Important Notes

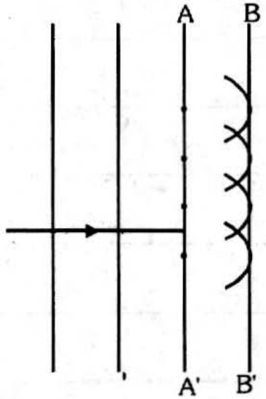
22 Wave Nature of Light and Wave optics

Huygen's Wave Theory :

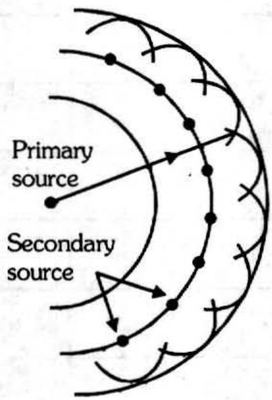
Huygen's in 1678 assumed that a body emits light in the form of waves.

- Each point source of light is a centre of disturbance from which waves spread in all directions. The locus of all the particles of the medium vibrating in the same phase at a given instant is called a wavefront.
- Each point on a wave front is a source of new disturbance, called secondary wavelets. These wavelets are spherical and travel with speed of light in that medium.
- The forward envelope of the secondary wavelets at any instant gives the new wavefront.
- In homogeneous medium, the wave front is always perpendicular to the direction of wave propagation.

Plane wavefront



Spherical wavefront



Coherent Sources :

Two sources will be coherent if and only if they produce waves of same frequency (and hence wavelength) and have a constant initial phase difference.

Incoherent sources :

Two sources are said to be incoherent if they have different frequency and initial phase difference is not constant w.r.t. time.

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Interference : YDSE

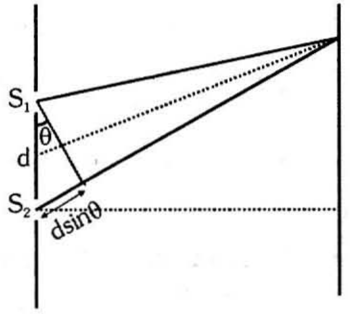
- Resultant intensity for coherent sources $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi_0$
- Resultant intensity for incoherent sources $I = I_1 + I_2$
- Intensity $\propto$ width of slit $\propto$ (amplitude)^2

$$\Rightarrow \frac{I_1}{I_2} = \frac{W_1}{W_2} = \frac{a_1^2}{a_2^2} \Rightarrow \frac{I_{max}}{I_{min}} = \frac{\left(\sqrt{I_1}+\sqrt{I_2}\right)^2}{\left(\sqrt{I_1}-\sqrt{I_2}\right)^2} = \left(\frac{a_1+a_2}{a_1-a_2}\right)^2$$

- Distance of n^{th} bright fringe $x_n = \frac{n\lambda D}{d}$

  Path difference = $n\lambda$

  where n = 0, 1, 2, 3, ...



- Distance of m^{th} dark fringe

$$x_m = \frac{(2m+1)\lambda D}{2d}$$

  Path difference = $(2m+1)\frac{\lambda}{2}$ where m = 0, 1, 2, 3,.....

- Fringe width $\beta = \frac{\lambda D}{d}$
- Angular fringe width = $\frac{\beta}{D} = \frac{\lambda}{d}$
- Fringe visibility = $\frac{I_{max} - I_{min}}{I_{max} + I_{min}} \times 100\,\%$
- If a transparent sheets of referactive index μ and thickness t is introduced in one of the paths of interfering waves, optial path will becomes 'μt' instead of 't'. Entire fringe pattern is displaced by $\frac{D\left[(\mu-1)t\right]}{d} = \frac{\beta}{\lambda}(\mu-1)t$ towards the side in which the thin sheet is introduced without any change in fringe width.

KEY POINTS

- The law of conservation of energy holds good in the phenomenon of interference.
- Fringes are neither image nor shadow of slit but locus of a point which moves such a way that its path difference from the two sources remains constant.
- In YPSE the interference fringes for two coherent point sources are hyperboloids with axis S_1S_2.
- If the interference experiment is repeated with bichromatic light, the fringes of two wavelengths will be coincident for the first time when

$$n(\beta)_{longer} = (n+1)(\beta)_{shorter}$$

- No interference pattern is detected when two coherent sources are infinitely close to each other, because $\beta \propto \frac{1}{d}$
- If maximum number of maximas or minimas are asked in the question, use the fact that value of sinθ or cosθ can't be greater than 1.

$n_{max} = \frac{d}{\lambda}$ Total maxima = $2n_{max} + 1$

DIFFRACTION

- **In Fraunhofer diffraction**
  - For minima $a \sin\theta_n = n\lambda$
  - For maxima $a \sin\theta_n = (2n + 1)\frac{\lambda}{2}$
  - Linear width of central maxima $W_x = \frac{2\lambda D}{a}$
  - Angular width of central maxima $W_\theta = \frac{2\lambda}{a}$
  - Intensity of maxima

    Where I_0 = Intensity of central maxima

$$I = I_0\left[\frac{\sin(\beta/2)}{\beta/2}\right]^2 \text{ and } \beta = \frac{2\pi}{\lambda}a\sin\theta$$

- **Polarization :**
  - Brewsters' law :-

    $\mu = \tan\theta_p \rightarrow$

    $\theta_p \rightarrow$ polarization of Brewster's angle
  - Here reflecting and refracting rays are perpendirular to each other.
  - Malus law :-

    $I = I_0 \cos^2\theta$

    $I_0 \rightarrow$ Maximum intensity of polarized light.

Important Notes

23 Modern Physics

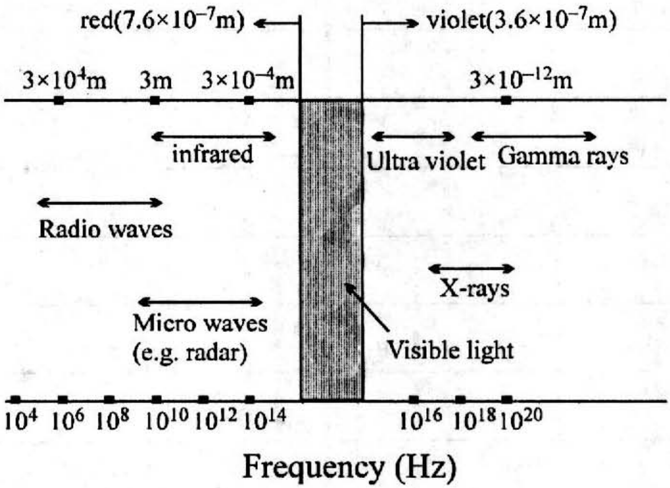
Cathode rays :

- Generated in a discharge tube in which a high vaccum is maintained.
- They are electrons accelerated by high potential difference(10 to 15 kV)
- K.E. of C.R. particle accelerated by a p.d. V is $eV = \frac{1}{2}mv^2 = \frac{p^2}{2m}$
- Can be deflected by Electric & magnetic fields.

Electromagnetic Spectrum :

Ordered arrangement of the big family of electro magnetic waves (EMW) either in ascending order of frequencies or decending order of wave lengths.

Speed of E.M.W. in vacuum : $c = 3 \times 10^8$ m/s = $\nu\lambda$



PLANK'S QUANTUM THEORY

A beam of EMW is a stream of discrete packets of energy called **PHOTONS**; each photon having a frequency ν and energy = $E=h\nu$

where h = planck's constant = 6.63×10^{-34} J-s.

- According to Planck the energy of a photon is directly proportional to the frequency of the radiation.

$$E = \frac{hc}{\lambda} = \frac{12400}{\lambda} eV - \text{Å} \qquad \left[\because \frac{hc}{e} = 12400(\text{Å} - eV)\right]$$

- Effective mass of photon $m = \frac{E}{c^2} = \frac{hc}{c^2\lambda} = \frac{h}{c\lambda}$ i.e. $m \propto \frac{1}{\lambda}$

So mass of violet light photon is greater than the mass of red light photon. $(\because \lambda_R > \lambda_V)$

- Linear momentum of photon $p = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$

- **Intensity of light** : $I = \frac{E}{At} = \frac{P}{A}$ ...(i)

Here P = power of source, A = Area, t = time taken

E = energy incident in t time = Nhν N = no. of photon incident in t time

Intensity $I = \frac{N(h\nu)}{At} = \frac{n(h\nu)}{A}$ ...(ii) $\left[\because n = \frac{N}{t} = \text{no. of photon per sec.}\right]$

From equation (i) and (ii), $\frac{P}{A} = \frac{n(h\nu)}{A} \Rightarrow n = \frac{P}{h\nu} = \frac{P\lambda}{hc} = 5 \times 10^{24} J^{-1} m^{-1} \times P \times \lambda$

- **Force exerted on perfectly reflecting surface**

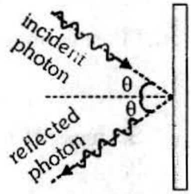
$$\therefore \quad F = n\left(\frac{2h}{\lambda}\right) = \frac{2P}{c} \text{ and Pressure} = \frac{F}{A} = \frac{2P}{cA} = \frac{2I}{c} \left[\because I = \frac{P}{A}\right]$$

- **Force exerted on perfectly absorbing surface**

$$F = \frac{P}{c}\left(\because n = \frac{P\lambda}{hc}\right) \text{ and Pressure} = \frac{F}{A} = \frac{P}{Ac} = \frac{I}{c}$$

- **When a beam of light is incident at angle θ on perfectly reflector surface**

$$F = \frac{2IA\cos^2\theta}{c}$$



- **When a beam of light is incident at angle θ on perfectly absorbing surface** $F = \frac{IA\cos\theta}{c}$

PHOTO ELECTRIC EFFECT

The phenomenon of the emission of electrons, when metals are exposed to light (of a certain minimum frequency) is called photo electric effect.

Results :

- Can be explained only on the basis of the quantum theory (concept of photon)
- Electrons are emitted if the incident light has frequency $\nu \geq \nu_0$ (threshold frequency). Emission of electrons is independent of intensity . The wave length corresponding to ν_0 is called threshold wave length λ_0.
- ν_0 is different for different metals.
- Number of electrons emitted per second depends on the intensity of the incident light.

EINSTEINS PHOTO ELECTRIC EQUATION :

Photon energy = KE_{max} of electron + work function

$h\nu = KE_{max} + \phi$

ϕ = Work function = energy needed by the electron in freeing itself from the atoms of the metal $\phi = h\nu_0$

STOPPING POTENTIAL OR CUT OFF POTENTIAL :

The minimum value of the retarding potential to prevent electron emission is

$$eV_{cut\ off} = (KE)_{max}$$

Note: The number of photons incident on a surface per unit time is called photon flux.

WAVE NATURE OF MATTER :

Beams of electrons and other forms of matter exhibit wave properties including interference and diffraction with a de Broglie wave length given by $\lambda = \frac{h}{p}$ (wave length of a praticle).

- **De Broglie wavelength associated with moving particles**

If a particle of mass m moving with velocity v.

Kinetic energy of the particle $E = \frac{1}{2}mv^2 = \frac{p^2}{2m}$

momentum of particle $p = mv = \sqrt{2mE}$

the wave length associated with the particles is $\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$

- **De Broglie wavelength associated with the charged particles :-**

- **For an Electron** $\lambda_e = \frac{12.27 \times 10^{-10}}{\sqrt{V}} m = \frac{12.27}{\sqrt{V}} Å$ so $\lambda \propto \frac{1}{\sqrt{V}}$

- **For Proton** $\lambda_p = \frac{0.286 \times 10^{-10}}{\sqrt{V}} m = \frac{0.286}{\sqrt{V}} Å$

- **For Deuteron** $\lambda_d = \frac{0.202}{\sqrt{V}} Å$

- **For α Particles** $\therefore \lambda_\alpha = \frac{0.101}{\sqrt{V}} Å$

ATOMIC MODELS :

(a) Thomson model : (Plum pudding model)

- Most of the mass and all the positive charge of an atom is uniformly distributed over the full size of atom (10^{-10} m).
- Electrons are studded in this uniform distribution .
- Failed to explain the large angle scattering α - particle scattered by thin foils of matter.

