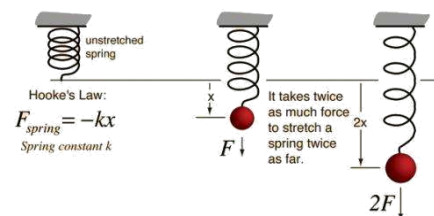
Elastomer These are the materials which possess the qualities **such as**



- Stress vs Strain is not a straight line.
- Elastic Region is large.
- Ex. Rubber

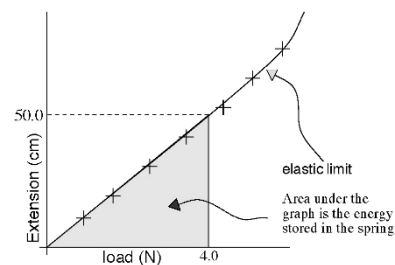
Hooke's Law

According to this law, within the elastic limits, the stress is directly proportional to the strain produced in a body.



i.e. $\text{Stress} \propto \text{Strain}$ or $\text{Stress} = E \times \text{Strain}$

$$\frac{\text{Stress}}{\text{Strain}} = E$$



Where, E is a constant called as **Modulus of Elasticity** (Proportionality constant)

It states that the extension produced in the wire is directly proportional to the load applied, within elastic limit.

i.e., within elastic limit, extension $\propto$ load applied.

The spring balance works on the principle of hooke law.

(SSC CGL 31.08.2016)

There are three Modulus of elasticity given as below

Young's Modulus of Elasticity (Y)

It is defined as the ratio of longitudinal stress to the longitudinal strain within the elastic limit. Thus,

$$Y = \frac{\text{Longitudinal stress}}{\text{Longitudinal strain}}$$

The SI unit of Young's modulus of elasticity is Nm^{-2} or Pascal (denoted by Pa and in CGS system is dyne/cm^2).

Bulk Modulus of Elasticity (B)

It is defined as the ratio of normal stress to the volumetric strain within the elastic limit. Thus,

$$B = \frac{\text{Normal stress}}{\text{Volumetric strain}}$$

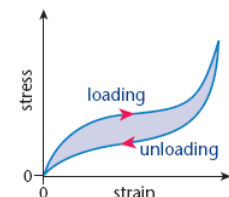
The SI unit of bulk modulus of elasticity is Nm^{-2} or pascal (denoted by Pa and in CGS system is dyne/cm^2).

Modulus of Rigidity (η)

It is defined as the ratio of shearing stress to the shearing strain within the elastic limit. It is also called shear modulus of rigidity.

$$\text{Thus, } \eta = \frac{\text{Shearing stress}}{\text{Shearing Strain}}$$

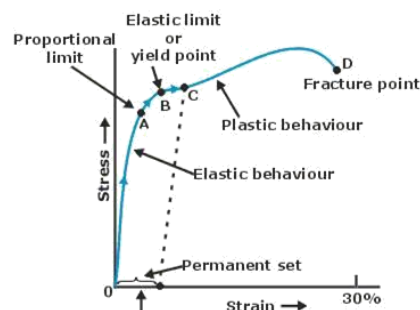
The SI unit of η is Nm^{-2} or Pascal (denoted by P and in CGS system is dyne/cm^2).



Note: Elastic hysteresis has an important application in shock absorbers.

Elastic Hysteresis. When a deforming force is applied on a body, then the strain does not change simultaneously with stress, rather it lags behind the stress. The lagging of strain behind the stress is defined as **elastic hysteresis**.

Stress-Strain Graph



- Upto Point A $\rightarrow$ Proportional limit
Slope of this graph gives us Modulus of Elasticity, Hooke's Law is obeyed in this region.
- A to B $\rightarrow$ Elastic property of material is retained i.e. if you will remove stress, material will regain its shape.
- B $\rightarrow$ Elastic limit or yield limit
 $\sigma_y \rightarrow$ Yield Stress: The value of stress on whose application we get yield point.
- After B $\rightarrow$ If you $\uparrow$ stress, there is a much increase in strain & stress, if will remove stress, material will not gain its original position.
- So, At C $\rightarrow$ Object is permanently reformed at strain $\Rightarrow$ Permanent Set.
- After C $\rightarrow$ Small increase in stress gives larger value of strain.
- D $\rightarrow$ ultimate Tensile strength
After this if we $\downarrow$ stress, strain $\uparrow$.
- a point after D, At E $\rightarrow$ fracture point $\rightarrow$ object break.

If there is very small gap or No gap between D & E $\Rightarrow$ Object is brittle

If there is large gap between D & E $\Rightarrow$ Object is Malleable (sheets) and Ductile (wires)

$$\text{Strain Energy} = \frac{F e}{2} ;$$

F $\rightarrow$ maximum force acting on object
e $\rightarrow$ elongation of object due to force

$$\text{Strain energy volume} = \frac{\text{Stress} \times \text{Strain}}{2}$$



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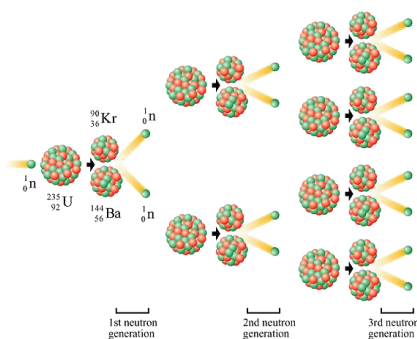
Nuclear Ractor

Nuclear Radioactivity:

Radioactivity is the property by virtue of which a heavy element disintegrates itself without being forced by any external agent to do so.

The element exhibiting this property is called radioactive element.

The total number of radioactive elements known at present is about 40. For instance, natural elements with atomic number greater than 82 are all radioactive. Their nuclei are thus Unstable nuclei. Some examples are Radium, Thorium, Actinium, Polonium etc.

**Cause of Radioactivity**

Emission of active radiations indicates that parent nucleus is **unstable**. This indicates that stability decreases as we move towards heavier nuclei. The heavy nuclei have larger atomic number Z and hence contain larger number of protons. The mutual repulsion of protons reduces the binding effect of nuclear forces. This is the main cause of relative instability of heavy nuclei. Radioactivity results from this instability.

Atomic Masses

One atomic mass unit or unified mass unit is defined as $1/12^{\text{th}}$ of the mass of an atom of ${}^{12}_6\text{C}$ isotope.

As Avogadro's number = 6.023×10^{23} ,
 $\therefore$ Mass of 6.023×10^{23} atoms of C^{12} = 12 g

$$\text{Mass of one atom of } \text{C}^{12} = \frac{12}{6.023 \times 10^{23}} \text{ g}$$

By definition, 1 a.m.u.

$$= \frac{1}{12} \times \text{mass of one atom of } \text{C}^{12}$$

$$\therefore 1 \text{ a.m.u.} = \frac{1}{12} \times \frac{12}{6.023 \times 10^{23}} \text{ g}$$

$$= 1.66 \times 10^{-24} \text{ g}$$

$$1 \text{ a.m.u.} = 1.66 \times 10^{-27} \text{ kg}$$

One electron volt is the energy gained by an electron, when accelerated through a potential difference of one volt.

$$1 \text{ a.m.u.} = 931 \text{ MeV}$$

Nuclear Density

Density of nuclear matter is the ratio of mass of nucleus and its volume.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{A}{\frac{4}{3}\pi R^3} = \frac{A}{\frac{4}{3}\pi (R_0 A^{\frac{1}{3}})^3}$$

$$\Rightarrow \frac{1}{\frac{4}{3}\pi R_0^3}$$

So, Density of nucleus does not depend on mass number

Radius of Nucleus is order of $10^{-15} = 1 \text{ fermi}$

Isotopes

Isotopes of an element are the atoms of the elements which have the same atomic number (Z) but different mass number (A).

For example, ${}^1_1\text{H}^1$, ${}^1_1\text{H}^2$, ${}^1_1\text{H}^3$ are the isotopes of hydrogen. ${}^2_2\text{He}^3$, ${}^2_2\text{He}^4$, ${}^2_2\text{He}^6$ are the isotopes of helium. ${}^{12}_6\text{C}^{10}$, ${}^{12}_6\text{C}^{11}$, ${}^{12}_6\text{C}^{12}$, ${}^{12}_6\text{C}^{13}$, ${}^{12}_6\text{C}^{14}$ are the isotopes of carbon.

As isotopes of an element have the same atomic number, they contain **same number of protons and same number of electrons**. But as their atomic weights are different they contain **different number of neutrons**.

Isobars

Isobars are the atoms of different elements which have the same mass number (A), but different atomic numbers (Z).

Isobars contain different number of protons, different number of electrons and also different number of neutrons. Only the total number of nucleons (number of protons + number of neutrons) in them is the same.

For example, ${}^{22}_{11}\text{Na}^{22}$ and ${}^{22}_{10}\text{Ne}^{22}$ are isobars. Similarly, ${}^{40}_{20}\text{Ca}^{40}$ and ${}^{40}_{18}\text{Ar}^{40}$ are isobars and ${}^{37}_{17}\text{Cl}^{37}$, ${}^{37}_{16}\text{S}^{37}$ are also isobars.

Similarly, ${}^3_1\text{H}^3$ and ${}^3_2\text{He}^3$ are isobars. Also, ${}^{14}_6\text{C}^{14}$ and ${}^{14}_7\text{N}^{14}$ are isobars.

Isotones

Isotones are the nuclides which contain the same number of neutrons i.e. in their case, $(A - Z) = N$ is the same. Their atomic number (Z) and mass number (A) are different.

For example, ${}^{37}_{17}\text{Cl}^{37}$ and ${}^{39}_{19}\text{K}^{39}$ are isotones. this is because number of neutrons in chlorine = $37 - 17 = 20$ and number of neutrons in potassium = $39 - 19 = 20$.

Similarly, ${}^3_1\text{H}^3$ and ${}^4_2\text{He}^4$ are isotones. Also, ${}^{16}_8\text{O}^{16}$ and ${}^{14}_6\text{C}^{14}$ are isotones.

Some other examples of isotones are:

${}^9_4\text{Be}^9$ and ${}^{10}_5\text{B}^{10}$; ${}^{13}_6\text{C}^{13}$ and ${}^{14}_7\text{N}^{14}$;

${}^{23}_{11}\text{Na}^{23}$ and ${}^{24}_{12}\text{Mg}^{24}$.

Mass-Energy Relation

Einstein was the first to establish the equivalence of mass and energy through the famous relation

$$E = mc^2$$

Where,

$c = 3 \times 10^8 \text{ m/s}$ = speed of light in vacuum.

Nuclear Binding Energy

Binding energy of a nucleus is the energy with which nucleons are bound in the nucleus. It is measured by the work required to be done to separate the nucleons an infinite distance apart from the nucleus, so that they may not interact with each other.

Mass defect = actual mass less than total mass of neutrons & protons

$$\underbrace{Z \text{ Mp}}_{\text{Proton mass}} + \underbrace{(A - Z) \text{ Mn}}_{\text{Neutron mass}} - \underbrace{M_{\text{nucleus}}}_{\text{Mass of nucleus}}$$

More

This releases some energy

This is called Binding Energy
 More BE, more stable the nucleus is

Laws of Radioactive Disintegration

1. Radioactivity is a spontaneous process which does not depend upon external factors like temperature, pressure etc. i.e. a radioactive element is in a state of disintegration which depends upon law of chance. It means it is impossible to predict which particular atom of the radioactive element will disintegrate in a given time interval.
2. During disintegration of an atom, either an α -particle or a β -particle is emitted. Both of these particles are never emitted simultaneously. Also at a time, an atom will not emit more than one α -particle or more than one β -particle. γ -rays emission follows the emission of α or β particle.
3. The emission of α -particle from an atom will change it, into a new atom whose charge number is reduced by two and mass number is reduced by four.



4. The emission of a β -particle from an atom will change it, into a new atom whose charge number is raised by one, without any change in its mass number.

Radioactive Decay Law

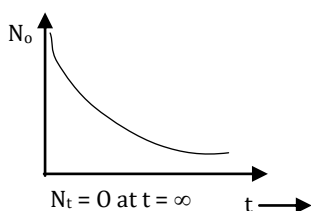
The number of atoms disintegrated per second (i.e. rate of disintegration of radioactive atoms) at any instant is directly proportional to the number of radioactive atoms actually present in the sample at that instant. This is also known as radioactive decay law.

$$\frac{dN}{dt} \propto N \Rightarrow \frac{dN}{dt} = -\lambda N$$

↑
decay constant

or

$$N_t = N_0 e^{-\lambda t}$$



Nuclear Reaction

A nuclear reaction represents the transformation of one stable nucleus into other nucleus by bombarding the former with suitable high energy particles.

Nuclear Fission

Nuclear Fission is the phenomenon of splitting of a heavy nucleus (usually $A > 230$) into two or more lighter nuclei.