(b) Rutherford model : (Nuclear Model)

- The most of the mass and all the positive charge is concentrated within a size of 10^{-14} m inside the atom. This concentration is called the atomic nucleus.
- The electron revolves around the nucleus under electric interaction between them in circular orbits.
- An accelerating charge radiates the nucleus spiralling inward and finally fall into the nucleus, which does not happen in an atom. This could not be explained by this model.

(c) Bohr atomic model : Bohr adopted Rutherford model of the atom & added some arbitrary conditions. These conditions are known as his postulates

- The electron in a stable orbit does not radiate energy.
- A stable orbit is that in which the angular momentum of the electron about nucleus is an integral (n) multiple of $\frac{h}{2\pi}$ i.e. $mvr = n\frac{h}{2\pi}$; n=1, 2, 3, ..(n ≠ 0).
- The electron can absorb or radiate energy only if the electron jumps from a lower to a higher orbit or falls from a higher to a lower orbit.
- The energy emitted or absorbed is a light photon of frequency ν and of energy. $\mathbf{E = h\nu}$

For hydrogen atom : (Z = atomic number = 1)

- L_n = angular momentum in the n^{th} orbit $= n\frac{h}{2\pi}$.
- r_n = radius of n^{th} circular orbit $= (0.529\ \text{Å})\ n^2 \Rightarrow r_n \propto n^2$.
- E_n = Energy of the electron in the n^{th} orbit $= \frac{-13.6\ eV}{n^2} \Rightarrow E_n \propto \frac{1}{n^2}$.

  Note : Total energy of the electron in an atom is negative, indicating that it is bound.

  Binding Energy $(BE)_n = -E_n = \frac{13.6\ eV}{n^2}$

- $E_{n2} - E_{n1}$ = Energy emitted when an electron jumps from n_2^{th} orbit to n_1^{th} orbit ($n_2 > n_1$).

$$\Delta E = (13.6\ eV)\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$\Delta E = h\nu$; ν = frequency of spectral line emitted .

$$\frac{1}{\lambda} = \text{wave no. [no. of waves in unit length (1m)]} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Where R = Rydberg's constant, for hydrogen $= 1.097 \times 10^7 \text{ m}^{-1}$

- For hydrogen like atom/species of atomic number Z :

$$r_{nz} = \frac{\text{Bohr radius}}{Z} n^2 = (0.529 \text{ Å}) \frac{n^2}{Z}; \; E_{nz} = (-13.6) \frac{Z^2}{n^2} \text{ eV}$$

$R_z = RZ^2$; Rydberg's constant for element of atomic no. Z .

Note : If motion of the nucleus is also considered , then m is replaced by μ. Where μ= reduced mass of electron - nucleus system = mM/(m+M)

$$\text{In this case } E_n = (-13.6 \text{ eV}) \frac{Z^2}{n^2} \cdot \frac{\mu}{m_e}$$

Spectral series :

- **Lyman Series :** (Landing orbit n = 1) .

Ultraviolet region $\bar{\nu} = R\left[\frac{1}{1^2} - \frac{1}{n_2^2}\right]; n_2 > 1$

- **Balmer Series:** (Landing orbit n = 2)

Visible region $\bar{\nu} = R\left[\frac{1}{2^2} - \frac{1}{n_2^2}\right]; n_2 > 2$

- **Paschan Series :** (Landing orbit n = 3)

In the near infrared region $\bar{\nu} = R\left[\frac{1}{3^2} - \frac{1}{n_2^2}\right]; n_2 > 3$

- **Bracket Series :** (Landing orbit n = 4)

In the mid infrared region $\bar{\nu} = R\left[\frac{1}{4^2} - \frac{1}{n_2^2}\right]; n_2 > 4$

- **Pfund Series :** (Landing orbit n = 5)

In far infrared region $\bar{\nu} = R\left[\frac{1}{5^2} - \frac{1}{n_2^2}\right]; n_2 > 5$

In all these series $n_2 = n_1 + 1$ is the α line

$= n_1 + 2$ is the β line

$= n_1 + 3$ is the γ line.......etc.

where n_1 = Landing orbit

❐ **Total emission spectral lines**

From $n_1 = n$ to $n_2 = 1$ state $= \dfrac{n(n-1)}{2}$

From $n_1 = n$ to $n_2 = m$ state $= \left(\dfrac{(n-m)(n-m+1)}{2}\right)$

Excitation potential of atom :

Excitation potential for quantum jump from $n_1 \to n_2 = \dfrac{E_{n2} - E_{n1}}{\text{electron charge}}$

Ionization energy of hydrogen atom :

The energy required to remove an electron from an atom. The energy required to ionize hydrogen atom is $= 0 - (-13.6) = 13.6$ eV.

Ionization Potential :

Potential difference through which a free electron is moved to gain ionization energy $= \dfrac{-E_n}{\text{electronic charge}}$

X - RAYS :

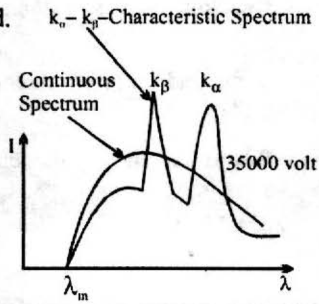
- X–rays are produced by bombarding high speed electrons on a target of high atomic weight and high melting point.
- Short wavelength (0.1 Å to 10 Å) electromagnetic radiation.
- Are produced when a metal anode is bombarded by very high energy electrons
- Are not affected by electric and magnetic field.
- They cause photoelectric emission.

Characteristics equation $eV = h\nu_m$

e = electron charge;

V= accelerating potential

ν_m = maximum frequency of X – radiation



- Intensity of X - rays depends on number of electrons hitting the target .
- Cut off wavelength or minimum wavelength, where V (in volts) is the p.d. applied to the tube $\lambda_{min} \cong \frac{12400}{V}$ Å
- Continuous spectrum due to retardation of electrons .

- **Characteristic X-rays**

For K_α, $\lambda = \frac{hc}{E_K - E_L}$ For K_β, $\lambda = \frac{hc}{E_L - E_M}$

- **Moseley's law for characteristic spectrum :**

Frequency of characteristic line $\sqrt{v} = a(Z - b)$

Where a, b are constant, for K_α line b = 1

Z = atomic number of target

v = frequency of characteristic spectrum

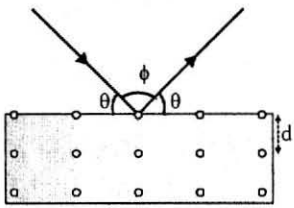
b = screening constant (for K– series b=1, L series b=7.4),

a = proportionality constant

Bohr model	**Moseley's correction**
1. For single electron species	**1.** For many electron species
2. $\Delta E = 13.6Z^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ eV	**2.** $\Delta E = 13.6\ (Z-b)^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ eV
3. $v = RcZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$	**3.** $v = Rc(Z-b)^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$
4. $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$	**4.** $\frac{1}{\lambda} = R(Z-b)^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

Diffraction of X–ray

Diffraction of X–ray take place according to Bragg's law $2d \sin\theta = n\lambda$



d = spacing of crystal plane or lattice constant or distance between adjacent atomic plane

θ = Bragg's angle or glancing angle

ϕ = Diffracting angle n = 1, 2, 3 ....

For Maximum Wavelength

$\sin\theta = 1, n = 1 \Rightarrow \lambda_{max} = 2d$

so if $\lambda > 2d$ diffraction is not possible i.e. solution of Bragg's equation is not possible.

KEY POINTS

- Binding energy = – [Total Mechanical Energy]
- Velocity of electron in n^{th} orbit for hydrogen atom $\cong \frac{c}{137n}$; c = speed of light.
- Series limit means minimum wave length of that series.

NUCLEAR COLLISIONS

We can represent a nuclear collision or reaction by the following notation, which means X (a,b) Y

$$\underset{\text{(bombarding particle)}}{a} + \underset{\text{(at rest)}}{X} \rightarrow Y + b$$

We can apply :

(i) Conservation of momentum (ii) Conservation of charge (iii) Conservation of mass–energy

For any nuclear reaction $\underset{K_1}{a} + \underset{K_2}{X} \rightarrow \underset{K_3}{Y} + \underset{K_4}{b}$

By mass energy conservation

(i) $K_1 + K_2 + (m_a + m_x)c^2 = K_3 + K_4 + (m_Y + m_b)c^2$

(ii) Energy released in any nuclear reaction or collision is called Q value of the reaction.

(iii) $Q = (K_3 + K_4) - (K_1 + K_2) = \Sigma K_P - \Sigma K_R = (\Sigma m_R - \Sigma m_P)c^2$

(iv) If Q is positive, energy is released and products are more stable in comparison to reactants.

(v) If Q is negative, energy is absorbed and products are less stable in comparison to reactants.

$$Q = \Sigma(B.E.)_{product} - \Sigma(B.E.)_{reactants}$$

Nuclear Fission

In 1938 by Hahn and Strassmann. By attack of a particle splitting of a heavy nucleus (A > 230) into two or more lighter nuclei. In this process certain mass disappears which is obtained in the form of energy (enormous amount)

$$A + p \longrightarrow \text{excited nucleus} \longrightarrow B + C + Q$$

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Nuclear Fusion :

It is the phenomenon of fusing two or more lighter nuclei to form a single heavy nucleus.

$$A + B \rightarrow C + Q \text{ (Energy)}$$

The product (C) is more stable then reactants (A and B) and $m_c < (m_a + m_b)$

and mass defect $\Delta m = [(m_a + m_b) - m_c]$ amu

Energy released is $E = \Delta m$ 931 MeV

The total binding energy and binding energy per nucleon C both are more than of A and B. $\Delta E = E_c - (E_a + E_b)$

RADIOACTIVITY

- **Radioactive Decays :** Generally, there are three types of radioactive decays (i) α decay (ii) β^- and β^+ decay (iii) γ decay
- **α decay:** By emitting α particle, the nucleus decreases it's mass number and move towards stability. Nucleus having A>210 shows α decay.
- **β decay** : In beta decay, either a neutron is converted into proton or proton is converted into neutron.
- **γ decay** : When an α or β decay takes place, the daughter nucleus is usually in higher energy state, such a nucleus comes to ground state by emitting a photon or photons.

  Order of energy of γ photon is 100 keV
- **Laws of Radioactive Decay :** The rate of disintegration is directly proportional to the number of radioactive atoms present at that time i.e., rate of decay $\propto$ number of nuclei.

  Rate of decay = λ (number of nuclei) i.e., $\frac{dN}{dt} = -\lambda N$

  where λ is called the decay constant.

  This equation may be expressed in the form $\frac{dN}{N} = -\lambda dt$.

  $$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_0^t dt \Rightarrow \ell n\left(\frac{N}{N_0}\right) = -\lambda t$$

  where N_0 is the number of parent nuclei at t=0. The number that survives at time t is therefore $N = N_0 e^{-\lambda t}$ and $t = \frac{2.303}{\lambda}\log_{10}\left(\frac{N_0}{N_t}\right)$

  $N = N_0 e^{-\lambda t}$ where λ = decay constant

- Half life $t_{1/2} = \dfrac{\ell n 2}{\lambda}$

- Average life $t_{av} = \dfrac{1}{\lambda}$

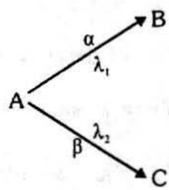
  • Within duration $t_{1/2} \Rightarrow$ 50% of N_0 decayed and 50% of N_0 remains active

  • Within duration $t_{av} \Rightarrow$ 63% of N_0 decayed and 37% of N_0 remains active

- Activity $R = \lambda N = R_0 e^{-\lambda t}$
- 1Bq = 1 decay/s,
- 1 curie = 3.7×10^{10} Bq,
- 1 rutherford = 10^6Bq
- After n half lives Number of nuclei left $= \dfrac{N_0}{2^n}$
- Probability of a nucleus for survival of time $t = \dfrac{N}{N_0} = \dfrac{N_0 e^{-\lambda t}}{N_0} = e^{-\lambda t}$

• **Parallel radioactive disintegration**

Let initial number of nuclei of A is N_0 then at any time number of nuclei of A, B & C are given by $N_0 = N_A + N_B + N_C$



$$\Rightarrow \frac{dN_A}{dt} = \frac{-d}{dt}(N_B + N_C)$$

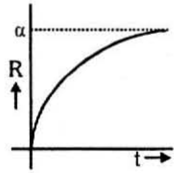
A disintegrates into B and C by emitting α,β particle.

Now, $\dfrac{dN_B}{dt} = -\lambda_1 N_A$ and $\dfrac{dN_C}{dt} = -\lambda_2 N_A \Rightarrow \dfrac{d}{dt}(N_B + N_C) = -(\lambda_1 + \lambda_2) N_A$

$$\Rightarrow \frac{dN_A}{dt} = -(\lambda_1 + \lambda_2) N_A \Rightarrow \lambda_{eff} = \lambda_1 + \lambda_2 \Rightarrow t_{eff} = \frac{t_1 t_2}{t_1 + t_2}$$

Radioactive Disintegration with Successive

Production $\xrightarrow[(\alpha = \text{rate of production})]{\alpha} A \xrightarrow{\lambda} B$



$\frac{dN_A}{dt} = \alpha - \lambda N_A$ ....(i)

when N_A is maximum $\frac{dN_A}{dt} = 0 \Rightarrow \alpha - \lambda N_A = 0$,

$N_{A\,max} = \frac{\alpha}{\lambda} = \frac{\text{rate of production}}{\lambda}$

By equation (i) $\int_0^t \frac{dN_A}{\alpha - \lambda N_A} = \int_0^t dt$, Number of nuclei is $N_A = \frac{\alpha}{\lambda}\left(1 - e^{-\lambda t}\right)$

- **Equivalence of mass and energy** $E = mc^2$

Note :- $1u = 1.66 \times 10^{-27}$ kg $\equiv 931.5$ MeV or $c^2 = 931.5$ MeV/u

- **Binding energy of ${}_ZX^A$**

$BE = \Delta mc^2 = [Zm_p + (A-Z)m_n - m_X]c^2 = [Zm_H + (A-Z)m_n - m_X]c^2$

- **Q-value of a nuclear reaction**

For $a + X \longrightarrow Y + b$ or $X(a, b)Y$; $Q = (M_a + M_X - M_Y - M_b)c^2$

- **Radius of the nucleus**

$R = R_0A^{1/3}$ where $R_0 = 1.3\ f_m = 1.3 \times 10^{-15}$ m

From Bohr Model

$n_1 = 1$, $n_2 = 2, 3, 4$.......K series

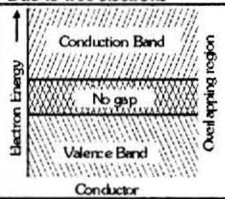
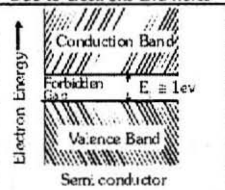
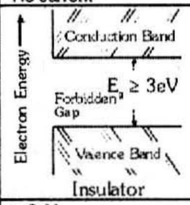
$n_1 = 2$, $n_2 = 3, 4, 5$.......L series

$n_1 = 3$, $n_2 = 4, 5, 6$.......M series

Important Notes

24 Semiconductor and Digital Electronics

Comparison between conductor, semiconductor and insulator :

Properties	**Conductor**	**Semiconductor**	**Insulator**
Resistivity	$10^{-2} - 10^{-8}\ \Omega m$	$10^{-5} - 10^{6}\ \Omega m$	$10^{11} - 10^{19}\ \Omega m$
Conductivity	$10^{2} - 10^{8}$ mho/m	$10^{5} - 10^{-6}$ mho/m	$10^{-11} - 10^{-19}$ mho/m
Temp. Coefficient of resistance (α)	Positive	Negative	Negative
Current	Due to free electrons	Due to electrons and holes	No current
Energy band diagram			
Forbidden energy gap	$\cong 0eV$	$\cong 1eV$	$\geq 3eV$
Example	Pt, Al, Cu, Ag	Ge, Si, GaAs, GaF_2	Wood, plastic, Diamond, Mica

- **Number of electrons reaching from valence band to conduction band**

$$n = AT^{3/2}e^{-\frac{\Delta E_g}{2kT}}$$

- **Classification of Semiconductors :**

SEMICONDUCTOR

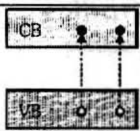
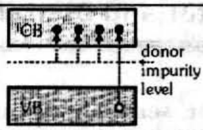
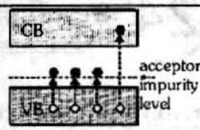
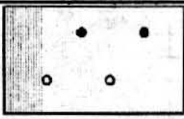
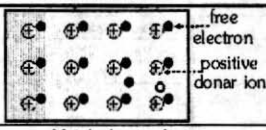
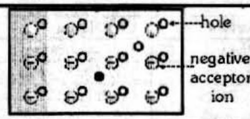
↓

Intrinsic semiconductor → (pure form of Ge, Si) $n_e = n_h = n_i$

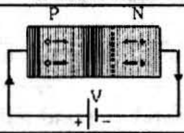
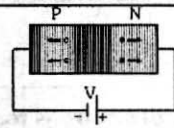
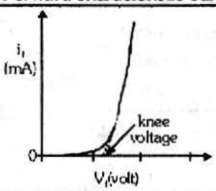
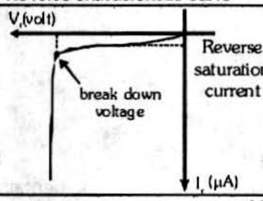
Extrinsic semiconductor (doped semicondutor)

- N-type: pentavalent impurity (P, As, Sb etc.) donar impurity (N_D) $n_e >> n_h$
- P-type: trivalent impurity (Ga, B, In, Al) acceptor impurity (N_A) $n_h >> n_e$

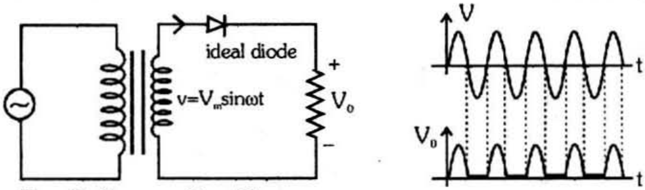
- **Mass-action law** $n_i^2 = n_e \times n_h$
  - ❑ For N-type semiconductor $n_e = N_D$
  - ❑ For P-type semiconductor $n_h = N_A$
- **Conductivity** $n_i e(\mu_e + \mu_h)$

Intrinsic Semiconductor	N-type (Pentavalent impurity)	P-type (Trivalent impurity)
		
		
Current due to electron and hole	Mainly due to electrons	Mainly due to holes
$n_e = n_h = n_i$	$n_h << n_e$ ($N_D \simeq n_e$)	$n_h >> n_e$ ($N_A \simeq n_h$)
$I = I_e + I_h$	$I \simeq I_e$	$I \simeq I_h$
Entirely neutral	Entirely neutral	Entirely neutral
Quantity of electrons and holes are equal	Majority – Electrons Minority – Holes	Majority – Holes Minority - Electrons

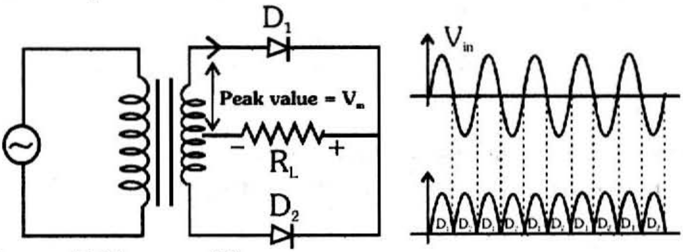
Comparison between Forward Bias and Reverse Bias

	Forward Bias		Reverse Bias
			
1	Potential Barrier reduces	1	Potential Barrier increases.
2	Width of depletion layer decreases	2	Width of depletion layer increases.
3	P-N jn. provide very small resistance	3	P-N jn. provide high resistance
4	Forward current flows in the circuit	4	Very small current flows.
5	Order of forward current is milli ampere.	5	Order of current is micro ampere for Ge or Neno ampere for Si.
6	Current flows mainly due to majority carriers.	6	Current flows mainly due to minority carriers.
7	Forward characteristic curves.	7	Reverse characteristic curve
			
8	Forward resistance : $R_f = \frac{\Delta V_f}{\Delta I_f} \cong 100\Omega$	8	Reverse resistance : $R_r = \frac{\Delta V_r}{\Delta I_r} \cong 10^6\Omega$
9	Order of knee or cut in voltage	9	Breakdown voltage
	Ge→ 0.3 V		Ge → 25 V
	Si → 0.7 V		Si → 35 V
	Special point : Generally $\frac{R_r}{R_f} = 10^3 : 1$ for Ge		$\frac{R_r}{R_f} = 10^4 : 1$ for Si

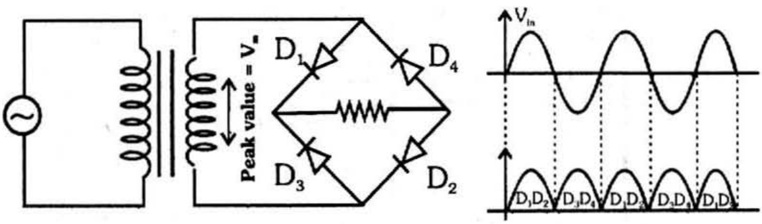
- **Half wave rectifier**



- **Centre – Tap Full wave Rectifier**



- **Full wave Bridge reactifier**

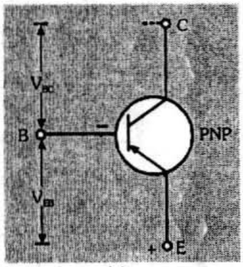


- **Form factor** $= \dfrac{I_{rms}}{I_{dc}}$
  - For HWR (Half wave rectifier) Form factor $= \dfrac{\pi}{2}$
  - For FWR (Full wave rectifier) Form factor $= \dfrac{\pi}{2\sqrt{2}}$

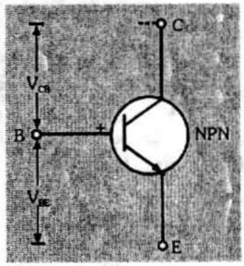
- **Ripple factor** $r = \dfrac{I_{ac}}{I_{dc}}$
  - For HWR $r = 1.21$
  - For FWR $r = 0.48$

- **Rectifier efficiency** $\eta = \dfrac{P_{dc}}{P_{ac}} = \dfrac{I_{dc}^2 R_L}{I_{rms}^2 (R_F + R_L)}$
  - For HWR $\eta\% = \dfrac{40.6}{1 + \dfrac{R_F}{R_L}}$ & FWR $\eta\% = \dfrac{81.2}{1 + \dfrac{R_F}{R_L}}$

- **For transistor** $I_E = I_B + I_C$



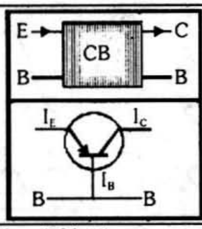
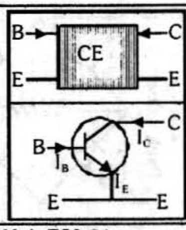
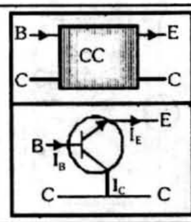
(a)



(b)

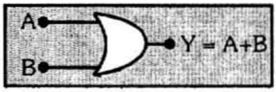
Comparative study of transistor configurations

1. Common Base **(CB)**
2. Common Emitter **(CE)**
3. Common Collector **(CC)**

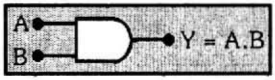
	CB	**CE**	**CC**
			
Input Resistance	Low (100 Ω)	High (750 Ω)	Very High ≅ 750 kΩ
Output resistance	Very High	High	Low
Current Gain	(A_i or α)	(A_i or β)	(A_i or γ)
	$\alpha = \frac{I_C}{I_E} < 1$	$\beta = \frac{I_C}{I_B} > 1$	$\gamma = \frac{I_E}{I_B} > 1$
Voltage Gain	$A_V = \frac{V_o}{V_i} = \frac{I_C R_L}{I_E R_i}$	$A_V = \frac{V_o}{V_i} = \frac{I_C R_L}{I_B R_i}$	$A_V = \frac{V_o}{V_i} = \frac{I_E R_L}{I_B R_i}$
	$A_v = \alpha \frac{R_L}{R_i} \cong 150$	$A_v = \beta \frac{R_L}{R_i} \cong 500$	$A_v = \gamma \frac{R_L}{R_i} < 1$
Power Gain	$A_p = \frac{P_o}{P_i} = \alpha^2 \frac{R_L}{R_i}$	$A_p = \frac{P_o}{P_i} = \beta^2 \frac{R_L}{R_i}$	$A_p = \frac{P_o}{P_i} = \gamma^2 \frac{R_L}{R_i}$
Phase difference (between output and input)	same phase	opposite phase	same phase
Application	For High Frequency	For Audible frequency	For Impedance Matching