Nuclear Fusion

(RRB NTPC 22.02.2021, 05.04.2016)

(RRB GROUP-D 09.10.2018)

Nuclear fusion is the phenomenon of fusing two or more lighter nuclei to form a heavier more stable nuclei

Sun generate energy through nuclear fusion.

(RRB NTPC 28.03.2016), (RRB GROUP-D 19.09.2018, 24.09.2018 & 26.10.2018), (SSC CGL 24.02.2003, SSC CPO SI 12.01.2003 & 26.05.2005, SSC (10+2) 28.11.2010, SSC CGL 27.10.2016)

Ex. Hydrogen bomb

(RRB NTPC 04.03.2021)

Nuclear Chain Reaction

A nuclear chain reaction is said to occur when neutrons emitted from the decay of one nucleus are free to initiate fission in the surrounding nuclei.

Nature of α , β , γ -Rays

The α -rays are deflected through smaller angles towards the negative plate. The β -rays

are deflected through larger angles towards the positive plate. The γ -rays remain undeflected.

α -Rays

1. An α -particle carries double the positive charge of proton, i.e same as charge on the **helium nucleus**.
2. Mass of an α -particle is roughly four times that of hydrogen atom i.e. it is equal to the mass of the helium nucleus.
3. The velocity of α -particle ranges between $1.4 \times 10^7 \text{ms}^{-1}$ to $2.1 \times 10^7 \text{ms}^{-1}$, depending upon the source emitting it.
4. Because of large mass, **the penetrating power of α -particles is very small**, it being 1/100 time that of β -rays and 1/10,000 time that of γ -rays.
 α -particle can be easily stopped by an aluminum foil only 0.02 mm thick. Air of thickness 7.0 cm absorbs them completely.
5. Because of large mass and large velocity, α -particle have **large ionising power**. Each α -particle produces about 20000 ion pairs before being absorbed.
6. At normal pressure in air, the range of α -particles varies from 3 to 8 cm.
7. α -particles produce fluorescence in certain substances, like barium-platinocyanide and zinc-sulphide.
8. α -particles affect photographic plate slightly.
9. α -particles are deflected by electric and magnetic fields, showing that **they carry positive charge**
10. α -particles are scattered while passing through thin metal foils.
11. α -particles cause burns on human body.
12. α -particles on being stopped, produce heating effect.

β -Rays

1. A β -particle carries $1.6 \times 10^{-19} \text{ C}$ of negative charge, i.e. unit negative charge, the charge on an electron.
2. The rest mass of β -particle is $9.1 \times 10^{-31} \text{ kg}$, which is the same as that of electron.
3. The velocity of β -particles ranges from 33% to 99% of the velocity of light. β -particles are **fast-moving electrons**.
4. Because of small mass, **the penetrating power of β -particles is large**. They can easily pass through a few millimeter of aluminium.
5. The β -particles **ionise the gas** through which they pass, but their ionising power is only 1/100th that of α -particle.

6. The range of β -particle in air is several metres.
7. The β -particles can also produce fluorescence in certain substances like barium platinocyanide and zinc sulphide.
8. They affect a photographic plate.
9. They are deflected by electric and magnetic fields, showing that **they carry negative charge**.

γ -Rays

1. γ -rays are not deflected by electric and magnetic fields, showing that **they do not carry any charge**.
2. The **rest mass of a γ -ray photon is zero**.
3. γ -rays travel with the **speed of light**.
4. γ -rays are **electromagnetic waves** like X-rays.
5. γ -rays have **very large penetrating power**. They can pass through several centimetre of iron and lead.
6. γ -rays have got **small ionising power**.
7. γ -rays can produce fluorescence in a substance like willimite (i.e zinc silicate mineral $(\text{Zn}_2\text{SiO}_4)$
8. γ -rays affect a photographic plate more than β -particles.
9. γ -rays can knock out electrons from the surface of a metal, on which they may fall.
10. γ -rays can cause nuclear reactions.

Half Life of Radioactive Element

Half life of a radioactive element is defined as the time during which half the number of atoms present initially in the sample of the element decay or it is the time during which number of atoms left undecayed in the sample is half the total number of atoms present initially in the sample. It is represented by T.

$$T = \frac{0.6931}{\lambda}$$

Half life of a radioactive substance is inversely proportional to the decay constant of the substance.

No. of half life's

$$N_0 \xrightarrow{t/2} N_0 / 2$$

$$N_t = \frac{N_0}{2^n}$$

$$\frac{T_1}{2} = \frac{0.693}{\lambda}$$

$$\text{When, } N_t = N/32$$

$$n = 5 \text{ half life}$$

Significance of Half Life

Half Life of a radioactive substance measures the time for which the substance lasts for one half of its total number of atoms.



Average Life or mean Life of Radioactive Element

Average life time of a radioactive element can be obtained by calculating the total life time of all the atoms of the element and dividing it by the total number of atoms present initially in the sample of the element.

$$\tau = \frac{\text{total life time of all the atoms}}{\text{total no. of atoms}}$$

$$\tau = \frac{1}{\lambda}$$

Average life of a radioactive element is reciprocal of the decay constant of the element.

Units of Radioactivity

(i) **Curie (Ci):** The activity of a radioactive sample is said to be one curie, when 3.7×10^{10} decays take place in every one second. Thus

$$1 \text{ Ci} = 3.7 \times 10^{10} \text{ decays/s}$$

This is the approximate activity of 1 gram of radium. In practice, smaller units are used such as

$$1 \text{ millicurie (1 m Ci)} = 3.7 \times 10^7 \text{ decays/s;}$$

$$1 \text{ microcurie (1 } \mu \text{ Ci)} = 3.7 \times 10^4 \text{ decays/s.}$$

(ii) **Becquerel (Bq):** It is the SI unit of activity.

$$\text{Thus } 1 \text{ Bq} = 1 \text{ decay/s}$$

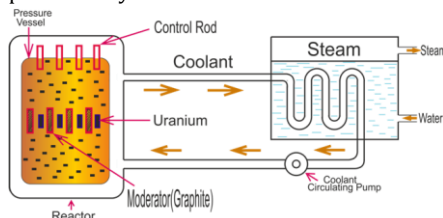
$$\therefore 1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$$

(iii) **Rutherford (Rd):** The activity of a radioactive sample is said to be one rutherford, when 10^6 decays take place in every one second. Thus,

$$1 \text{ Rd} = 10^6 \text{ decays/s.}$$

Nuclear Reactor

It is a device where nuclear energy is produced by nuclear chain reaction.

**1. Nuclear Fuel:**

It is a fissionable material to be used for the fission process to take place. Used fuels in a nuclear reactor are U^{233} , U^{235} , Pu^{239} .

Hydrogen is the nuclear fuel in the sun. It is converted into helium by the process of nuclear fusion.

(RRB JE 31.08.2019)

2. Moderator:

Its function is to slow down the fast moving secondary neutrons produced during the fission. The material of moderator should be light and it should not absorb neutrons. Usually, heavy graphite, heavy water, deuterium and paraffin

(RRB NTPC 31.07.2021, RRB SSE 21.12.2014)

3. Control Rods:

They have the ability to capture the slow neutrons. Ex: Rods of boron or cadmium (called control rods).

(RRB NTPC 11.04.2016 & 27.04.2016)

4. Coolant:

A substance which is used to remove the heat produced and transfer it from the core of the nuclear reactor to the surroundings is called coolant. Water and heavy water serve as coolants but at high temperatures, generally liquid sodium is used as a coolant.

5. Shielding:

The whole reactor is protected with concrete walls, 2 to 2.5 metre thick, so that radiations emitted during nuclear reactions may not produce harmful effects on the persons working on the reactor.

Uses:

- Used in medicine, industry and agriculture
- electric power generation.
- They can be used for the propulsion of ships, submarines and air crafts.
- They are used to produce neutron beam of high intensity which is used in treatment of cancer and nuclear research.

Here are some Nuclear power plants in India :

- Tarapur Atomic Power Station in Maharashtra
- Rajasthan Atomic Power Station near Kota
- Narora Atomic Power Station in U.P.
- Kalpakkam Atomic Power Station in Tamil Nadu. (KAMINI)

(RRB NTPC 10.01.2021)

- Mumbai atomic energy institute (homibhabha)

(RRB NTPC 04.04.2016)

- Kolkata nuclear physical institute (saha nuclear physical institute.)

(RRB NTPC 19.01.2017)

- Proposed nuclear power plant will be established at mandla district of Madhya Pradesh.

(RRB NTPC 08.03.2021)

Note:

As of September 2022, India has total 22 nuclear reactors are operational. National power corporation of India is operating these nuclear reactors. In the given, 18 reactors are of pressurized heavy water reactor type and remaining 4 are of simple hydro reactors.

(RRB NTPC 04.01.2021)

Nuclear Holocaust

Nuclear holocaust is the name given to large scale destruction and devastation that would be caused by the use of nuclear weapons.

India 1 And 2 Research Test:

India conducted its first nuclear test on **18 May 1947** at a place called **pokhran in Jaisalmer district** of Rajasthan. The test was named by smiling Buddha. A 12-ton capacity fission device was included in this nuclear test.

(RRB GROUP-D 26.09.2018 & RRB NTPC 06.04.2016)

India conducted its Second nuclear test in 1998, at pokhran this operation named as Shakti.

(RRB NTPC 18.01.2021, 03.04.2016),

(RRB NTPC 18.04.2016)

Some Nuclear Reactor in India are:-

The nuclear reactors used for Research purposes in India are **Apsara, Zarlina, CIR** (Canada India Reactor), **Dhruva** and **Purnima**.

Apsara is the Asia first/oldest nuclear reactor.

(RRB NTPC 31.07.2021 & 11.03.2021)

KAMINI was the first and currently the only reactor in the world designed specifically to use Uranium-233 fuel.

(RRB NTPC 02.03.2021)

Important Note:-

The first nuclear reactor was formally inaugurated on 20 January, 1957 by former prime minister Jawaharlal Nehru which was named "apsara". (RRB NTPC 05.01.2021)

BARC was also inaugurated on the same day. BARC has three operating research reactors-apsara, cirus and dhruva.

The approach called 'magnetic confinement of plasma' is the scientific principle of **Fusion reactor** technique.

(SSC Steno 17.11.2022 Shift-1)



16**Modern Physics**

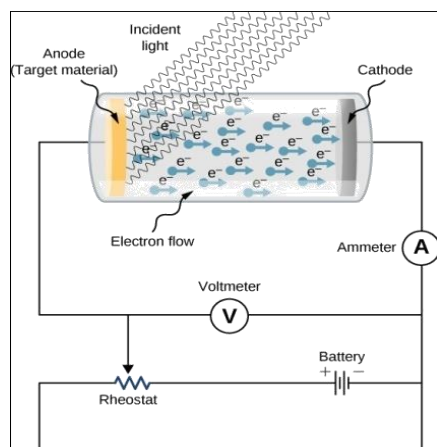
Modern physics deals with the underlying structure of the smallest particles in nature (quantum mechanics), as well as a rigorous understanding of the fundamental interaction of particles. Small velocities and large distance is usually the realm of classical physics

Modern Physics		
Particle	Mass	Charge
e^-/e^+ positron	$9.1 \times 10^{-31} \text{ kg}$	$1.6 \times 10^{-19} \text{ C}$
Proton/neutron	$m_p = 1.6 \times 10^{-27} \text{ kg}$	+1
Deuteron	$2 m_p$	e
α -particle	$4 m_p$	$2e$
Photon	$m_0 = 0$ (rest mass)	0
Nutron	$m_n = 1.67 \times 10^{-27} \text{ kg}$	0

The light composed of small particles, called photon.

(SSC Steno 12.09.2017)

Types of Emissions			
Thermionic Emission	Photoelectric Emission	Field Emission or Cold Cathode Emission	Secondary Emission
It is the phenomenon of emission of electrons from the metal surface when heated suitably.	It is the phenomenon of emission of electrons from the surface of metal when radiations of suitable frequency fall on it.	It is the phenomenon of emission of electrons from the surface of a metal under the application of a strong electric field.	It is the phenomenon of emission of electrons from the surface of metal in large number when fast moving electrons (called primary electrons) strike the metal surface.

Photoelectric Effect

The phenomenon of emission of electrons from a metal surface, when light of appropriate frequency is incident on it, is called photoelectric effect. The electrons emitted during photoelectric effect, are called **photoelectrons**. In photoelectric effect, it should be noted that one photon interacts with one electron and not more than one electron.

(SSC CGL 11.08.2017)

Emission of electron caused by heat is known as thermionic emission. Electrons emitted in a thermionic emission are called **thermions**. The photoelectric effect is based on the principle of conservation of energy.

Terms Related to Photoelectric Effect

Work Function (ϕ): The minimum energy required to eject an electron from a metal surface, is called its work function.

It is given by, $\phi = h\nu_0$

Where,

h = Planck's constant and ν_0 = threshold frequency.

Note: The minimum frequency of incident light that can eject photoelectron from a metal surface, is called its threshold frequency. It is denoted by ν_0 .

Threshold Wavelength (λ_0): The maximum wavelength of incident light that can eject photoelectron from a metal surface, is called

its threshold wavelength (λ_0) = $\frac{hc}{\phi}$ where, h

= Planck's constant, c = speed of light/EM radiation

Stopping Potential (V_0): The negative potential given to the anode of a photoelectric cell for which photoelectric current becomes zero, is called the stopping potential or cut-off potential. It is denoted by V_0 .

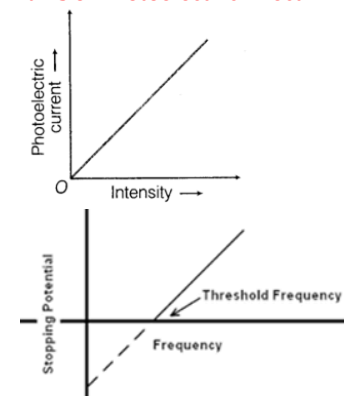
Maximum kinetic energy of photoelectrons is given by

$$E_k = eV$$

where, e is the charge of an electron.

Note:

The stopping potential V_0 is independent of the intensity of light.

Laws of Photoelectric Effect

- The rate of emission of photoelectrons from a metal surface is directly proportional to the intensity of incident light.
- The maximum kinetic energy of photoelectrons does not depend on the intensity of the incident light.
- Maximum kinetic energy of emitted photoelectrons increases with increase in frequency of incident light.
- If the frequency of incident light is below than a certain minimum value called threshold frequency, then no



emission of photoelectrons take place from the metal surface.

- There is negligible time lag between the incidence of light and emission of photoelectrons from the metal surface.

Einstein's Photoelectric Equation

Einstein explained photoelectric effect on the basis of Max Planck's quantum theory. According to which light is emitted from a source in the form of packets or bundles of energy, called quanta or **photon**.

Energy supplied = Work function + kinetic energy of photo electrons emitted

$$E_{\text{supplied}} = \phi_0 + K.E.$$

$$h\nu = h\nu_0 + \frac{1}{2}mv^2.$$

This is called Einstein's photoelectric equation.

where, h = Planck's constant = 6.6×10^{-34} Js (Joule second)

and ν = frequency of incident light (in Hertz)
The energy of each photon is given by

$$E = h\nu$$

Kinetic energy of emitted photoelectron is given by

$$E_K = h\nu - \phi \Rightarrow \frac{1}{2}mv^2 = h(\nu - \nu_0) [\because \phi = h\nu_0]$$

This is known as Einstein's photoelectric effect.

Cathode Rays

Properties of cathode rays are as follows

- They travel in straight lines.
- They can be deflected by electric and magnetic fields.
- They heat up the material on which they fall.
- They can produce physical and chemical change.
- They have small ionising power and ionise the gas through which they pass.

Anode Rays

These are discovered by Goldstein. Properties of positive rays are as follows

- These consist of fast moving positively charged particles.
- These rays are deflected in magnetic field.
- These rays travel in a straight line.
- These rays can affect the photographic plates.
- These rays can produce fluorescence and phosphorescence.

X-Rays

When cathode rays strike on a heavy metal of high melting point, then a very small

fraction of its energy converts into a new type of waves, called X-rays. X-rays were discovered by **Roentgen**.

(RRB NTPC 11.04.2016)

Properties of X-Rays

- X-rays are electromagnetic waves of wavelengths ranging from $0.1 \text{ \AA}$ to $100 \text{ \AA}$ and frequencies ranging from 10^{16} Hz to 10^{18} Hz .
- Soft X-rays have greater wavelength and lower frequency.
- Hard X-rays have lower wavelength and higher frequency.
- X-rays are produced by Coolidge tube.
- Molybdenum and tungsten act as suitable targets. These elements have large atomic number and high melting point, which is required for the purpose.
- The intensity of X-rays depends on the heating voltage or filament current.
- The kinetic energy of X-ray photons depends upon the voltage applied across the ends of Coolidge tube.
- If the voltage between the filament and the target is increased, harder X-rays will be received.
- Scientists have created world's shortest X-ray laser pulse with a duration of just 43 seconds

(SSC CHSL 25.03.2018)

Application of X-Rays

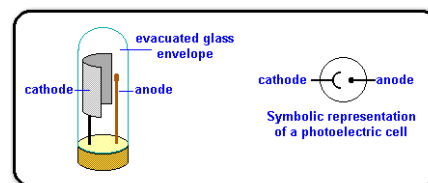
- X-ray is used to detect and study the bone fractures due to any accident.
- Dentists also use X-ray for study of tooth decay.
- X-ray is used in industry and material science research.

Photoelectric Cell

It is a device which converts light energy into electrical energy. It is also called an electric eye.

When light of suitable frequency is allowed to fall on the cathode, photoelectrons are emitted. These are attracted by anode which is kept at positive potential with respect to cathode. So a current starts flowing in the circuit. Due to it, micro-ammeter shows a deflection. The photoelectric current is very small, so it is to be amplified first before it is used for some useful purpose. When the light is cut off, no photoelectrons are ejected from the cathode and hence there is no current in the external circuit.

Application of photoelectric Cells

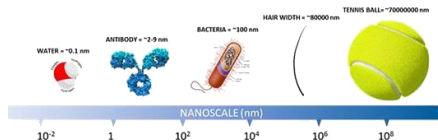


1. Photoelectric cells are used in television camera for telecasting scenes and in phototelegraphy.
2. Photocells are used for the reproduction of sound recorded on films along with pictures in the movie theatre.
3. Photocells are used in counting devices, e.g., to count the persons entering the hall provided they come one by one.
4. Photocells are also used in burglar alarm and fire alarms.
5. Photocells are also used to measure the temperature of stars and to study the spectrum of the heavenly bodies.
6. They are used to switch on and off the street lighting system at dusk and dawn, without any manual attention.
7. They are used in photometry to compare the illuminating powers of two sources.
8. They are used in industries for locating minor flaws or holes in metallic sheets.
9. They are used for the determination of Planck's constant.

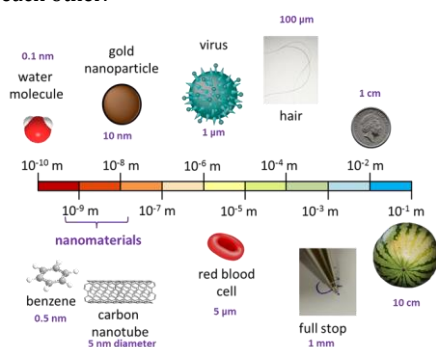


Nanotechnology

It is an applied science, which deals with the study of the objects at the range of one nanometre. It was an idea of **Sir Richard Feynman**, who gave the nanoscience in the form, which we see today.



The wide range applicability of **nanotechnology** can be quoted by giving the examples like quantum computing, nanorobotics, optics, nanocomputing, etc. The world is fastly reducing its size and the habitants are coming closer and closer to each other.



Applications of Nanotechnology

Nanotechnology and Medicine:

Scanning Ion Conductance Microscope

Researchers at the National Heart and Lung Institute at Imperial College, London are using a Scanning Ion Conductance Microscope (SICM), a new device, which helps in producing better images of live heart muscle cells than previously possible. They use a nanopipette insert in drugs, that activate beta molecules in certain portions of cells. This method helps the researchers to understand the differences between damaged and healthy heart muscle cells, which could lead to improvement both in the use of current drugs called **beta-blockers** and in the design of future treatments.

Bucky Balls



It may be used to trap free radicals generated during an allergic reaction and block the inflammation, that results from allergic reaction. The antioxidant properties of bucky balls may be able to fight the deterioration of motor function due to multiple sclerosis.

Bio capsule

NASA is developing such an implant, called a Biocapsule, to protect astronauts from the effects of radiation. The implants may also be useful for releasing insulin in diabetic patients and for delivering chemo-therapy drugs directly to tumours.

Targeted Heat Therapy

It is being developed to destroy Breast Cancer Tumours. In this method, antibodies, that are strongly attracted to proteins produced in one type of breast cancer cell are attached to nanotubes causing the nanotubes to accumulate at the tumour.

Nanotechnology and Food

Silver Nanoparticles: Storage bins are being produced with silver nanoparticles embedded in the plastic. The silver nanoparticles kill bacteria from any material that was previously stored in the bins, minimizing health risks from harmful bacteria.

Clay Nanocomposites: These are being used to provide an impermeable barrier to gases such as oxygen or carbon dioxide in light weight bottles, cartons and packaging films.

Nanotechnology and Environment

Volatile Organic Compounds (VOCs) On environmental basis, the monitoring is more important step to have the control over further degradation of environment.

The application of nanoscience is utilized for clearing Volatile Organic Compounds (VOCs) from air. Researchers have demonstrated a catalyst that breaks down Volatile Organic Compounds (VOCs) at room temperature.

Nanotechnology and Space Telecommunication Space Elevator

It is essentially a long cable extending from our planet's surface into space with its centre of mass at Geostationary Earth Orbit (GEO), 35786 km in altitude, Using carbon nanotubes to make the cable needed for the space elevator, a system which could

significantly reduce the cost of sending material into orbit.

Aerogel

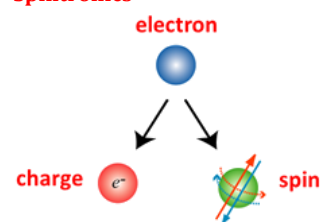
A nano porous material called Aerogel, that is an excellent insulator, e.g. insulating the walls of the house would only need about one third the thicknesses, if this material is used instead of conventional insulation.

This material is used extensively in building and constructional sector.

Micro Electromechanical Systems (MEMS)

MEMS techniques allow both electronic circuits and mechanical devices to be manufactured on a silicon chip, similar to the process used for integrated circuits. Four devices using MEMS technology have been commercially successful for several years.

Spintronics



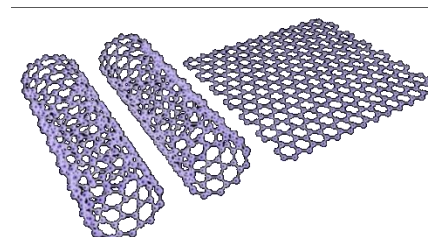
Spintronics or spin electronics refers to the study of the role played by electron (and more generally nuclear) spin in solid state physics and possible devices that specifically exploit spin properties instead of or in addition to charge degree of freedom.

e.g. spin relaxation and spin transport in metals and semiconductors are of fundamental research interest not only for being basic solid state physics issues.

Nanoparticles and Nanopowder

Nanoparticles are particles that have one dimension that is 100 nm or less in size. The properties of many conventional materials change when formed from nanoparticles.

Nanotechnology and Electronics Carbon Nanotubes and Nanofibers



Carbon nanotubes are molecular scale tubes of graphitic carbon with outstanding properties. They are among the stiffest and strongest fibers known and have remarkable electronic properties and many other unique characteristics.

Nanofibers are defined as the fibers with diameters less than 100 nanometres. In the textile industry, this definition is often extended to include fibres as large as 1000 nm diameter. They can be produced by interfacial polymerization, electrospinning and electrostatic spinning.

Nanocomputing

The technique of computing by using the various nanocomponents is known as nanocomputing. The processors used here are nanosized and can be used in every walks of life including feeding of pets up to big operations.

Quantum Algorithm

It is a design used in quantum computing so as to reduce the complexity of computational problems and to speed up the computation.

Molecular Manufacturing

The technology can be utilized by building an object atom by atom or molecule by molecule, molecular manufacturing, also called molecular nanotechnology, can produce new materials with improved performance over existing materials. e.g. an airplane strut must be very strong, but also light weight.

Qubit

It is the **quantum analogue of the bit** and is the classical fundamental unit of information.

Sonodrugs

Sonodrugs (Image-controlled Ultrasound-Induced Drug Delivery) was an integrated project, partly funded by NMP program of the European commission. It addressed clinical needs by developing novel drug delivery technologies for localized treatment of cardiovascular diseases and cancer.

Nanotechnology in India

Nanotechnology in India only emerged after 2005, when it started to work in three phases

1. Knowledge generation
2. Knowledge transfer
3. Knowledge application

There are 19 public sector research institutes like TERI. There are 11 functional units of Nanoscience, 7 Centres of Nanotechnology and a Centre for Computational Material Science in India.

The knowledge is applied by the various ministries like Ministry of Agriculture, Ministry of Environment and Forest, Ministry of Health and Family Welfare, Ministry of Defence and DRDO, Ministry of New and Renewable Energy, Ministry of Commerce and Industry and Ministry of Textiles.