- **Relation between α, β and γ :** $\beta = \dfrac{\alpha}{1-\alpha}$, $\gamma = 1+\beta$, $\gamma = \dfrac{1}{1-\alpha}$
- **Logic gates**

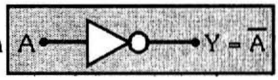
❐ OR gate



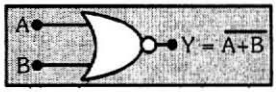
❐ AND gate



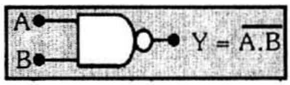
❐ NOT gate



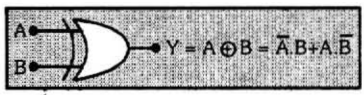
❐ NOR gate



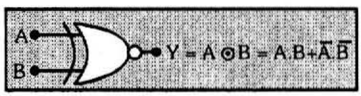
❐ NAND gate



❐ XOR gate



❐ XNOR gate



- **De Morgan's theorem** $\overline{A+B} = \overline{A} \bullet \overline{B}$, $\overline{A \bullet B} = \overline{A} + \overline{B}$

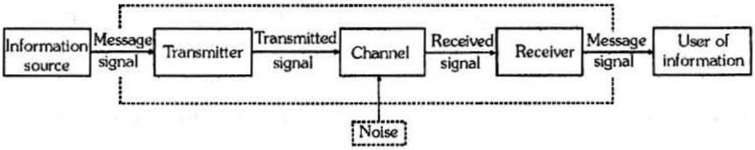
OR	AND	NOT
$A + 0 = A$	$A.\ 0 = 0$	$A + \overline{A} = 1$
$A + 1 = 1$	$A.\ 1 = A$	$A \cdot \overline{A} = 0$
$A + A = A$	$A\ .\ A = A$	$\overline{\overline{A}} \cdot A = A$

Important Notes

25 Communication System

Faithful transmission of information from one place to another place is called communication.

Basic components of a communication system



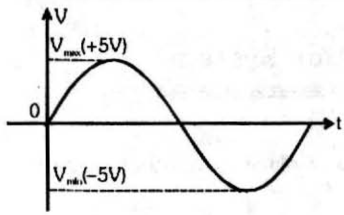
- **Transmitter :** Transmitter converts the message signal produced by information source into a form (e.g. electrial signal) that is suitable for transmission through the channel to the receiver.
- **Communication channel** : Communication channel is a medium (transmission line, an optical fibre or free space etc) which connects a receiver and a transmitter. It carries the modulated wave from the transmitter to the receiver.
- **Receiver** : It receives and decode the signal into original form.

Important terms used in communication

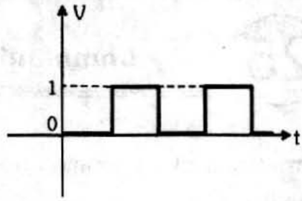
- **Transducer.** Transducer is the device that converts one form of energy into another. Microphone, photo detectors and piezoelectric sensors are types of transducer.
- **Signal** Signal is the information converted in electrical form. Signals can be analog or digital. Sound and picture signals in TV are analog.

  It is defined as a single–valued function of time which has a unique value at every instant of time.

  - **Analog Signal :–** A continuously varying signal (Voltage or Current) is called an analog signal. A decimal number with system base 10 is used to deal with analog signal.
  - **Digital Signal :–** A signal that can have only discrete stepwise values is called a digital signal. A binary number system with base 2 is used to deal with digital signals.

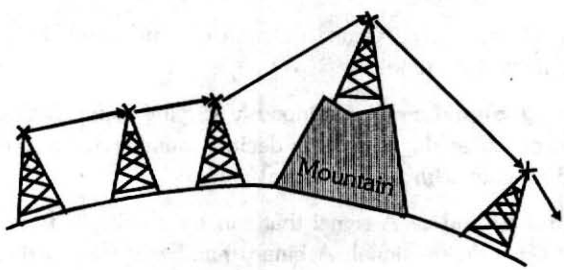


An analog signal



A Digital Signal

- **Noise :** There are unwanted signals that tend to disturb the transmission and processing of message signals. The source of noise can be inside or outside the system.
- **Attenuation :** It is the loss of strength of a signals while propagating through a medium. It is like damping of oscillations.
- **Amplification :** It is the process of increasing the amplitude (and therefore the strength) of a signal using an electronic circuit called the amplifier. Amplification is absolutely necessary to compensate for the attenuation of the signal in communication systems.
- **Range :** It is the largest distance between the source and the destination upto which the signal is received with sufficient strength.
- **Repeater :** A repeater acts as a receiver and a transmitter. A repeater picks up the signal which is coming from the transmitter, amplifies and retransmits it with a change in carrier frequency. Repeaters are necessary to extend the range of a communication system as shown in figure A communication satellite is basically a repeater station in space.



Use of repeater station to increase the range of communication

BANDWIDTH

- **Bandwidth of signals :** Different signals used in a communication system such as voice, music, picture, computer data etc. all have different ranges of frequency. The difference of maximum and minimum frequency in the range of each signal is called bandwidth of that signal.

  Bandwidth can be of message signal as well as of transmission medium.

  (i) Bandwidth for analog signals : Bandwidth for some analog signals are listed below :

Signal	Frequency range	Bandwidth required
Speech	300-3100 Hz	3100-300 =2800 Hz
Music	High frequencies produced by musical instrument audible range =20 Hz - 20 kHz	20 kHz
Picture	—	4.2 MHz
TV	Contains both voice and picture	6 MHz

  (ii) Bandwidth for digital signal : Basically digital signals are rectangular waves and these can be splited into a superposition of sinusoidal waves of frequencies ν_0, $2\nu_0$, $3\nu_0$, $4\nu_0$, ..$n\nu_0$, where n is an integer extending to infinity. This implies that the infinite band width is required to reproduce the rectangular waves. However, for practical purposes, higher harmonics are neglected for limiting the bandwidth

Bandwidth of Transmission Medium

Different types of transmission media offer different band width of which some are listed below

	Service	Frequency range	Remarks
1	Wire (most common : Coaxial Cable)	750 MHz (Bandwidth)	Normally operated below 18 GHz
2	Free space (radio waves)	540 kHz-4.2 GHz	
	(i) Standard AM	540 kHz to 30 MHz	
	(ii) FM	88-108 MHz	
	(iii) Television	54-72 MHz 76-88 MHz 174-216 MHz 420-890 MHz	VHF (Very high frequencies) TV UHF (Ultra hight frequency) TV
	(iv) Cellular mobile radio	896-901 MHz 840-935 MHz	Mobile to base Station Base station to mobile
	(v) Satellite Communication	5.925-6.425 GHz 3.7 - 4.2 GHz	Uplinking Downlinking
3	Optical communication using fibres	1THz-1000 THz (microwaves- ultra violet)	One single optical fibre offers bandwidth > 100 GHz

Ground Wave Propagation :

(a) The radio waves which travel through atmosphere following the surface of earth are known as ground waves or surface waves and their propagation is called ground wave propagation or surface wave propagation. These waves are vertically polarised in order to prevent short-circuiting of the electric component. The electrical field due to the wave induce charges in the earth's surface. As the wave travels, the induced charges in the earth also travel along it. This constitutes a current in the earth's surface. As the ground wave passes over the surface of the earth, it is weakened as a result of energy absorbed by the earth. Due to these losses the ground waves are not suited for very long range communication. Further these losses are higher for high frequency. Hence, ground wave propagation can be sustained only at low frequencies (500 kHz to 1500 kHz).

(b) The ground wave transmission becomes weaker with increase in frequency because more absorption of ground waves takes place at higher frequency during propagation through atmosphere.

(c) The ground wave propagation is suitable for low and medium frequency i.e. upto 2 MHz only.

(d) The ground wave propagation is generally used for local band broadcasting and is commonly called medium wave.

(e) The maximum range of ground or surface wave propagation depends on two factors :

(i) The frequency of the radio waves and (ii) Power of the transmitter

Sky Wave Propagation :

(a) The sky waves are the radio waves of frequency between 2 MHz to 30 MHz.

(b) The ionoopheric layer acts as a reflector for a certain range of frequencies (3 to 30 MHz). Therefore it is also called has inospheric propagation or short wave propagation. Electromagnetic waves of frequencies higher than 30 MHz penetrate the ionosphere and escape.

(c) The highest frequency of radio waves which when sent straight (i.e. normally) towards the layer of ionosphere gets reflected from ionosphere and returns to the earth is called critical frequency. It is given by $\boxed{f_c = 9\sqrt{N_{max}}}$, where N is the number density of electron/m^3.

Space wave propagation :

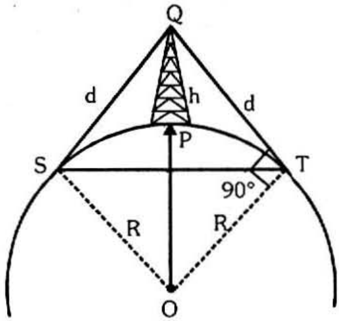
(a) The space waves are the radio waves of very high frequency (i.e. between 30 MHz. to 300 MHz or more).

(b) The space waves can travel through atmosphere from transmitter antenna to receiver antenna either directly or after reflection from ground in the earth's troposphere region. That is why the space wave propagation is also called as tropospherical propagation or line of sight propagation.

(c) The range of communication of space wave propagation can be increased by increasing the heights of transmitting and receiving antenna.

(d) **Height of transmitting Antenna :**

The transmitted waves, travelling in a straight line, directly reach the received end and are then picked up by the receiving antenna as shown in figure. Due to finite curvature of the earth, such waves cannot be seen beyond the tangent points S and T.



$(R+h)^2 = R^2 + d^2$

As R>>h, So $h^2 + 2Rh = d^2$

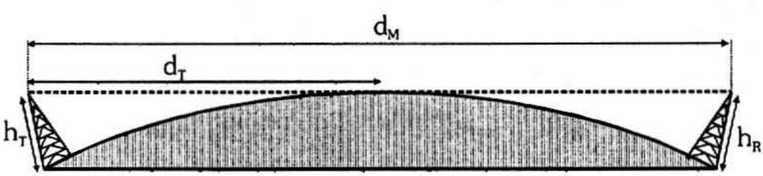
$\Rightarrow d = \sqrt{2Rh}$

Area covered for TV transmission : $A = \pi d^2 = 2\pi Rh$

Population covered = population density × area covered

If height of receiving antenna is also given in the question then the maximum line of sight

$$d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$



Line of sight communication by space waves

where ;

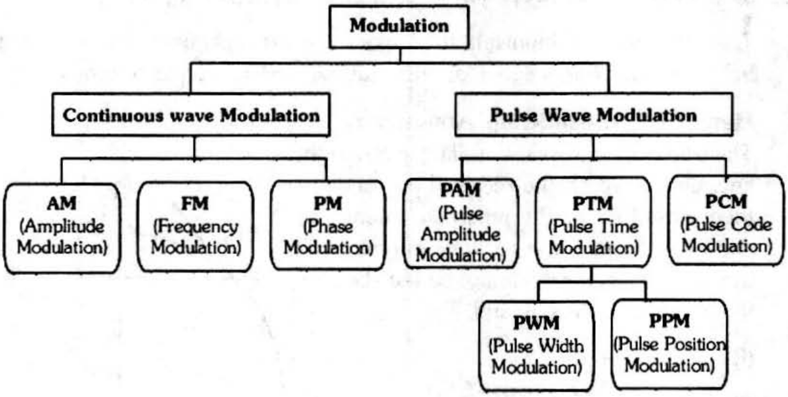
R=radius of earth (approximately 6400 km)

h_T = height of transmitting antenna

h_R = height of receiving antenna

MODULATION

The phenomenon of superposition of information signal over a high frequency carrier wave is called modulation. In this process, amplitude, frequency or phase angle of a high frequency carrier wave is modified in accordance with the instantaneous value of the low frequency information.