NanoIndia

It is a scientific event of INDIA nano program. It aims to bridge the gap between invention and commercial reality by providing pragmatic support for technology entrepreneurs in the areas of operations, Intellectual Property Management, Intellectual Property Commercialization, Business Development, Technology Licensing and Technology Transfer, so as to create ventures, that could compete in global markets.

Nano Mission

Building upon the promotional activities carried out as part of the Nanoscience and Technology Initiative (NSTI) in the highly promising and competitive area of Nanoscience and Technology, the Government of India launched a Mission on Nanoscience and Technology (Nano Mission) in May 2007.

Aim of Nano Mission

Professor CNR Rao is called **Father of Nanotechnology** in India. Nanotechnology is directed by two advisory groups.

1. Nanoscience Advisory Group (NSAG)
2. Nano Application and Technical Advisory Group (NATAG)

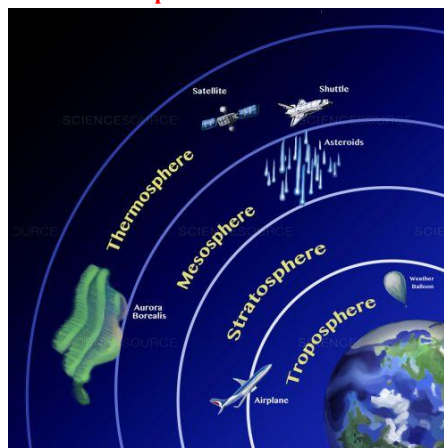
Basic aims of Nano Mission are given as below

- Research and Development.
- Development of basic structure of Nanoscience and Technology.
- Establishment of Nanotechnology development centre.
- Human development in Nanoscience and technology.
- International help in Nanotechnology.

Centre of Nanotechnology

- Amrita Institute of Medical Science, Kochi.
- SN Bose National Centre for Basic Science, Kolkata.
- Tata Institute of Fundamental Research, Mumbai.
- IIT (Nano Electronics, Polymer Nanocentre, Nanobio- technology), Roorkee.
- Indian Institute of Science, Bengaluru.
- IIT, Kanpur (Printable Electronics, Nanopatterning).
- Indian Association for the cultivation of Science, Kolkata.



17**Communication System****Earth's Atmosphere**

The gaseous envelope surrounding the earth is called earth's atmosphere. It contains the following layers

1. **Troposphere:** This region extends up to a height of 12 km from the earth's surface. The electrical conductivity of this region is least as compared to other regions of earth's atmosphere.
2. **Stratosphere:** This region extends from 12 to 50 km. In this region, most of the atmospheric ozone is concentrated from 30 to 50 km. This layer is called **ozone layer** which absorbs a large portion of ultraviolet radiations.
3. **Mesosphere:** This region extends from 50 to 80 km.

4. **Ionosphere:** This region extends from 80 to 400 km. In ionosphere, the electron density is very large in a region beyond 110 km from earth's surface, which extends vertically for a few kilometre. This layer is called **Kennelly Heavyside** layer. In ionosphere, a layer having large electron density is found at height 250 km from the earth's surface, called **Appleton layer**. The atmospheric layer reflecting radio wave is called ionosphere.

(SSC CGL 13.11.2005, 27.07.2008, 21.04.2013 & SSC MATRIC LEVEL 30.03.2008)

Communication

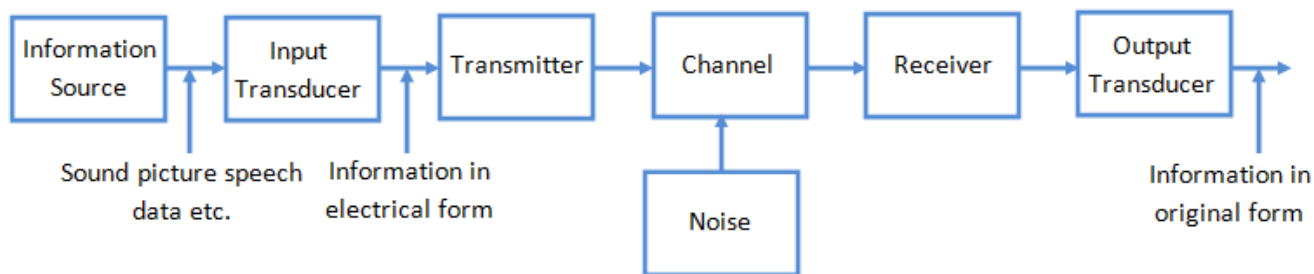
Every living creature in the world experiences the need to impart or receive information, almost continuously, with others in the surrounding world. For communication, it is essential that both the communicating bodies have known a common language.

Point to Point/Wired

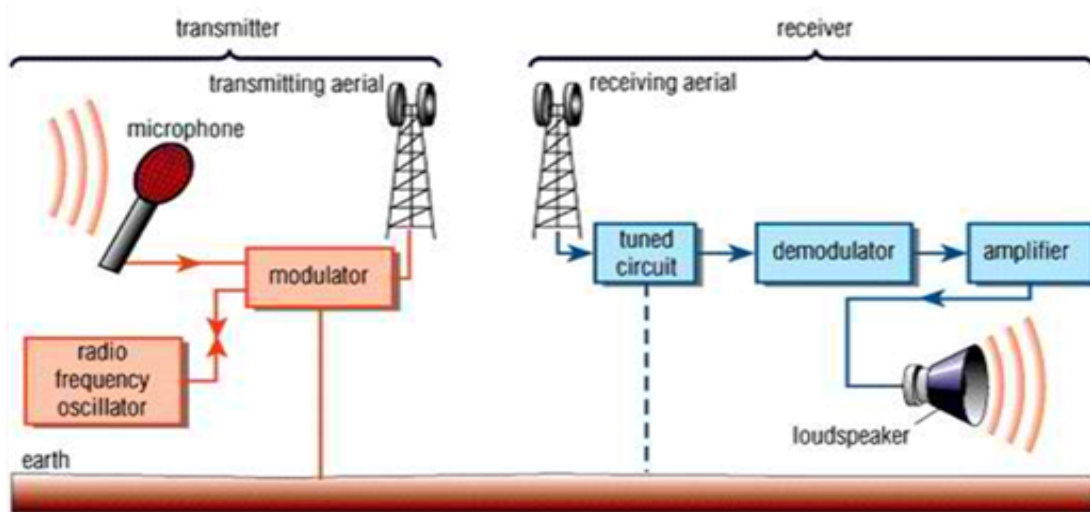
Message is transmitted over a link between a single transmitter and a receiver. For example, **telephony** represents point to point communication.

**Broadcast/Wireless**

There are a large number of receivers corresponding to a single transmitter. Radio and T.V. are common examples of this mode.

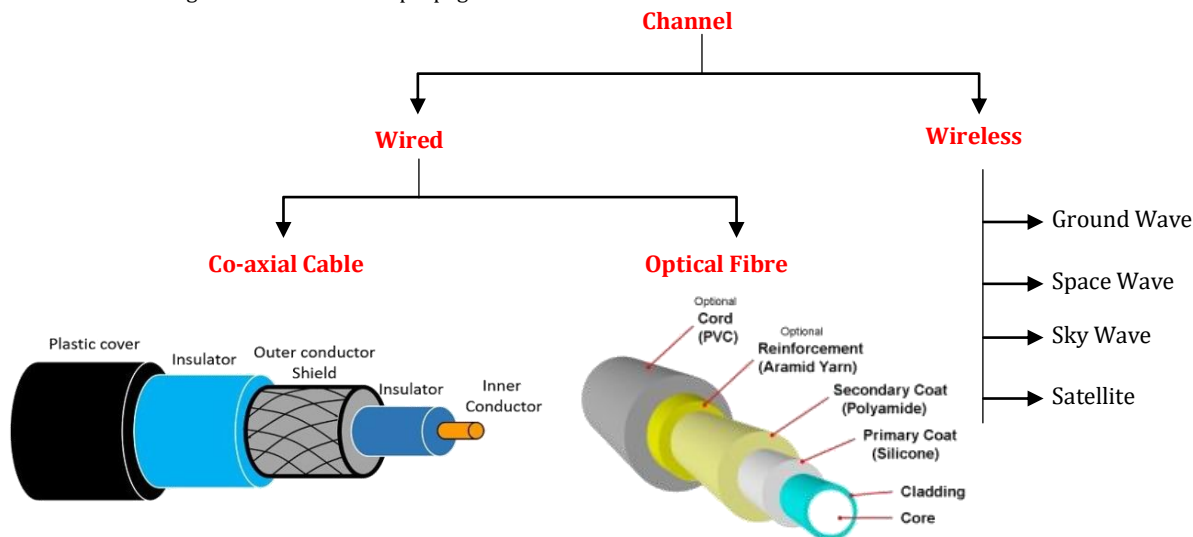
**Block diagram of communication system****Transmitter**

It processes and encode the information and make it suitable for transmission. The message signal for communication can be analog signals or digital signals. An analog signal can be converted suitably into a digital signal and vice-versa. An analog signal, is one in which current or voltage value varies continuously with time. A digital signal is a discontinuous function of time which is usually in the form of pulses.



Communication channel

The medium through which information propagates from transmitter to receiver is called communication channel.



Coaxial cable is a type of copper cable specially built with a metal shield and other components engineered to block signal interference.

Coaxial cables have concentric layers of electrical conductors and insulating material. This construction ensures that signals are enclosed within the cable and prevents electrical noise from interfering with the signal.

It is primarily used by cable TV companies to connect their satellite antenna facilities to customer homes and businesses. It is also sometimes used by telephone companies to connect central offices to telephone poles near customers.

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. The light forms an electromagnetic carrier wave that

is modulated to carry information. Fiber is preferred over electrical cabling when high bandwidth, long distance, or immunity to electromagnetic interference are required.

Optical Fibre

- Invented by – Narinder Singh Kapany
- It is made from Silica (SiO_2), quartz, polyester/poly carbonate, PMMA (Polymethyl methacrylate) also known as acrylic, acrylic glass, or plexiglass)
- It works on the principle of Total internal reflection (TIR).

(Delhi Plice Constable 02.12.2020)

The two main conditions for TIR are:

- (i) The light should enter from rarer medium to denser medium.
- (ii) The angle of incidence is greater than the critical angle.

So the whole of light is reflected back into the same medium with minimum energy loss.

A typical optical fiber comprises three main components:

1. Core:

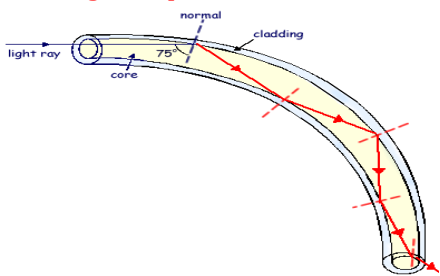
It carries the light. It is usually made of glass, although some are made of plastic. The glass used in the core is extremely pure silicon dioxide (SiO_2). In the manufacturing process, dopants such as phosphorous pentoxide, or alumina are used to raise the refractive index under controlled conditions. Optical fiber cores are manufactured in different diameters for different applications. Typical glass cores range from as small as 3.7 μm up to 200 μm . Core sizes commonly used in telecommunications are 9 μm , 50 μm and 62.5 μm . Plastic optical fiber cores can be much larger than glass. A popular plastic core size is 980 μm .

2. Cladding:

It surrounds the core with a lower refractive index and contains the light. When glass cladding is used, the cladding and the core are manufactured together from the same silicon dioxide-based material in a permanently fused state. The manufacturing process adds different amounts of dopants to the core and the cladding to maintain **a difference in refractive indexes between them of about 1%**. Like the core, the cladding is manufactured in standard diameters. The two most commonly used diameters are 125µm and 140µm. The 125µm cladding typically supports core sizes of 9µm, 50µm, 62.5µm and 85µm. The 140µm cladding typically has a 100µm core.

3. Coating:

It protects the fragile fiber within. The coating absorbs the shocks, nicks, scrapes, and even moisture that could damage the cladding. Without the coating, the optical fiber is very fragile. Most common types of coating is acrylate (**Acrylates** (IUPAC name: prop-2-enoates) are the salts, esters, and conjugate bases of acrylic acid and its derivatives. The **acrylate** ion is the anion $\text{CH}_2=\text{CHCOO}^-$. Often **acrylate** refers to esters of acrylic acid). A typical acrylate may perform at temperatures up to 125°C. Silicone, carbon, and polyimide are coatings that may be found on optical fibers that are used in harsh environments such as those associated with avionics, aerospace, and space. They may also be used on optical fibers designed for mining, or oil and gas drilling.

Advantages of Optical Fiber**Greater Bandwidth & Faster Speed:**

Optical fiber cable supports extremely high bandwidth and speed. The amount of information that can be transmitted per unit of optical fiber cable is its most significant advantage.

Cheap: Several miles of optical fiber cable can be made cheaper than equivalent lengths of copper wire.

Thinner and Light-weighted: Optical fiber is thinner, and can be drawn to smaller diameters than copper wire. They are of

smaller size and light weight than a comparable copper wire cable, offering a better fit for places where space is a concern.

Higher carrying capacity: Because optical fibers are much thinner than copper wires, more fibers can be bundled into a given-diameter cable. This allows more phone lines to go over the same cable or more channels to come through the cable into your cable TV box.

Less signal degradation: The loss of signal in optical fiber is less than that in copper wire.

Light signals: Unlike electrical signals transmitted in copper wires, light signals from one fiber do not interfere with those of other fibers in the same fiber cable. This means clearer phone conversations or TV reception.

Long Lifespan: Optical fibers usually have a longer life cycle for over 100 years.

Disadvantages of Optical Fiber

Limited Application: Fiber optic cable can only be used on ground, and it cannot leave the ground or work with the mobile communication.

Low Power: Light emitting sources are limited to low power. Although high power emitters are available to improve power supply, it would add extra cost.

Fragility: Optical fiber is rather fragile and more vulnerable to damage compared to copper wires. You'd better not to twist or bend fiber optic cables.

Distance: The distance between the transmitter and receiver should kept short or repeaters are needed to boost the signal.

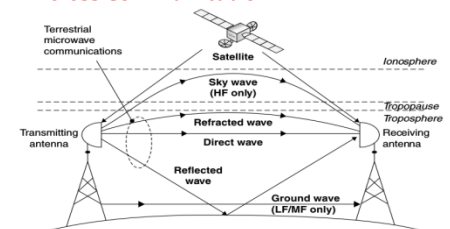
Optical splitter

Planar lightwave circuit (PLC) **splitter** is a type of **optical** power management device that is fabricated using silica.

Optical waveguide technology to distribute **optical** signals from Central Office (CO) to multiple premise locations.

Optical filter

It transmit or absorbs light of different colors. (SSC CGL 30.08.2016)

Wireless Communication**Receiver**

It receives and decodes the signal (output).

Transducer: Any device that converts any signal into electrical signal is called a transducer, e.g. a microphone converts speech signals into electrical signals.

Noise: The disturbance or distortion in the transmission and processing of message signals in a communication is referred as noise.

Bandwidth: It refers usually to the range of frequencies over which the communication system works.

Attenuation: The loss of strength of a signal during its propagation through the communication channel is referred as attenuation.

Amplification: The process of increasing the strength of the transmitted signal using some suitable electronic circuit is called amplification.

Range: It is the largest distance between the transmitter and receiver, where the signal is received with high strength.

Demodulation: It is the reverse process of modulation. Demodulation is the phenomenon of retrieval of information from the modulated wave at the receiver.

Repeater: It is a combination of receiver, amplifier and transmitter. Its function is to extend the range of communication.

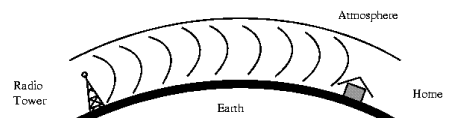
Propagation of Electromagnetic Waves

In radio wave communication between two places, the electromagnetic waves are radiated out by the transmitter antenna at one place, which travel through the space and reach the receiving antenna at the other place.

Types of Propagation of Electromagnetic Waves**Ground Wave Propagation**

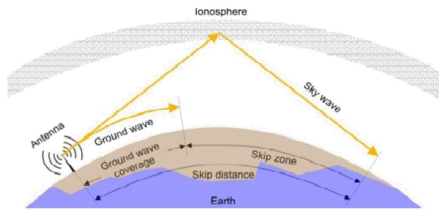
In ground wave propagation, the radio waves travel along the surface of earth. These waves are called ground waves or surface waves. In fact, these waves are not confined to surface of the earth but are guided along the earth's surface and they follow the curvature of the earth.

The ground wave propagation is used for low frequency (LF) band and medium frequency band (i.e. 2 MHz) but not for high frequency (HF) band. **It is used for local broadcasting.**



Sky Wave Propagation

Sky waves are the AM radio waves, which are received after being reflected from ionosphere. The propagation of radio wave signals from one point to another via reflection from ionosphere is known as sky wave propagation. It is suitable for radio waves of frequency between 2 MHz to 30 MHz. **It is used for a long distance (i.e. 65 to 400 km) radio communication.**

**Space Wave Propagation**

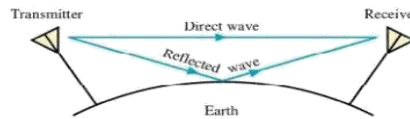
It is the mode of wave propagation in which the radio waves emitted from the transmitter antenna, reaches the receiving antenna through space. These radio waves are called space waves.

The space waves are the radio waves of frequency range from 54 MHz to 4.2 GHz. Space waves travel in straight lines. These are used in television communication and radar communication. It is also called **Line of Sight (LOS)** communication.

Note: Distance up to which a signal can be obtained from an antenna is given by

$$d = \sqrt{2hR}, R \gg h$$

Where, h is height of antenna and R is radius of the earth.

**Satellite Communication**

It is carried out between a transmitter and a receiver through a satellite. A geo-stationary satellite is utilized for this purpose, whose time period is 24 h.

A communication satellite is a spacecraft, provided with microwave receiver and transmitter. It is placed in an orbit around the earth. In India, remote sensing satellites are IRS-IA, IRS-IB and IRS-IC. The Line of Sight (LOS) microwaves communication, through satellite is possible, if the communication satellite is always at a fixed location with respect to the earth, e.g. the satellite which is acting as a repeater must be at rest with respect to the earth.

It is known as **geo-stationary satellite**.

**Merits of Satellite Communication**

- The satellite communication covers wide area for broadcasting as compared to other communication systems, i.e. it has wide coverage range.
- The satellite communication is also used effectively in mobile communication.
- The satellite communication is found to be much economical and accurate as compared to other communication systems on the earth for search and navigation purpose. In fact, the cost involved in satellite communication is independent of the distance.
- The satellite communication is most cost effective in remote and hilly areas, such as Ladakh, Himachal Pradesh, etc.
- The satellite communication permits transmission of data at high rate.
- radio waves are used for communication satellite.

(SSC CAPFS ASI & Delhi Police SI 02.07.2017)

Modulation

It is the most important step in communication. Modulation is the phenomenon of superimposing the low frequency message signal (called the modulating signal) on a high frequency wave (called the carrier wave). The resulting wave is called the modulated wave, which is transmitted.

Amplitude Modulation**Amplitude Modulation**

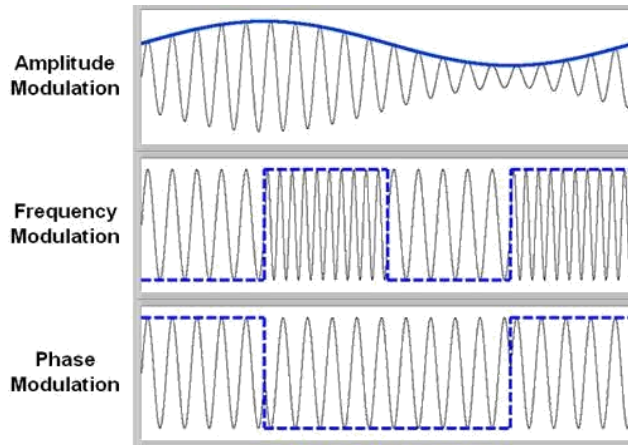
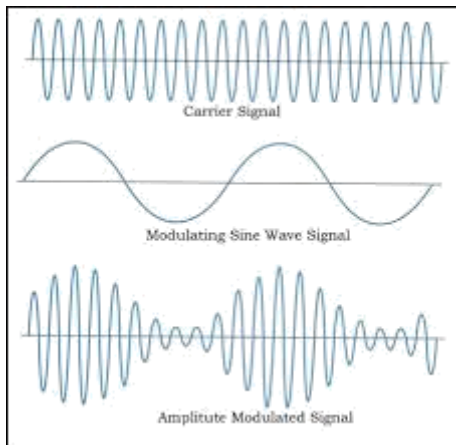
(AM) It is the process under which carrier wave is modulated so that its amplitude varies with the signal being transmitted.

Phase Modulation

(PM) In this, the phase of the carrier signal is modulated as per original signal so phase of a modulated wave contains the hidden information or message.

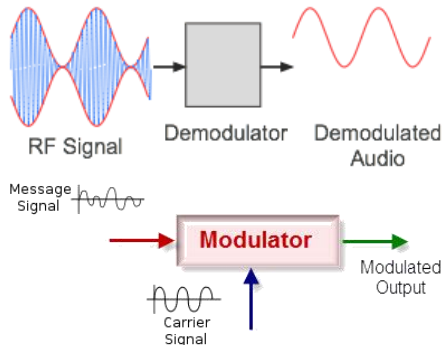
Angle Modulation**Frequency Modulation**

(FM) It is the process under which carrier wave is modulated so that its frequency is modified according to frequency of information signal. It is used to transmit musical programme.



Demodulation

It is a reverse process of modulation
It is used for the retrieval of information from the modulated wave.



Encoding: Process of coding the information in particular coded form so that it may be sent over communication channel. It is performed at transmitting side by a Encoder.

Decoding: Process of extracting the original data from the coded received data so that original hidden information may be obtained. It is performed at receiving side by a Decoder.

Modem (Modulator Demodulator)

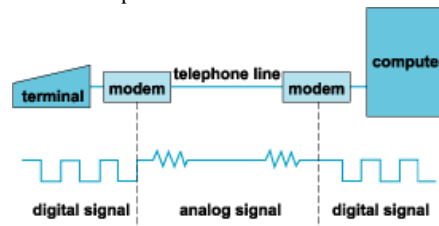
A modem is also called dataset. It acts as a modulator in transmitting mode and as a demodulator in the receiving mode. It allows a computer to communicate with other computers over a communication link.

The efficiency of a modem is determined by a bit rate (bps) at which the data is transmitted. The fastest modems run at 57600 bps.

Modems can be inbuilt in computers in ISA (Industry Standard Architecture) or PCI (Peripheral Component Interconnect) slot or attached externally to RS-232 port.

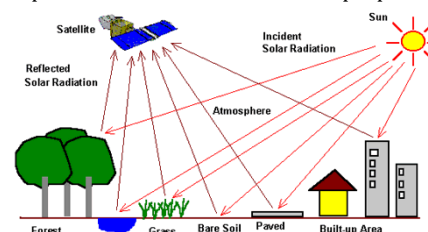
The standard fax/phone modem, cable modem, DSL (Digital Subscriber Line)

modem or satellite modem Interconnect are some examples of modems

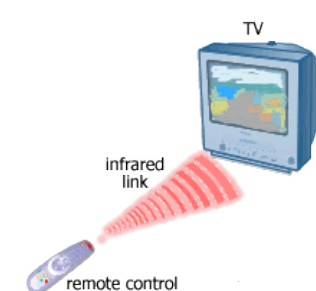


Remote Sensing

It is a technique of observing or measuring the characteristics of the object at a distance. A polar satellite is utilized for this purpose.



Tv Remote Control



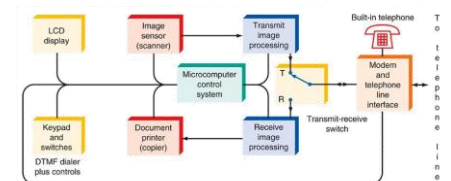
It is an electronic device containing an IC (Integrated Circuit) and few other components. If a key on a remote control is pressed, it emits infrared signals. These signals are received by the electronic circuit of the TV and desired operation is performed.

Fax

The Fax or facsimile telegraphy is the electronic transmission and reproduction of a document at a distance place.

It is the most popular example of a digital communication system. Fax transmission usually involves transmission of document or photograph. The different regions of the document to be transmitted are first scanned by a light source.

The scanner gives optical signals carrying the information regarding the writings, patterns, signatures etc. in different parts of the document. These optical signals are converted into electrical signals by a photodetector. The electrical signals are coded and transmitted by some suitable communication method.



Set-Top Box (STB)



It is an information appliance that contains a tuner and connects to television set or the music system and the external source of signal. It demodulates broadcasted signal into audio-visual content that can be displayed on a monitor.



STB enhances the source signal quality and are used in cable television and satellite televisions. It may be mpeg4 (Motion picture experts group layer 4) or HD (High Definition). A HD set top box gives a powerful sound and much sharper picture than mpeg4.

Note: Under the Cable Television Networks (regulation) Amendment Bill 2011, complete digitization of cable TV in India has been made mandatory by the end of 2014.