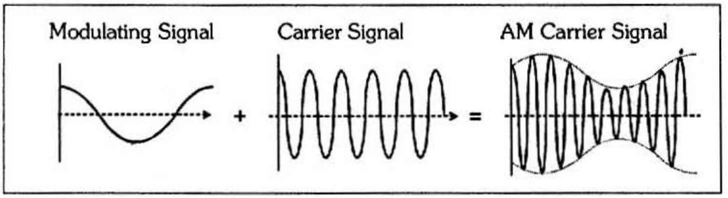
Need for Modulation :

(i) To avoid interference: If many modulating signals travel directly through the same transmission channel, they will interfere with each other and result in distortion.

(ii) To design antennas of practical size : The minimum height of antenna (not of antenna tower) should be $\lambda/4$ where λ is wavelength of modulating signal. This minimum size becomes impracticale because the frequency of the modulating signal can be upto 5 kHz which corresponds to a wavelength of $3 \times 10^8/5 \times 10^3 = 60$ km. This will require an antenna of the minimum height of $\lambda/4 = 15$ km. This size of an antenna is not practical.

(iii) Effective Power Radiated by an Antenna : A theoretical study of radiation from a linear antenna (length ℓ) shows that the power radiated is proportional to (frequency)^2 i.e. $(\ell/\lambda)^2$. For a good transmission, we need high powers and hence this also points out to the need of using high frequency transmission.

Amplitude Modulation :



Modulation factor, $m = \dfrac{\text{amplitude of modulating wave}}{\text{amplitude of normal carrier wave}}$

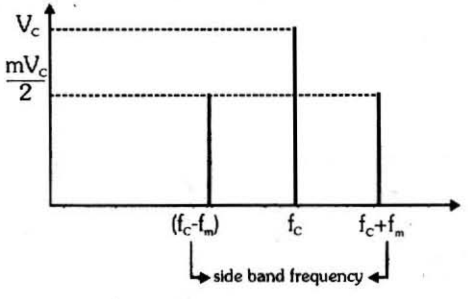
If $v_m = V_m \cos\omega_m t$ and $v_c = V_c \cos\omega_c t$ then $m = \dfrac{V_m}{V_c}$

- As amplitude of the carrier wave varies at signal frequency f_m so the amplitude of AM wave = $V_C + mV_C \cos\omega_m t$ & frequency of AM wave = $\dfrac{\omega_c}{2\pi}$

Therefore $v = \left[V_c(1+m)\cos\omega_m t\right]\cos\omega_c t$

$$\Rightarrow v = V_C\cos\omega_c t + \frac{mV_C}{2}\cos(\omega_C+\omega_m)t + \frac{mV_C}{2}\cos(\omega_C-\omega_m)t$$

Frequency spectrum of AM wave



Power in AM wave :

- Power of carrier wave : $P_C = \dfrac{V_C^2}{2R}$ where R = resistance of antenna in which power is dissipated.

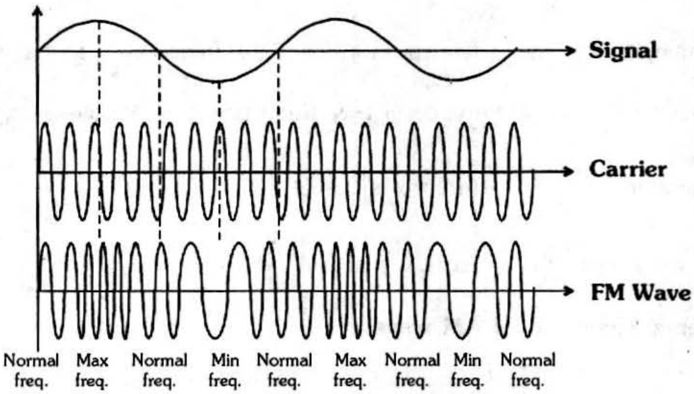
- Total power of side bands : $P_{sidebands} = 2 \times \frac{1}{2R}\left(\frac{mV_C}{2}\right)^2 = \frac{m^2}{2}P_C$

- Total power of AM wave = $P_C\left(1+\frac{m^2}{2}\right)$

- Fraction of total power carried by sidebands = $\frac{m^2}{2+m^2}$

Frequency Modulation (FM) :

When the frequency of carries wave is changed in accordance with the instantaneous value of the modulating signal, it is called frequency modulation.



MODULATION FACTOR OR INDEX AND CARRIER SWING (CS)

- ***Modulation factor*** : $m = \frac{\text{max. frequency deviation}}{\text{Modulating frequency}} = \frac{\Delta f}{f_m}$

$$\Delta f = f_{max.} - f_c = f_c - f_{min.} \ ; \ v_{FM} = V_C \cos[\omega_C t + m_f \cos\omega_m t]$$

- ***Carrier Swing (CS)***

  The total variation in frequency from the lowest to the highest is called the carrier swing ⇒ CS = 2xΔf

- ***Side Bands***

  FM wave consists of an infinite number of side frequency components on each side of the carrier frequency f_C, $f_C \pm f_m$, $f_C \pm 2f_m$, $f_C \pm 3f_m$, & so on.

	Amplitude Modulation		Frequency Modulation
1	The amplitude of FM wave is constant, whatever be the modulation index.	1	The amplitude of AM signal varies depending on modulation index.
2	It require much wider channel (Band width) [7 to 15 times] as compared to AM.	2	Band width* is very small (One of the biggest advantage).
3	Transmitters are complex and hence expensive.	3	Relatively simple and cheap.
4	Area of reception is small since it is limited to line of sight. (This limits the FM mobile communication over a wide area)	4	Area of reception is Large.
5	Noise can be easily minimised amplitude variation can be eliminated by using limiter.	5	It is difficult to eliminate effect of noise.
6	Power contained in the FM wave is useful. Hence full transmitted power is useful.	6	Most of the power which contained in carrier is not useful. Therefore carrier power transmitted is a waste.
7	The average power is the same as the carrier wave.	7	The average power in modulated wave is greater than carrier power.
8	No restriction is placed on modulation index (m).	8	Maximum m = 1, otherwise over modulation (m > 1) would result in distortion.
9	It is possible to operate several independent transmitter on same frequency.	9	It is not possible to operate without interference.

MODEM :

The name modem is a contraction of the terms Modulator and Demodulator. Modem is a device which can modulate as well as demodulate the signal.

FAX (Facsimile Telegraphy)

FAX is abbreviation for facsimile which means exact reproduction. The electronic reproduction of a document at a distnace place is called Fax.

Important Notes

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26 Important Tables

26 (a) SOME FUNDAMENTAL CONSTANTS

Gravitational constant (G)	=	6.67×10^{-11} N m^2 kg^{-2}
Speed of light in vacuum (c)	=	3×10^8 ms^{-1}
Permeability of vacuum (μ_0)	=	$4\pi \times 10^{-7}$ H m^{-1}
Permittivity of vacuum (ε_0)	=	8.85×10^{-12} F m^{-1}
Planck constant (h)	=	6.63×10^{-34} Js
Atomic mass unit (amu)	=	1.66×10^{-27} kg
Energy equivalent of 1 amu	=	931.5 MeV
Electron rest mass (m_e)	=	9.1×10^{-31} kg = 0.511 MeV
Avogadro constant (N_A)	=	6.02×10^{23} mol^{-1}
Faraday constant (F)	=	9.648×10^4 C mol^{-1}
Stefan-Boltzman constant (σ)	=	5.67×10^{-8} W m^{-2} K^{-4}
Wien constant (b)	=	2.89×10^{-3} mK
Rydberg constant (R_∞)	=	1.097×10^7 m^{-1}
Triple point for water	=	273.16 K (0.01°C)
Molar volume of ideal gas (NTP)	=	22.4×10^{-3} m^3 mol^{-1}

26 (b) CONVERSIONS

- 1 year = 365.24 days = 3.16×10^7 s
- 1 day = 24 h = 8.64×10^4 s
- 1 J = 10^7 ergs
- 1 cal = 4.184 J
- 1 eV = 1.6×10^{-19} J
- 1 hp = 0.746 kW
- 1 bar = 10^5 N/m^2
- 1 fm = 10^{-15} m
- 1 atm = 760 mm Hg = 76 cm Hg = 1.013×10^5 N/m^2 = 1.013×10^5 Pa
- 1 light year = 9.46×10^{12} km
- 1 Parsec = 3.26 ly
- 1 Btu = 1055 J = 252 cal
- 1 kWh = 3.6×10^6 J
- 1 T = 1 Wb m^{-2} = 10^4 G

2 (c) Notations for Units of Measurement

- A → ampere
- Å → angstrom
- amu → atomic mass unit
- atm → atmosphere
- Btu → British thermal unit
- C → coulomb
- °C → degree Celsius
- cal → calorie
- deg → degree (angle)
- eV → electronvolt
- F → farad
- fm → femtometer
- ft → foot
- G → gauss
- g → gram
- H → henry
- h → hour
- hp → horse power
- Hz → hertz
- J → joule
- K → kelvin
- m → meter
- min → minute
- Mx → maxwell
- Oe → oersted
- Pa → pascal
- Ω → ohm
- rad → radian
- s → second
- S → siemens
- T → tesla
- V → volt
- W → watt
- Wb → weber

26 (d) Decimal Prefixes for Units of Measurement

- T → tera (10^{12})
- G → giga (10^{9})
- M → mega (10^{6})
- k → kilo (10^{3})
- h → hecto (10^{2})
- da → deca (10^{1})
- d → deci (10^{-1})
- c → centi (10^{-2})
- m → milli (10^{-3})
- μ → micro (10^{-6})
- n → nano (10^{-9})
- p → pico (10^{-12})

27 Dictionary of Physics

- **Abbe number**

  Reciprocal of the dispersive power of a substance.

- **Absorption Coefficient**

  Measure of rate of decrease in intensity of em radiation when it is passes through the given substance.

- **Admittance**

  Reciprocal of impedance. It refers to the measure of the ability of a circuit to conduct an alternating current.

- **Aclinic line**

  The line joining the places of zero dip. This line is also known as magnetic equator and goes nearly side by side with geographical equator.

- **Acoustics**

  Branch of physics that is concerned with the study of sound & sound waves.

- **Actinometer**

  Instruments for measuring the intensity of em radiation.

- **Agonic line**

  The line of zero declination.

- **Albedo**

  Ratio of the amount of light reflected from a surface to the amount of incident light.

- **Alfa-decay**

  A form of radioactive decay where a radioactive nuclei spontaneously emits α-particles (nuclei of ${}_2He^4$)

- **Alternator**

  Any device that is used to generate an alternating current.

- **Altimeter** An electronic device that indicates altitudue above the surface of earth.

- **Amalgam**

  An alloy (a material consisting of two or more elements e.g. brass is an alloy of Cu and Zn, steel is an alloy of iron & carbon) one of whose constituents is mercury (Hg)

- **Ammeter**

  An instrument used to measure electric current.

■ **Ampere-hour**

A practical unit of electric charge equal to the charge flowing in one hour through a conductor passing one ampere. It is equal to 3600 coulombs.

■ **Ampere-rule**

A rule that relates the direction of the electric current passing through a conductor and the magnetic field associated with it. The rule states that if the electric current is moving away from an observer, the direction of the lines of force of the magnetic field surrounding the conductor is clockwise and that if the electric current is moving towards an observer, the direction of the lines of force is counter clockwise.

■ **Amorphous**

A solid that is not crystalline i.e. one that has no long range order in its lattice. Example : Glass.

■ **Amplifier**

A device that increases the strength of an electrical signal by drawing energy from a separate dc source to that of the signal.

■ **Anisotropic**

Substance showing different physical properties in different directions.

■ **Aperture**

The size of the opening that admit light in an optical instrument. The effective diameter of mirror and lens.

■ **Aphelion**

The farthest point in the orbit of planet, comet and artificial satellite around the sun. The earth is at aphelion on about july 3.

■ **Apogee**

Maximum distance of a satellite from the earth during its orbit around the earth.

■ **Asteroids or minor planets**

Small bodies that revolve around the sun.

■ **Astrology**

Branch of science that is concerned with the study of influence of heavenly bodies on human affairs.

■ **Astronomical unit AU**

A unit of distance in astrology in the solar system. It is equal to the mean distance of sun from earth ($\sim 1.496 \times 10^{11}$ m)

■ **Astronomy**

The study of the universe beyond the earth's atmosphere.