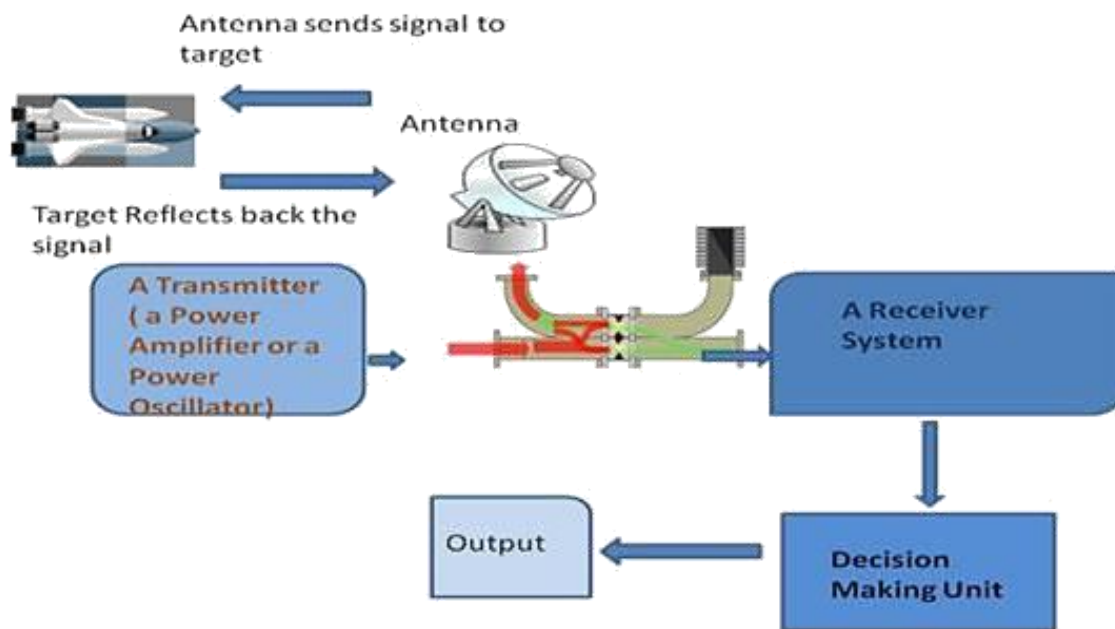
Radar

It is an abbreviation of Radio Detection and Ranging. It is used to locate, guide or identify the objects such as aeroplanes, ships, missiles, etc.

A continuous or pulse radio waves are sent towards the object and receive back after its reflection from the objects.

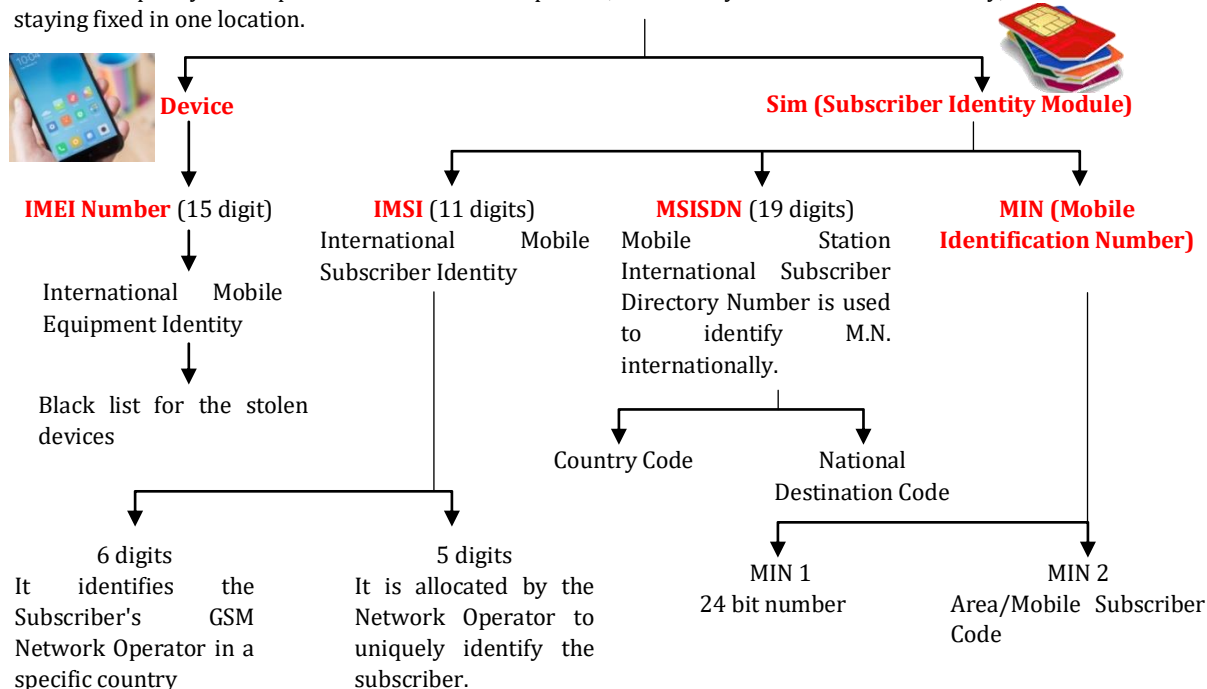
Uses of Radar

- To detect and measure the position and distance of the cloud.
- To explore the evidence of any metal or oil reserve.
- To detect the outer layer of the atmosphere.



Mobile Technology

Mobile Telephony is the provision of services to phones, which may be moved around freely, rather than staying fixed in one location.



Mobile phone is a full duplex device and walky talky is half duplex device.

Full and Half Duplex

Full duplex device refers to the simultaneous transmission and reception of data in two directions at a time while half duplex device refers to the transmission of data in one direction at a time.

Mobile phones or cellphones are a rage amongst the younger generation. They operate typically in the Ultra High Frequency (UHF) range of 800-950 MHz.

Some common Terms

TRAI – Telecom Regulatory Authority of India, Regulator of the telecommunication sector in India.

GSM – Global System for Mobile Communication

LTE – Long Term Evolution

VOLTE – voice over LTE

CDMA – Code Division Multiple Access

Frequency bands in Satellite Communication

L – band – (1 – 2GHz)

S – band – (2 – 4GHz)

C – band – (4 – 8GHz)

X – band – (8 – 12GHz)

Ku – band – (12 – 18GHz)

Ka – band – (26 – 40GHz)

Frequency Band for

- ◆ 4G → 2 to 8 GHz
- ◆ 5G → LTE frequency range (600 MHz to 6 GHz)
- ◆ 3G → 1.8 to 2.5 GHz
- ◆ VHF (Very High Frequency) low – TV – (2 – 6 Channel) → 54 – 88 MHz
- ◆ VHF High – TV – (7 – 19 Channel) → 174 – 216 MHz
- ◆ UHF (Ultra High Frequency) -TV - (14 – 69 Channel) → 470 – 806 MHz
- ◆ FM Radio → 87.5 – 108 MHz

Hazards Due to Mobile Towers

As per the inter-ministerial committee report, exposure to a mobile tower located within 50 m of home or workplace, is like being in a microwave oven for 24 hours. Electromagnetic radiations in the microwave region from these towers and handsets is carcinogenic to humans and may cause glioma, a type of brain cancer. Other health problems related to these radiations are fatigue, sleep disturbance, dizziness, increased reaction time, increased heart beat, headache.

Li-Fi

Li-Fi (short for *light fidelity*) is wireless communication technology, which utilizes

light to transmit data and position between devices. The term was first introduced by Harald Haas during a 2011 TEDGlobal talk in Edinburgh. Li-Fi is a light communication system that is capable of transmitting data at high speeds over the visible light, ultraviolet, and infrared spectrums. In its present state, only LED lamps can be used for the transmission of visible light.



In terms of its end use, the technology is similar to Wi-Fi - the key technical difference being that Wi-Fi uses radio frequency to transmit data.

Using light to transmit data allows Li-Fi to offer several advantages such as,

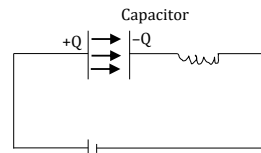
- a wider bandwidth channel,
- The ability to safely function in areas otherwise susceptible to electromagnetic interference (e.g. aircraft cabins, hospitals, military)
- offering higher transmission speeds.

18**EM Waves and Maxwell**

A wave which contains electric field(E.F) and magnetic field(M.F)perpendicular to each other and perpendicular to direction of propagation of wave is called an electromagnetic wave. The EF & MF are varying continuously with time.

These rays is not show interference and diffraction.

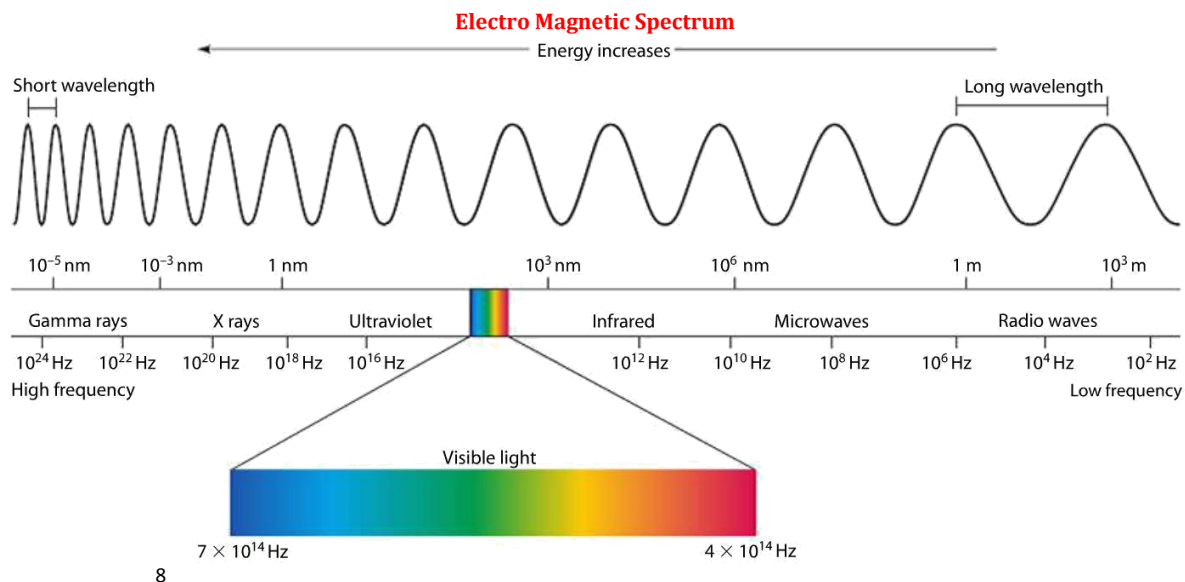
(SSC CGL 09.08.2017)

Displacement Current

When charge varies, it creates Electric Field, So, it produces current called displacement current I_0 .

RADAR as an acronym for **Radio Detection And Ranging.**

Radar is a detection system that uses radio waves to determine the range, angle, or velocity of objects. It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain



	Gamma Rays	X Rays	UV Rays	Visible Rays	Infrared Rays	Microwaves	Radio Waves
Detection	Photography Film	- Photography Film - Geiger tubes	- Photography Film - photocells	- Photography Film - eye - photocells	- Thermopile - Bolometer - Infrared photo film	Point contact Diodes	Receiver's Aerials
Inventors	Becquerel	Roentgen	Reigger	Newton	W. Herschel	Hertz	Marconi
Uses	- Treatment of cancer/ tumors - To preserve food stuffs for long times - To study structure of atomic nucleus	- In surgery detection of fractures, stones, bullets - In radio Therapy - To study structure of crystals - To detect cracks in metals - To cure undetectable skin disease.	- Sterilizing - Lasik eye surgery - To kill germs in water purifier - to pressure food stuff - In burglar Alarm	- Vision - Photography - Astronomy - Optical microscopy	- Physical Therapy i.e. muscular strain - Photography during fog, smoke - Secret writings study on walls - Weather fore casting - Purity of chemicals - Solar water heaters and cookers	- Radar Systems - Air craft navigation - Microwave ovens - To detect speed of tennis ball, automobile while in motion	- Wireless Communicat-ion System - FM, AM - Cellular phones - Communicat-ion . - Television



NOTE:

- | | | |
|---|--|---|
| <p>1. Electromagnetic radiation is used for satellite communication
(SSC (10+2) 28.10.2012)</p> <p>2. The waveform of a certain signal can be studied by sonometer.
(SSC MTS 10.03.2013)</p> <p>3. Gamma rays has the least/longest/minimum wavelength
(SSC MTS 17.03.2013, SSC CAPFS ASI & SI Delhi Police 07.07.2017, SSC CHSL 21.03.2018)</p> <p>4. Device used for measuring the wavelength of x- rays is bragg spectrometer.</p> | <p>(SSC CGL 19.05.2013)</p> <p>5. Arrange according to increasing wavelength
(SSC CAPFS SI & CISF ASI 23.06.2013)
X- RAYS > INFRARED RAYS > VISIBLE RAYS > MICROWAVE.</p> <p>6. The damage of the human body due to radiation is measured in Rems.
(SSC CGL 27.04.2014)</p> <p>7. Every hot objects emits infrared rays.
(SSC CGL 09.09.2016)</p> <p>8. Visible light has lowest frequency.
(SSC CGL 06.09.2016)</p> <p>9. Cathode ray is not an electromagnetic ray.</p> | <p>(SSC CGL 07.09.2016)</p> <p>10. The reverse effect of x- rays emission is photoelectric.
(SSC CGL 04.09.2016)</p> <p>11. X -rays electromagnetic radiation have wavelength in the range of 10^{-11} to 10^{-8} meter.
(SSC CHSL 27.03.2018)</p> <p>12. MRI machine, used magnetic wave.
(FCI ASSISTANT 22.01.2012)</p> <p>13. In the remote control of television, electromagnetic waves are used are infrared.
(SSC Delhi Police SI 19.08.2012)</p> |
|---|--|---|



19**Inventions & Discoveries****MEASURING INSTRUMENT**

It is a device that is used to measure physical quantity.

INSTRUMENT	USED FOR	PREVIOUS YEAR ASKED
Ammeter	measuring electric current	(RRB JE 04.12.2014)
Altimeter	measuring height	
Anemometer	measuring wind speed	(RRB GROUP-D 12.10.2018), (RRB NTPC 25.01.2021, 23.07.2021)
actinometer	measuring intensity of radiation	
Compass	navigation and indicates direction	
Cyclotron	measure small magnitude cyclone	(RRB NTPC 23.02.2021)
Electroscope	detects the presence of electric charge	(RRB NTPC 19.03.2021)
Barometer	measure atmospheric pressure	
Tachometer	measure the rotation per minute in vehicle	(RRB JE 14.12.2014) (RRB NTPC 31.03.2016)
Galvanometer	measuring small electric current	(RRB GROUP-D 24.09.2018, 22.09.2018), (RRB NTPC 26.04.2016)
Heliscope	see the sun	(RRB NTPC 10.04.2016)
Hydrometer	measure density of liquid	(RRB NTPC 05.04.2016)
Hygrometer	measure the humidity in atmosphere	(SSC CPO SI 07.09.2003, SSC CHSL 06.12.2011)
Polygraph	detect lie	(RRB NTPC 03.03.2021, 01.02.2021)
Lactometer	check the purity of milk	(SSC CAPFS SI, Delhi Police SI & CISF ASI 12.12.2019)
Multimeter	measure two or more electrical value	
Odometer	measure distance in vehicle	(RRB GROUP-D 10.10.2018, 25.10.2018, 05.11.2028), (RRB ALP & TECH 14.08.2018)
Periscope	see in submarine to see things above the level of sea.	(RRB NTPC 10.04.2016)
Pyrometer	measure high temperture	(RRB NTPC 01.04.2016)
Infrared thermometer	measure temperture without touching	(RRB JE 14.12.2014)
Telescope	magnifying distant object	(SSC MATRIC LEVEL 14.05.2017)
Potentometer	measure an electromotive force	(RRB JE 14.12.2014)
Wavemeter	determine the distance between the wavelength	
Stalagmometer	measure surface tension	(RRB SSE 21.12.2014)
Venturimeter	measure discharge	
Pitot tube	measure velocity in pipe	
Rotameter	measure the volumetric flow rate of liquids	(RRB SSE 21.12.2014)
Speedometer	indicate the speed of vehicle	
Richter scale	measure power of earthquake	(RRB NTPC 03.04.2016)
Seismograph	measure seismic wave	(SSC TAX ASSISTANT 12.11.2016, SSC CONSTABLE (GD) & Rifleman (GD) 22.04.2012)
Rheostat	to adjust resistance	
Voltmeter	to measure voltage	(RRB JE 29.05.2019), (RRB GROUP -D 27.09.2018, 08.10.2018)
Sonometer	study the behavior of a vibrating string.	(SSC CAPFS SI & CISF ASI 23.06.2013)
Hydroscope	that shows change in density of liquid	(SSC CAPFS SI & ASI, Delhi Police SI EXAM 05.06.2016)



Inventions and inventors

Invention	Inventors
Centigrade scale	Anders Celsius
Radio	Marconi
Telephone	Alexander Graham Bell
Electricity	Benjamin Franklin
Electric light bulb	Thomas Edison
Thermometer	Galileo Galilei
Telescope	Lippershey and Zacharias Johnsons
Telegraph	Samuel Morse
Automatic cash machine (ATM)	John Adrian
Automobile	Karl Benz
Magnetic tape	Fritz Pfleumer
Transformer	Faraday (Otto von Guericke)
Induction	Michael Faraday
Radioactivity	Henry Becquerel

Fuel cell	William Grove
Airplane	Wright brothers
Barometer	Torricelli
Camera	Nicephore Niepce
Diesel engine	Rudolf Diesel
Helicopter	Igor Sikorsky
Dynamite	Alfred Nobel
Mobile phone	Martin Cooper
Steam engine	Thomas Newcomen
Railway engine	George Stephenson
Jet engine	Frank Whittle
Seismograph	John Milne
Electric generator	Michael Faraday
Television	John Logie Baird
Refrigerator	William Cullen
Carburetor	Luigi de Cristoforis Enrico Bernadi
Mercury Manometer	Evangelista Torricelli

**(SSC CGL Pre. 2022,
03.12.2022 Shift-3)**

**Spherometer
(SSC CGL Pre. 2022,
12.12.2022 Shift-4)**

Which measuring instrument consists of a metal triangular frame supported on three legs, used to measure the radius of curvature of an object such as lenses and curved mirrors which are spherical in shape?

In early 1610, **Galileo Galilei** discovered with his newly invented telescope that Jupiter has four moons.

(SSC CGL Pre. 2022, 06.12.2022 Shift-4)



20

Miscellaneous

Quantum Theory of Light

- Proposed by Albert Einstein
- According to this, Light consists of packets of energy called photons
- Energy of a photon, E
 $E = h\nu$
 Where
 h = Planck's constant = 6.6×10^{-34} JS
 ν = Frequency of radiation
 Where frequency = Number of waves passing through a point in one second. and

$$c = \lambda \nu$$

Speed of light $\rightarrow$ Frequency

Wavelength

So, for a particular wave
 If frequency is more, energy will be more
 and wavelength will be small.

Phenomenon Explained by Quantum Theory

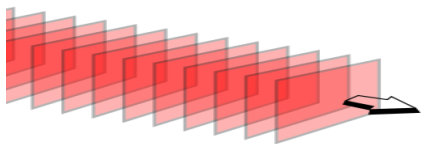
- Photo Electric
- Raman Effect
- Compton Effect

Quantum Theory failed to explain

- Interference
- Diffraction
- Polarization

De-broglie's Dual Nature of Light
Based on the fact 'That Nature loves Symmetry'.

Wave Front: A wave front is defined as the continuous locus of all the particles of a medium, which are vibrating in the same phase at a given instant.



A Source of light Sends out distances in all directions.

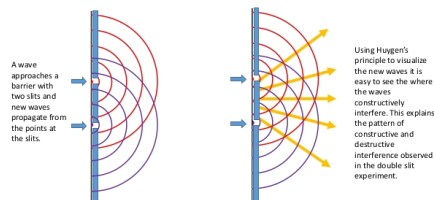
Source of Light	Nature of Wave Front	
1. Point Source	Spherical Wave Front	Wave Fronts Propagating From a Point Source

2. Linear	Cylindrical Wave Front	
3. Point source or Linear source but kept at very large distance	Plane Wave Front	

Huygen Principle: According to Huygen, we can draw straight lines perpendicular to the wave front. These straight rays are 'Rays of Light' and light energy flows along these rays and every point on the primary wave front acts as a fresh source for secondary wave front.

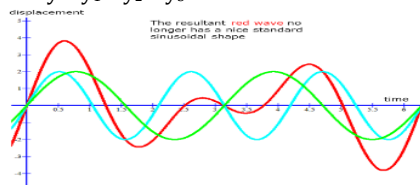
Note: Wave front propagates parallel to itself.

- Reflection and Refraction can be explained on the basis of wave theory also.

**Superposition of Waves**

According to this, two or more waves travelling in same medium superimpose one another to give a new resultant wave.

$$y = y_1 + y_2 + y_3 + \dots$$



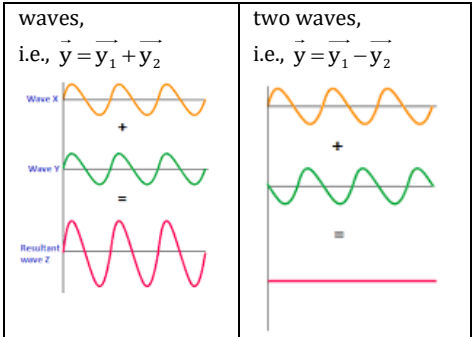
If the sources of 2 waves is coherent, the process is called INTERFERENCE

Constructive Interference

When crest of one wave falls on crest of the other, the amplitude of the resultant wave is sum of the amplitudes of two

Destructive Interference

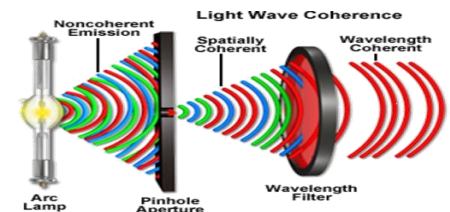
When crest of one wave falls on trough of the other, the amplitude of resultant wave is difference of the amplitudes of the

**Sources of Light****Coherent**

The sources of light, which emit continuous light waves of the same wavelength, same frequency and in same phase or having a constant phase difference are called coherent sources.

Non-Coherent

A **source** that emits waves having random frequencies and phase differences. In such **source**, there is no relationship between the waves in terms of frequencies and phase difference. Examples include:- Electric bulb, night lamp

**Two Independent Sources**

Two independent sources of light cannot be coherent. This is because light is emitted from individual atoms of the source, when they return to ground state after being excited by heat or electric discharge. Even the smallest sources of light contains billions and billions of such atoms which obviously cannot emit light waves in the same phase.

Two coherent light sources can be obtained from a single source of light by reflection, refraction.

In practice, coherence in interference is obtained by two methods:

- By division of wavefront such as in Young's double slit experiment: Lloyd's mirror experiment and Fresnel's biprism experiment.
- By division of amplitude by partial reflection and refraction of waves such as in interference of light in thin films,

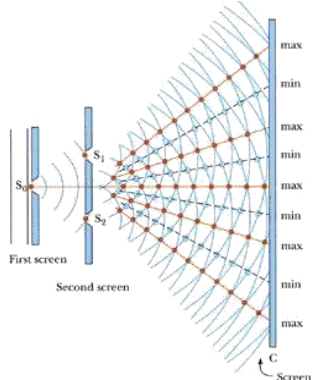


Newton's Rings and Michelson's interferometer.

Conditions for Obtaining Two Coherent Sources of Light

1. Coherent sources of light should be obtained from a single source by some device.
2. The two sources should give monochromatic light.
3. The path difference between light waves from two sources should be small.

Young's Double Slit Experiment



It explained the phenomenon of interference using two slits and one source of light and explaining the causes of light and dark patches obtained on the screen.

At the points, where the resultant intensity of light is maximum, interference is said to be **constructive**.

At the points, where the resultant intensity of light is minimum, the interference is said to be **destructive**.

In a moving car, radio signals are interrupted sometimes. Why?

While we are in moving car, there are periodic interruptions in a radio signal that we hear. It occurs an account of interfering radio waves. This is a common form of interference, called multipath interference between a radio wave and its reflection.

Why two independent light bulbs fail to produce interference?

The light from an ordinary electric lamp undergoes about 100 million (10^8) random changes every second. Therefore, light from two independent light bulbs, the given set of interference conditions last for only about 10^{-8} second. As human eye cannot follow such a rapid change, therefore, no interference effects are observed from two independent light bulbs.

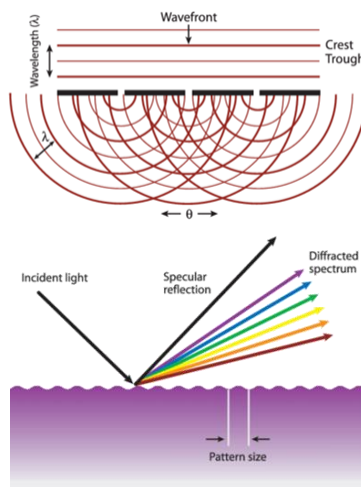
What is responsible for streaks of coloured light from a compact disc?

The streaks of colored light reflected from a compact disc (CD) resemble the colors that appear when white light

passes through a prism. However, a CD does not separate colors on account of refraction. Instead, the light waves undergo interference here.