- **Atomic clock**

  A highly accurate clock. It is regulated by the resonance frequency of atoms or molecules of certain substances such as cesium.

- **Atomic mass unit (a.m.u.)**

  A unit of mass used to express "relative atomic masses. It is 1/12 of the mass of an atom of the isotope carbon-12 and is equal to 1.66033×10^{-27} kg.

- **Atomiser**

  A device that is used for reducing liquid to a fine spray.

- **Aurora**

  An intermittent electrical discharge that takes place in rarefied upper atmosphere. Charge particles in the solar wind (or cosmic - rays) becomes trapped in the earth's magnetic field and move in helical paths along the lines of force between the two magnetic poles. The intensity of the aurora is greatest in polar regions although it is seen in temperate zones.

- **Autotransformer**

  A transformer having a single winding instead of two or more independent windings.

- **Avogadro constant**

  Symbol N_A. The number of atoms or molecules in one mole of substance. It has the value $6.0221367\ (36) \times 10^{23}$. Formerly it was called Avogadro's number.

- **Avogadro's Law**

  Equal volumes of all gases contain equal numbers of molecules at the same pressure and temperatue. The law, often called Avogadro's hypothesis, is true only for ideal gases. It was first proposed in 1811 by Amadeo Avogadro.

- **Ballistic galvanometer :**

  A device used to measure the total amount of charge that passes through a circuit due to a momentary current.

- **Band spectrum**

  In such a spectrum there appears a number of bands of emitted or absorbed radiations. This type of spectrum are characteristic of molecules.

- **Band width**

  It refers to the width of the range of frequencies.

- **Barn**

  A unit of area & generally used for measuring nuclear cross section (1 barn $=10^{-28}$ m^2)

- **Barometer**

  A device used to measure atmospheric pressure.

- **Becquerel**

  SI unit of radio-activity (1Bq = 1 disintegration/sec. = $\frac{1}{3.7 \times 10^{10}}$ curie)

- **Bel**

  Ten decibels (10 dB)

- **β-rays**

  A stream of β-particles (fast moving electrons)

- **Betatron**

  A device used to accelerate the electrons.

- **Bevatron**

  An accelerator used to accelerate protons and other particles to very high energies.

- **Binary star**

  A system of two stars which revolve around a common centre of gravity.

- **Binding energy**

  The energy required to separate the nucleons (protons & neutrons) of a nucleus from each other. The binding energy per nucleon is least for very light and very heavy nuclei and nearly constant (~ 8 MeV/nucleon) for medium nuclei.

- **Bipolar transistor**

  A transistor that uses two type of charge carries (electrons & holes) for its operation.

- **Black body**

  A perfectly black body is one that absorbs completely all the radiations falling on it. Its absorptance and emissivity are both equal to 1.

- **Black hole (collapsar)**

  An astronomical body having so high gravitational field in which neither matter particles nor photons can escape (they captured permanently from the outside)

- **Bolometer**

  A device used to measure amount of radiation by means of changes in the resistance of an electric conductor caused due to changes in its temperature.

- **Boson**

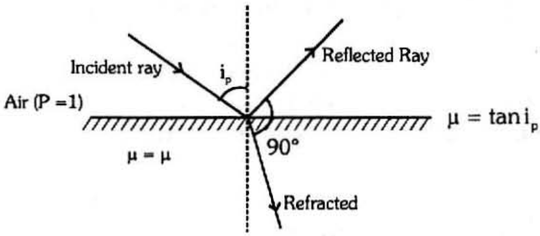
  An elementary particle with integral spin. ex. : photon.

- **Bragg's law**

  When an X - ray beam of wavelength λ is incident on a crystal of interplaner spacing d at grazing angle [complement of the angle of incidence] then the direction of diffraction maxima are given by $2d \sin\theta = n\lambda$, which is known as Bragg's law.

- **Brewster's law**

  The extent of the polarization of light reflected from a transparent surface is a maximum when the reflected ray is at right angles to the refracted ray. The angle of incidence (and reflection) at which this maximum polarization occurs is called the Brewster angle or polarizing angle.



- **British Thermal Unit (BTU)**

  Quantity of heat required to raise the temperature of 1 pound of water thorugh 1°C.

- **Bulk modulus (K)**

$$K = \frac{\text{stress}}{\text{volume strain}} = \frac{\Delta P}{(\Delta V / V)} = \frac{1}{\text{compressibility}}$$

- **Calibration**

  It is the process of determining the absolute values corresponding to the graduations on an arbitrary or inaccurate scale on an instrument.

- **Calipers**

  An instrument used for measuring internal and external diameters. it is a graduated rule with one fixed and one sliding jaw.

- **Caloric theory**

  It regards heat as a weightless fluid. It has now been abandoned.

- **Calorie**

  It is equal to the amount of heat required to raise the temperature of 1 gram of water thorugh 1°C. 1 cal = 4.2 Joules.

- **Calorific value**

  The quantity of heat liberated on complete combustion of unit mass of a fuel. The determination is done in a bomb calorimeter and the value is generally expressed in J kg^{-1}.

- **Calorimeter**

  An instrument used for measuring quantity of heat. It consists of an open cylinderical container of copper or some other substance of known heat capacity.

- **Calorimetry**

  It is the study of the measurement of quantities of heat.

- **Canal rays, Anode rays, Positive rays :**

  Positively charged rays produced during the discharge of electricity in gases.

- **Candela**

  It is a S.I. unit of luminous intensity. It is equal to 1/60 of the luminous intensity of a square centimeter of a black body heated to the temperature of solidification of platinum (1773.5°C) under a pressure of 101325 N/m^2 in the perpendicular direction.

- **Cannon**

  A mounted gun for firing heavy projectiles.

- **Capacitor**

  It is a device which is used for storing electric charge. It consists of two metal plates separated by an insulator. It is also known as **condenser**.

- **Capacitive reactance**

  It is the opposition offered by a capacitance to the flow of alternating current.

  $X_C = \frac{1}{2\pi fC}$ Where

  X_c = capacitive reactance in ohms

  f = frequency in cycles/sec

  C = capacitance in farads

- **Capillary action or Capillarity**

  The phenomenon of rise or fall of a liquid in a capillary tube when it is dipped in the liquid. Due to this the portion of the surface of the liquid coming in contact with a solid is elevated or depressed.

- **Carat**

  • A measure of fineness (purity) of gold. Pure gold is described as 24-carat gold. 14-carat gold contains 14 parts in 24 of gold, the remainder usually being copper.

  • A unit of mass equal to 0.200 gram, used to measure the masses of diamonds and other gemstones.

- **Capillary tube**

  A tube having a very small internal diameter.

- **Carbon dating**

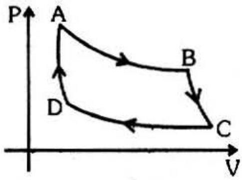
  It is a method used to determine the age of materials that contain matter of living organism. It consists of determining the ratio of $^{12}_{6}C$ to $^{14}_{6}C$.

- **Carbonize**

  Means to enrich with carbon.

- **Carnot cycle**

  It is a reversible cycle and consists of two isothermal ($A \rightarrow B$ and $C \rightarrow D$) & two adiabatic ($B \rightarrow C$, $D \rightarrow A$) changes.



- **Carnot theorem**

- The efficiency of a reversible heat engine (carnot engine) working between any two temperatures is greater than the efficiency of any heat engine working between the same two temperatures.
- The efficiency of a reversible heat engine depends only on the temperature of the source and the sink and is independent of the working substance.

- **Cathode**

  The electrode that emits electrons or gives off negative ions and toward which positive ions move or collect in a voltaic cell, electron or X-ray tube etc.

- **Cathode ray**

  The rays emitted in a discharge tube when the pressure falls to about 10^{-4} mm of mercury.

- **Cathode-ray oscilloscope or CRO**

  An instrument based on the cathode-ray tube that provides a visual image of electrical signals.

- **Cathode ray tube**

  A vacuum tube generating a focussed beam of electrons that can be deflected by electric and magnetic fields.

- **Cation**

  A positively charged ion i.e. Na^+, Ba^{2+} etc.

- **Cauchy dispersion formula**

  A formula for the dispersion of light of the form : $n = A + \left(\frac{B}{\lambda^2}\right) + \left(\frac{C}{\lambda^4}\right)$,

  where n is the refractive index, λ the wavelength, and A , B, and C are constants. Sometimes only the first two terms are necessary.

- **Centre of buoyancy**

  It is the point through which the resultant of the buoyancy forces on a submerged body act, it coincides with the centre of gravity of the displaced fluid.

- **Centre of gravity**

  It is the point through which the weight of the body acts. It is the point where the whole of the weight of the body may be supposed to be concentrated.

- **Centre of mass**

  For any system it is the point at which the whole of the mass of the body (or system) may be considered to be acting for determining the effect of some external force.

- **Cerenkov radiation**

  Electromagnetic radiation, usually bluish light, emitted by a beam of high-energy charged particles passing through a transparent medium at a speed greater than the speed of light in that medium. It was discovered in 1934 by the Russian physicist Pavel Cerenkov (1904). The effect is similar to that of a sonic boom when an object moves faster than the speed of sound ; in this case the radiation is a shock wave set up in the electromagnetic field. Cerenkov radiation is used in the Cerenkov counter.

- **Chip**

  A very small semi-conductor having a component (transistor, resistor, etc.) or an integrated circuit.

- **Choke**

  It is a coil of high inductance and low resistance which is used to block or reduce the high frequency components of an electrical signal.

- **Chromatic aberration**

  It is a defect of the image formed by a lens (but not a mirror), in which different colours come to focus at different points. It can be corrected by using a suitable combination of lenses.

- **Circuit breaker**

  It is a device that is used for interrupting an electric circuit when the current becomes excessive.

- **Classical physics**

  Refers to the physics that has been developed before the introduction of quantum theory.

- **Classical mechanics**

The branch of mechanics based on Newton's laws of motion. It is applicable to those systems which are so large that in their case Planck's constant can be neglected.

- **Closed end organ pipe**

In these case one end of the pipe is closed. In them first harmonic is given by $\lambda/4$. In such cases only the odd harmonics are produced and even harmonics are missing. Fundamental frequency = $v/4\ell$

- **Coefficient of expansion**

It is the increase in unit length, area or volume per degree rise in temperature.

- **Coefficient of friction** $\mu = \frac{f}{R}$

Where f = Limiting friction . R = Normal reaction

Also $\mu = \tan\theta$; where θ = angle of friction

- **Coefficient of restitution**

The ratio of the relative velocity of two bodies after direct impact to that before impact.

- **Coefficient of mutual inductance**

- It is numerically equal to the magnetic flux linked with one circuit when unit current flows through it. The effective flux N_s linked with secondary circuit is given by $N_s = Mi$
- It is numerically equal to the e.m.f. induced in one circuit when the rate of change of current in the other is unity. The e.m.f. induced in a secondary coil, when the rate of change of current with time in primary coil is $\frac{di}{dt}$ is given by, $e_s = M\frac{di}{dt}$

- **Coefficient of thermal conductivity (K)**

It is the amount of heat flowing in one second across the $1m^2$ area, of a 1 metre rod, maintained at a temperature difference of 1°C.

- **Coefficient of viscosity**

It is the tangential force required to maintain a unit velocity gradient between two layers of unit area. Its units are Nsm^{-2} or poiseulle or decapoise.

- **Coefficient of self - induction**

- It is numerically equal to the magnetic flux linked with the coil when the unit current flows through it. The effective flux N is given by N = Li where i = curent flowing through the circuit.
- It is numerically equal to the e.m.f. induced in the circuit when the rate of change of current is unity.
- It is numerically equal to twice the work done against the induced e.m.f. in establishing unit current in the coil.

- **Coercive force**

  It is the magnetic intenstiy required to reduce the magnetic induction in a previously magnetised material to zero.

- **Complementary colours**

  A pair of colours which, when combined give the effect of white light. A large number of such pairs are possible.

- **Compound microscope**

  A microscope consisting of an objective lens with a short focal length and an eye piece of a longer focal length, mounted in the same tube.