Diffraction of light

It is the phenomenon of bending of light around corners of an obstacle or aperture in the path of light. On account of this bending, light penetrates into the geometrical shadow of the obstacle or aperture.



Diffraction occurs on account of mutual interference of secondary wavelets starting from portions of the wavefront which are not blocked by the obstacle or from portions of the wavefront which are allowed to pass through the aperture.

Examples

Although this principle applies to all types of waves it is easier – to explain using sound waves since sound waves have longer wavelengths. If someone is playing music in their room with the door closed you might not be able to hear it while walking past the room however. If that person were to open their door while playing music you could hear it not only when directly in front of the door opening but also on a considerable distance down the hall to either side is a direct effect of diffraction. When light passes through much smaller openings called slits Huygens's principle shows that light bends similar to the way sound does just on a much smaller.

Diffraction	
Fresnel Diffraction	Fraunhofer Diffraction
The source of light or the screen or both are at finite distance from the	The source of light and the screen are effectively at infinite distance from the

obstacle/aperture. Diffraction at a straight edge, diffraction at a thin wire, diffraction at a small opaque disc.

obstacle/aperture. Light from the source at infinity, after diffraction is focused on the screen using a convex lens. Diffraction at a single slit, diffraction at a double slit and diffraction at a diffraction grating.

Diffraction Types

Fresnel/Near field
→ Circular Aperture/opening
→ At Straight edge
→ At Circular obstacle/disc

Fraunhofer/Far Field
→ Single Slit
→ Double Slit/Double Grating
→ Diffraction Grating (N-slits)
→ At circular aperture (Airy's Disc)
→ At Rectangular aperture

(Δt) **Coherence Time:** Time for which phase remains constant

(ΔL) **Coherence Length:** Distance travelled by pulses during coherence time

Resolving Power: It is the ability of the instrument to resolve or to see as separate, the images of two closely spaced objects.

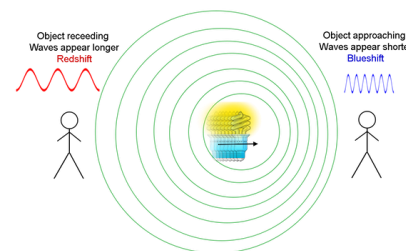
Limit of Resolution:

The minimum distance between two objects which can just be seen as separate by the optical instrument is called the Limit of Resolution of the instrument. Obviously smaller the limit of resolution of the optical instrument, greater is its Resolving Power and vice-versa.

1. Resolving power of a microscope depends upon wavelength of light and the refractive index of the medium between the object and objective lens of the microscope.
2. Resolving power of a telescope increases with the increase in the diameter of objective lens and also with the decrease in wavelength of incident light.

Doppler's Effect

According to Doppler's Effect, whenever there is a relative motion between a source of light and observer, the apparent frequency of light received by observer is different from the true frequency of light emitted actually from the source of light.



Blue Shift

When source and observer approach each other, Δv is +, i.e., apparent frequency increases or apparent wavelength decreases. This is called

Blue shift. ($\because \lambda_b < \lambda_r$)

Red Shift

When source and observer recede away from each other, Δv is negative i.e. apparent frequency decreases or apparent wavelength increases. This is called **Red shift.** ($\because \lambda_r < \lambda_b$)

Applications

Some important applications of Doppler's effect in light are in

- measuring the speed of a star and speed of galaxies,
- measuring speed of rotation of the sun, about its own axis which is about 2 km/s.
- measurement of plasma temperatures in thermo-nuclear reactions,
- Doppler's effect is used in RADAR (Radio Detection and Ranging) to estimate the speed of aeroplanes, rockets, etc.
- Doppler's effect is used in SONAR (Sound Navigation and Ranging) to estimate the velocity of submarines, ships, etc. and in estimating the depth of sea.
- Doppler's effect confirms the hypothesis that universe is expanding.

Polarisation

The phenomenon of reconstructing of electric vectors of light into a single direction is called polarization. Ordinary light has electric vectors in all possible directions in a plane, perpendicular to the direction of propagation of light.

When ordinary light is passed through a tourmaline, calcite or quartz crystal, the transmitted light have electric vectors in a particular direction parallel to the axis of crystal. This light is plane polarised light. A plane containing the vibrations of polarised light is called plane of vibration. A plane perpendicular to the plane of vibration is called **plane of polarisation**. Polarisation can take place only in transverse waves.

$$S = \frac{100}{LC}$$

$l \rightarrow$ length of tube

$\theta \rightarrow$ Optical Rotation

$C \rightarrow$ Concentration = g/cc or % = 20% = 0.2 g/cc 5% = 0.05 g/cc

$S \rightarrow$ Specific Rotation

Polaroids

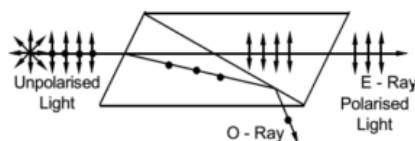
Polaroids are thin and large sheets of crystalline polarising materials (made artificially) capable of producing plane polarised beams of large cross-section. In 1852, Herapath discovered that the synthetic small needle-shaped crystals of iodosulphate of quinine possess the property of polarising the light.

Applications of Polaroids

- Polaroids are used in sun glasses. Such goggles are more efficient than those made of coloured glasses. They protect the eyes from the glare.
- The wind shield of an automobile is made of polaroid. Such a wind shield protects the eyes of the driver of the automobile from the dazzling light of the approaching vehicles. For the same reasons, the covers of head lights are made of polaroids.
- The polaroids are used in window panes of a train and especially of an aeroplane. They help to control the light entering through the windows.
- The pictures taken by a stereoscopic camera, when seen with the help of polaroid spectacles, create three-dimensional effect.

Nicol Prism

A nicol prism is an optical device, which is used for producing plane polarized light and analysing the same.

Detection of Polarized Light

A naked eye cannot distinguish between polarized and unpolarized light. A crystal can be used for making this distinction. A calcite crystal, quartz crystal a nicol prism (made from calcite (CaCO_3) crystal) can be used as polarizer as well as analyser of polarized light.

Applications

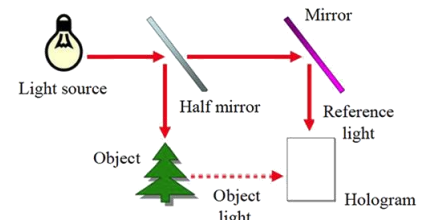
- Clear photographs of white clouds are obtained by fitting polaroids in front of the camera lens.
- Polaroids are useful in three dimensional motion pictures, i.e., in holography.
- Polaroids are used to improve colour contrast in old oil paintings.
- In calculators, watches, T.V., computers, etc. letters and numbers formed by liquid crystal display (LCD) through polarization of light.

- Polarization of scattered sunlight is used for navigation in solar compass in polar regions.

- To study asymmetries in crystals and molecules.

Holography is the science and practice of making **holograms**

A **hologram** is an image that appears to be three dimensional and which can be seen with the naked eye.

**KINETIC THEORY OF GASES**

The **kinetic theory of gases** describes a gas as a large number of submicroscopic particles (atoms or molecules), all of which are in constant, rapid, random motion. The randomness arises from the particles' many collisions with each other and with the walls of the container.

Kinetic theory of gases explains the macroscopic properties of gases, such as pressure, temperature, viscosity, thermal conductivity, and volume, by considering their molecular composition and motion. The theory posits that gas pressure results from particles' collisions with the walls of a container at different velocities.

The absolute temperature is achieved only when kinetic energy of molecules is zero. (**RRB ALP 29/08/18**)

Kinetic Theory of Matter

- (a) **Solids:** It is the type of matter which has got fixed shape and volume. The force of attraction between any two molecules of a solid is very large.

Solids have large molecular attraction as compare to all the state of matter.

(**RRB JE 14/12/14**)

- (b) **Liquids:** It is the type of matter which has got fixed volume but no fixed shape. Force of attraction between any two molecules is not that large as in case of solids.

- (c) **Gases:** It is the type of matter does not have any fixed shape or any fixed volume.

The kinetic energy of particle is maximum in gaseous state.

(**RRB GROUP-D 19/09/18**)

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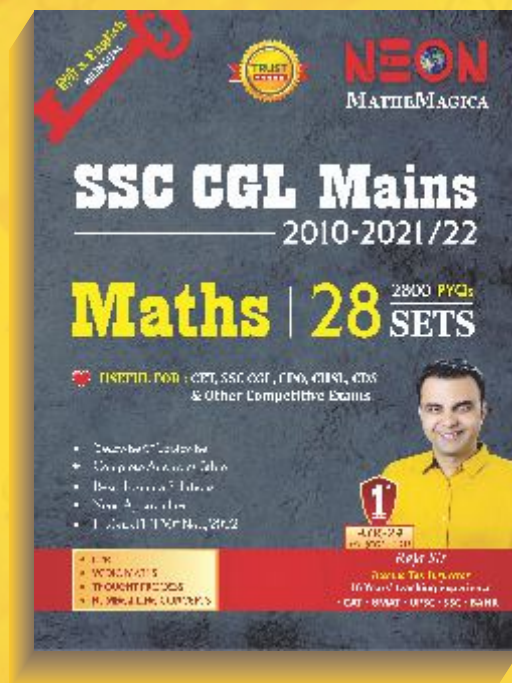
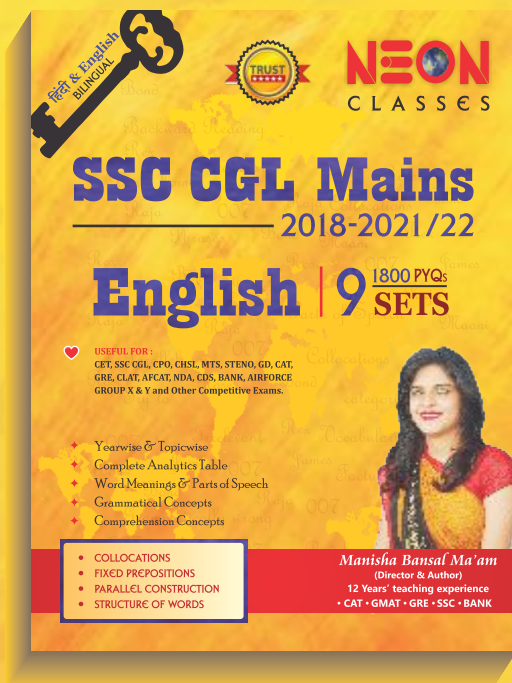
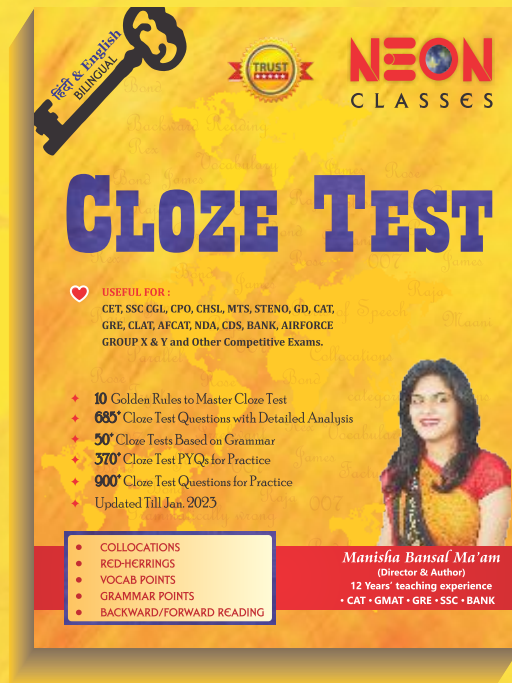
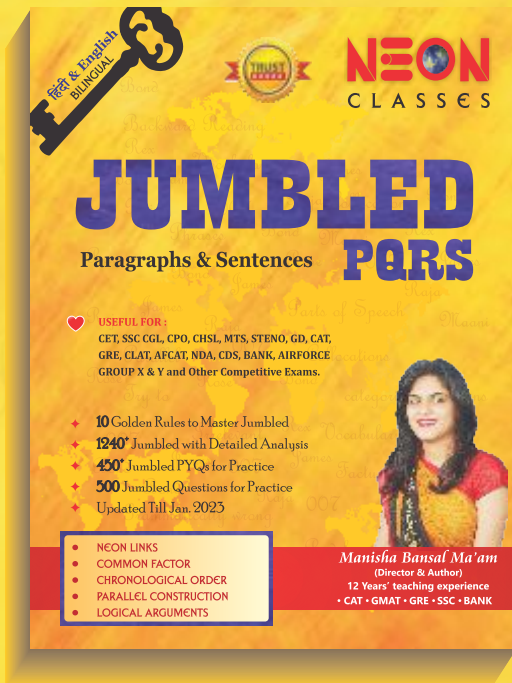
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