- **Compound pendulum**

  In such a pendulum the moment of the restoring force is $\tau = \text{mgd}\sin\theta$ If θ (in radians) is sufficiently small, then $\tau = -\text{mgd}\ \theta$. Time period of such a pendulum is $T=2\pi\sqrt{\frac{I}{Mgd}}=2\pi\sqrt{\frac{\ell}{g}}$

- **Compton effect**

  The phenomenon according to which the wave length of radiation scattered by a particle is greater than that of the original radiation is called compton effect.

- **Condensation**

  A change of state from vapour to liquid. In this state the vapour pressure becomes equal to the saturated vapour pressure (SVP) of liquid state.

- **Conductance**

  It is the reciprocal of resistance. It is the ability of a conductor to transmit current. Its unit is mho, ohm^{-1} or siemens.

- **Conduction**

  A method of heat transfer. In this mode of heat transfer the particles do not move.

- **Conservation of angular momentum**

  In the absence of any external torque the total angular momentum of a system remains unchanged.

- **Conservation of charge**

  For an isolated system the total charge remains constant.

- **Conservation of linear momentum**

  In the absence of any external force the total linear momentum of the system remains constant.

- **Conservation of mass and energy**

  The total energy of a closed system, viz., rest mass energy + kinetic energy + potential energy remains constant. This principle treats the rest mass as energy. The rest mass energy of a particle having rest mass m_0 is $m_0 c^2$.

- **Conservative field**

  It is that vector field for which the line integral depends on the end points of the path only and is independent of the path. A conservative field can always be expressed as the gradient of a scalar field.

- **Constantan**

  An alloy containing about 50% copper and 50% nickel having a comparatively high resistance and low temperature coefficient of resistance.

- **Convection**

  A mode of heat transfer. In this mode the movement of particles occur.

- **Corona discharge**

  A discharge, generally luminous, at the surface of a conductor or between two conductors of the same transmission line.

- **Corpuscular theory of light** It assumes that light travels as particles or corpuscles. It is useful to explain reflection, refraction etc. It can not explain diffraction, polarisation etc.

- **Cosmic rays**

  These are high energy radiations. These consist of protons and some α-particles, electrons and other atomic nuclei and γ-rays reaching the earth from space.

- **Cosmology**

  The branch of astonomy that deals with the evolution, general structure, and nature of the universe as a whole.

- **Critical mass**

  It is the minimum mass of a fissile material that will sustain a chain reaction.

- **Critical pressure**

  It is the saturated vapour pressure of a liquid at its critical temperature.

- **Critical temperature**

  It is the temperature above which a gas can not be liquified by increasing the pressure alone.

- **Critical velocity**

  The velocity of fluid flow at which the motion changes from laminar to turbulent flow.

- **Critical volume**

  The volume of a certain mass of substance measured at critical pressure and temperature.

- **Cryogenics**

  The study of the production and effects of very low temperatures. A cryogen is a refrigerant used for obtaning very low temperatures.

- **Cryometer**

  A thermometer designed to measure low temperatures.

- **Curie**

  A unit to measure the activity of a radioactive substance (see radio activity) It is the quantity of radon in radioactive equilibrium with 1 g of radium. Also defined as that quantity of a radioactive isotope which decays at the rate of 3.7×10^{10} disintegrations per second. Named after Madame Curie (1867-1984).

- **Curie's law**

  The value of (χ) susceptibility of a paramagnetic substance is inversely proportional to its absolute temperature $\chi \propto \frac{1}{T}$

- **Cyclotron**

  An accelerator in which particles move in a spiral path under the influence of an alternating voltage and a magnetic field.

- **Daughter nucleus**

  Refers to the nucleus that results from the radioactive decay of another nucleus known as parent nucleus.

- **Dead beat galvanometer**

  A galvanometer which is damped so that its oscillations die away very quickly. In such galvanometer its resistance is less than its critical damping resistance.

- **De broglie wavelength**

  The wavelength of the wave associated with a moving particle. The wavelength (λ) is given by $\lambda = h/mv$, where h is the Planck constant, m is the mass of the particle, and v its velocity. The de Broglie wave was first suggested by the French physicist Louis de Broglie (1892-) in 1924 on the grounds that electromagnetic waves can be treated as particles and one could therefore expect particles to behave in some circumstances like waves. The subsequent observation of electron diffraction substantiated this argument and the de Broglie wave became the basis of wave mechanics.

- **Debye length**

  It is the maximum distance at which coulombs fields of charged particles in a plasma may be expected to interact.

- **Deca**

  Symbol : The prefix meaning 10, e.g. 1 decameter=10 metres.

- **Deci**

  A prefix measuring 10^{-1}

- **Decibel dB**

  A unit for expressing the intensity of a sound wave. It is measured on a logarithmic scale.

- **Declination**

  The horizontal angle between the directions of true north and magnetic north.

- **Delta-ray**

  A low energy electron emitted by a substance after bombardment by high energy particles (e.g. α-particles)

- **Degrees of freedom**

  The number of independent co-ordinates needed to define the state of a system.

- **Demagnetisation**

  To remove the ferromagnetic properties of a body. It can be done by disordering the domain structure.

- **Deutron**

  Nucleus of deuterium atom. It consists of one proton and one neutron.

- **Dew**

  Water droplets formed due to condensation of water vapour in the air when the temperature of air drops so that the quantity of vapour present at that temperature reaches saturation.

- **Dew point**

  It is the temperature to which air must be cooled for dew to form. At this temperature air becomes saturated with water vapours present in it.

- **Dew point hygrometer**

  It is an instrument used for determination of relative humidity.

- **Diamagnetic substances**

  Refers to those substances that have a negative value of susceptibility. They are repelled when placed in a magnetic field.

- **Diamagnetism**

  Diamagnetic substances when placed in a magnetic field get feebly magnetised in direction opposite to that of magnetising field. This property of diamagnetic substances is known as diamagnetism.

- **Dielectric**

  Refers to an insulator, a non-conducting substance.

- **Dielectric constant (Relative permittivity)**

  $$\text{Dielectric constant } \frac{\text{Absolute permittivity of the medium}}{\text{Absolute permittivity of vacuum}} = \frac{\epsilon}{\epsilon_0} = \epsilon_r = K$$

- **Dielectric strength**

  Refers to the maximum electric field that a dielectric is capable of withstanding without a break down.

- **Diffraction**

  It refers to the bending of light round an obstacle.

- **Diffraction grating**

  A glass plate with a very large number of closely spaced parallel lines (usually more than 5000 to the inch) scrapped across it. These are used for diffracting light to produce optical spectra.

- **Diffusion length**

  It is the average distance that is travelled by minority carriers between generation and recombination in a semiconductor.

- **Dioptre**

  It is a unit of measurement of the refractive power of a lens. It is equal to the reciprocal of the focal length of a lens expressed in metres.

- **Dip, Inclination (ϕ)**

  The dip at a place is the angle which the earth's field makes with earth's surface at a place.

- **Dip circle**

  It is an instrument that is used to measure the angle of dip at a place. It consists of a magnetic needle mounted in such a way that it can rotate in a vertical plane. The angle is measured on a circular scale.

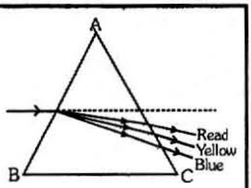
- **Dipole**

  Refers to two equal and opposite electric charges (or magnetic poles) separated by a distance.

- **Dipole moment**

  It is equal to the product of pole strength and the length of magnetic electric dipole.

Dispersion



The separation of white light into its constituent colours by refraction or other means is called dispersion of light.

Dispersive power (ω)

Dispersive power of the material of the prism is given by

$\omega = \dfrac{\mu_b - \mu_r}{\mu - 1}$ for blue & red rays. Where μ_b and μ_r are the refractive indices of blue and red rays respectively and μ is the refractive index for yellow rays.

Doping

It refers to the process of adding some amount of impurities in semi-conductors to achieve a desired conductivity.

Double refraction

When a beam of light is incident on certain materials, it breaks it into two plane polarised beams with their plane of polarisation perpendicular to each other. The two beams have different velocities in the medium. This phenomenon is called double refraction.

Dry ice

Solid carbon dioxide.

Ductility

Property by which metals are capable of being, drawn in wires.

Dulong and Petit's law

It states, "The product of atomic weight and specific heat of a solid element is approximately 6.4".

Dynamo

An electric generator. It produces direct current by converting mechanical energy into electrical energy. It consists of a strong electromagnet between the poles of which an armature is rotated, consisting of a number of coils suitably wound. It is based on the principle of electromagnetic induction.

Earthing

Refers to connecting an electrical conductor to earth which is assumed to have zero electric potential.

Earth's atmosphere

The gas that surrounds the earth. The composition of dry air at sea level is : nitrogen 78.08%, oxygen 20.95%, argon 0.93%, carbon dioxide 0.03%, neon 0.0018%, helium 0.005%, krypton 0.0001%, and xenon 0.00001% . In addition to water vapour, air in some localities contains sulphur compounds, hydrogen peroxide, hydrocarbons, and dust particles.

- **Eclipse**

  To prevent light from a source reaching an object. It refers to shadowing one heavenly body by another. In **solar eclipse** shadow of the moon falls on the earth when the sun, moon and earth are in line. In **lunar eclipse** shadow of the earth falls on the moon, when the earth is in between the sun and the moon.

- **Efficiency**

  The ratio of the useful energy output to the total energy input in any energy transfer. It is often given as percentage and has no units.

- **Effusion**

  The flow of gas through a small aperture.

- **Einstein's equation**

  Refers to the equation, maximum $KE_{max} = h\nu - \phi_0$ for the kinetic energy of electrons which are emitted in photoelectric effect, ν the frequency of incident radiation and ϕ_0 the work function of the photomaterial upon which the radiation is incident.

- **Einstein's law**

  Mathematically it can be expressed as $E = mc^2$.

- **Electric motor**

  A device that converts electrical energy into mechanical energy.

- **Electrocardiograph (ECG)**

  It is a sensitive instrument that records the voltage and current waveforms associated with the action of the heart. The trace obtained is called electrocardiogram.

- **Electroencephalograph (EEG)**

  A sensitive instrument that records the voltage waveforms associated with the brain. The trace obtained is called electroncephalogram.

- **Electrogen**

  A molecule that emits electrons on being illuminated.

- **Electron microscope**

  It is a type of microscope in which an electron beam is used to study very minute particles.

- **Electromagnet**

  A magnet formed by winding a coil of wire around a piece of soft iron. It behaves as a magnet as long as the current passes through the coil.

- **Electrometer**

  An instrument that is used for determining the potential difference between two charged bodies by measuring the electrostatic force between them.

- **Electroscope**

  A device consisting of two pieces of gold leaf enclosed in a glass walled chamber. It is used for detecting the presence of electric charge or for determining the sign of electric charge on a body.

- **Electrostatic shield**

  A conducting substance which protects a given apparatus against electric fields. It consists of a hollow conductor and completely surrounds the apparatus to be shielded.

- **Emissivity**

  The ability of a surface to emit radiant energy compared to that of a black body at the same temperature and with the same area.

- **Emissive power**

  The total energy emitted from unit area from the surface of a body per second.

- **Enthalpy (H)**

  $H = E = PV$, $H = U + PV$

  WhereU = Internal energy of the system.

  P = Pressure and V = Volume

- **Entropy (S)**

  A measure of the degree of disorder of a system. An increase in entropy is accompanied by a decrease in energy availability. When a system undergoes a reversible change then $\Delta S = \frac{\Delta Q}{T}$. The importance of entropy is that in any thermodynamic process that proceeds from one equilibrium state to another, the entropy of system + environment either remains unchanged or increases.

- **Evaporation**

  The change of state from liquid to gas which can occur at any temperature upto the boiling point. If a liquid is left in an open container for long enough it will all evaporate.

- **Extrinsic semi-conductor**

  A semi-conductor in which the carrier concentration is dependent upon extent of impurities.

- **Expansion of the universe**

  The hypothesis, based on the evidence of the *redshift, that the distance between the galaxies is continuously increasing. The original theory, which was proposed in 1929 by Edwin Hubble (1889-1953), assumes that the galaxies are flying aprt like fragments from a bomb as a consequence of the big bang with which the universe originated.

- **Fall-out** (or **radioactive fall-out**)

Radioactive particles deposited from the atmosphere either from a nuclear explosion or from a nuclear accident. Local, fall-out, within 250 km of an explosion, falls within a few hours of the explosion. Tropospheric fall-out consists of fine particles deposited all round the earth in the approximate latitude of the explosion within about one week. Stratospheric fall-out may fall anywhere on earth over a period of years.

- **Faraday's law of electrolysis**

First Law W=Zit

Where

W	=	Wt. of ions liberated from an electrolyte.
Z	=	Electrochemical equivalent (E.C.E.)
t	=	Time in seconds for which current is passed
i	=	Current in amperes

- **Faraday's Law of electromagnetic induction**

• Whenever the number of lines of force linked (flux) with any closed circuit changes and induced current flows through the circuit which lasts only so long as the change lasts.

• The magnitude of induced e.m.f. produced in a coil is directly proportional to the rate of change of lines of force threading the coil $e \propto \frac{d\phi}{dt}$; where ϕ = flux (or number of lines of force threading the circuit)

- **Fahrenheit scale of temperature**

On this scale the melting point of ice is 32°F and the boiling point of water is 212°F The distance between these two points is divided in 180 equal parts, each part being 1°F. It is related to centigrade scale as $\frac{C}{100} = \frac{F-32}{180}$

- **K–capture**

Refers to an absorption of electron from the innermost (K–shell) shell of an atom into its nucleus.

- **Karat (US)**

It is a unit used to specify the purity of gold. a pure gold is 24 Karat gold.

Kepler's law

- The planets move around the sun in elliptical orbits with the sun at one focus of the ellipse
- The radius vector from the planet to the sun sweeps out equal areas in equal intervals of time.
- The ratio of $\frac{T^2}{a^3}$ =constant, where T is the period of the planet's orbit around the sun and a is the semi–major axes of the ellipse.

Kilo watt–hour (kWh)

It is a practical unit of work (or energy). It is equal to the energy supplied by one kilowatt of power in one hour.

$$1 \text{ kWh} = 3.6 \times 10^6 \text{ joule.}$$

Kinetic friction

Refers to the friction that acts on a body when it is moving over a second body.

Kirchhoff's law (Electrostatics)

- **First Law** : It is also known as Junction rule. It states, "The algebraic sum of the currents at a given junction in a circuit is zero". $\Sigma i = 0$. Thus there could be no accumulation of current at any point in the circuit.
- **Second law :** It is also known as loop rule "In a closed circuit, the algebraic sum of the products of the current and the resistances of each part of the circuit is equal to total emf in the circuit."$\Sigma ir = \Sigma E$

Kirchhoff's law (Heat)

For a given temperature and wavelength the ratio of emissive power of a substance to its absorptive power is the same for all substances and is equal to the emissive power of a perfectly black body at that temperature.

Kundt's tube

It is a glass tube whose one end is fitted with a light adjustable piston and its another end is closed by a cap through which passes a metal rod clamped at its centre. A small quantity of lycopodium powder is spread uniformly through out the tube. The free end of the rod is rubbed to and fro along its length. Stationary waves are produced in the air column in the tube. By measuring the wavelength it is possible to calculate the velocity of sound in air in terms of the Young's modulus, length and density of the rod and the wave length of stationary waves.

Lactometer

It is an instrument that is used to find out the specific gravity of milk.

- **Lambert's law**

The illuminance of a surface that is illuminated by a point source of light normally is proportional to $1/r^2$ where r is the distance between the source and the surfance. If the incident rays make an angle θ with the normal to the ray, then the illuminance is proportional to cosθ.

- **Laminar flow**

Refers to the flow of a fluid along a stream lined surface without any turbulance.

- **Laminated iron**

A piece of iron consisting of thin sheets of iron. Such a piece of iron is used for cores of transformers. It helps to minimize losses due to eddy currents.

- **Laser**

It stands for light amplification by stimulated emission of radiation. A highly powerful, coherent, monochromatic light source. Such light is of great use in medicine, telecommunications, industry and holography.

- **Latent heat**

Hidden heat. It is the energy involved in changes of state. In each case, the temperature stays constant while the change of state takes place. A similar situation exists in the changes from liquid to gas and gas to liquid. The quantity of energy transformed from and to the particles during changes of state depends on the nature of the substance and its state.

- **Lateral inversion**

Refers to the type of inversion produced in the image formed by a plane mirror. The left hand side appears as right hand side and vice versa.

- **Latitude**

Refers to the angular distance north or south from the equator of a point on the earth's surface, measured on the meridian of the point.

- **Laws of dynamic friction**

• Dynamic friction is proportional to the normal reaction. It is less than static friction.

• It does not depend on the velocity if the velocity is neither too large nor too small.

- **Laws of limiting friction**

• The force of limiting friction is directly proportional to normal reaction for the same two surfaces in contact and it takes place in a direction which is opposite to the direction of the force of the pull. Limiting friction is maximum static friction, it is less than static friction. $F \propto R$ (when the body just begins to move $F = \mu R$) Where μ is coefficient of friction.

• Limiting friction is independent of the size and shape of the bodies in contact as long as the normal reaction remains the same.

- **Law of gravitation**

  According to it, all bodies and particles in universe exert gravitational force on one another. The force of gravitation between any two bodies is directly proportional to the product of their masses and inversely proportional to the distance between them.

- **Laws of intermediate temperature**

  The e.m.f. of a thermocouple between any two temperatures is equal to the sum of the e.m.f. of any number of successive steps in which the given range of temp. is divided. Thus if $E_{t_1}^{t_n}$ is the thermo e.m.f. between two temp. t_1 & t_n, $E_{t_1}^{t_n} = E_{t_1}^{t_2} + E_{t_2}^{t_3} + E_{t_3}^{t_4} + E_{t_{n-1}}^{t_n}$.

  Where the given temp. range is divided between the steps $t_1, t_2, t_3 \ldots\ldots t_n$.

- **Light Emitting Diode (LED)**

  This is a p–n junction diode and is usually made from gallium arsenide or indium phosphide. Energy is released with in the LED and this is given off as light. The junction is made near to the surface so that the emitting light can be seen. No light is emitted with a reverse bias. LED are generally coloured red, yellow or green. They are widely used in a variety of electronic devices.

- **Light year**

  It is a unit used to measure the distance between the earth and stars. 1 light year = $365 \times 86400 \times 3 \times 10^8$ m = 9.46×10^{15} m.

- **Liquid Crystal**

  A substance that flows like a liquid but has some order in its arrangement of molecules. Nematic crystals have long molecules all aligned in the same direction, but otherwise randomly arranged. Cholesteric and smectic liquid, crystals also have aligned molecules, which are arranged in distinct layers, In cholesteric crystals the axes of the molecules are parallel to the plane of the layers; in smectic crystals they are perpendicular.

- **Liquid–Crystal Display (LCD)**

  A digital display unit used in watches, calculators, etc. It provides a source of clearly displayed digits for a very low power consumption. In the display unit a thin film of liquid crystal is sandwiched between two transparent electrodes (glass with a thin metal or oxide coating). In the commonly used field–effect display, twisted nematic crystals are used. The nematic liquid crystal cell is placed between two crossed polarizers. Polarized light entering the cell follows the twist of the nematic liquid crystal, is rotated through 90°, and can therefore pass through the second polarizer. When an electric field is applied, the molecular alignment in the liquid crystal is altered the polarization of the entering light is unchanged and no light is therefore transmitted. In these circumstances, a mirror placed behind the second polarizer will cause the display to appear black. One of the electrodes, shaped in the form of a digit, will then provide a black digit when the voltage is applied.

- **Lissajou's figures**

  The loci of the resultant displacement of a point subject to two or more simple harmonic motions simultaneously. When the two periodic motions are of the same frequency and are at right angles to each other. The resulting figure varies from a straight line to an ellipse depending on the phase difference between the two motion.

- **Longitude**

  It is the angular distance east or west on earth's surface. It is measured by the angle contained between the meridian of a particular place and some prime meridian.

- **Lumen**

  A unit of luminous flux. One lumen is the luminous flux emitted in a unit solid angle by a point source of one–candle intensity.

- **Lux**

  It is S.I. unit of illuminance. 1 lux = 1 lumen/square meter

- **Mach number**

  It is number that indicates the ratio of the speed of an object to the speed of sound in the medium through which the object is moving.

- **Magic numbers**

  Atomic nuclei with 2, 8, 20, 28, 50, 82, 126 neutrons or protons are quite stable. These number are known as magic numbers.

- **Magnetic axis**

  It is the line joining the two poles of a magnet inside its body.

- **Magnetic elements**

  These are the magnetic declination, magnetic dip and the horizontal component of Earth's magnetic field which completely define the Earth's magnetic field at any point on the Earth's surface.

- **Magnetic equator**

  A line perpendicular to magnetic axis and passing through the middle point of the magnet is called equitorial line or magnetic equator.

- **Magnetic meridian**

  It is that vertical plane which passes through the magnetic axis of a freely suspended magnet.

- **Magnetic storm**

  A temporary disturbance of the earth's magnetic field induced by radiation and streams of charged particles from the sun.

- **Magnetization (M)**

The magnetic moment per unit volume of a magnetised substance.

$$B = \mu_0(H + M) \text{ or } M = \frac{B}{\mu_0} - H$$

Where H is the magnetic field strength, B is the magnetic flux and μ_0 is constant.

- **Malus law**

It states that the intensity of light transmitted through an analyser is proportional to $\cos^2\theta$ where θ is the angle between the transmission planes of the polariser and the analyser.

- **Manganin**

A copper alloy containing 13–18% of manganese and 1–4% of nickel. It has a high electrical resistance, which is relatively insensitive to temperature changes. It is therefore suitable for use as a resistance wire.

- **Maser**

It is a device that is used for amplifying electrical impulses by stimulated emission of radiation.

- **Mass defect (ΔM)**

It is the difference between the actual nuclear mass and the sum of the masses of its constituents nucleons.

- **Mass–Energy equation**

$E = mc^2$.

- **Maxwell Mx.**

It is unit of magnetic flux on C.G.S. system.

$$1 \text{ Mx} = 10^{-8} \text{ Weber}$$

One maxwell is equal to magnetic flux through one square centimetre normal to a magnetic field of one gauss.

- **Maxwell's formula**

A formula that connect the relative permittivity ε_r of a medium and its refractive index n. If the medium is not ferromagnetic the formula is $\varepsilon_r = n^2$.

- **Mayer's relationship** : $C_P - C_V = R$ Where

C_P = Molar specific heat of gas at constant pressure

C_V = Molar specific heat of gas at constant volume

R = Gas constant = 8.314 Jk^{-1} mol^{-1}

- **Mechanical advantage**

  It is the ratio of output force to the input force applied to any mechanism.

  $P \times AF = W \times BF \qquad \frac{W}{P} = \frac{AF}{BF} = \frac{\text{Power arm}}{\text{Weight arm}}$

- **Meissner effect**

  The falling off of the magnetic flux within a superconducting metal when it is cooled to a temperature below the critical temperature in a magnetic field. It was discovered by Walther Meissner in 1933 when he observed that the earth's magnetic field was expelled from the interior of tin crystals below 3.72 K, indicating that as "superconductivity appeared the material became perfectly diamagnetic".

- **Melde's experiment**

  It is an experiment carried out for verification of transverse vibrations of strings.

- **Melting point**

  The fixed temperature at which a solid changes into the liquid state. The melting point of ice is 0°C. Melting point of a solid depends upon pressure. it is also called fusion temperature of the liquid.

- **Michelson–Morley experiment**

  An experiment conducted by Michelson–Morley in 1881 to show that the velocity of light is not influenced by motion of medium through which it passes.

- **Micro**

  A prefix denoting 10^{-6}.

- **Micron (μ)**

  A unit of length $1\ \mu = 10^{-6}$ m.

- **Micrometer**

  Refers to any device used for measuring minute distances, angles etc.

- **Microphone**

  An instrument that can transform the air pressure waves of sound into electrical signals and vice–versa. It is used for recording or transmitting sound.

- **Mirage**

  An optical phenomenon that occurs as a result of the bending of light rays through layers of air having very large temperature gradients. An inferior mirage occurs when the ground surface is strongly heated and the air near the ground is much warmer that the air above. Light rays from the sky are strongly refracted upwards near the surface giving the appearance of a pool of water. A superior mirage occurs if the air close to the ground surface is much colder than the air above. Light is bent downwards from the object towards the viewer so that it appears to be elevated or floating in the air.

- **Mirror equation**

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

u = distance of object
v = distance of image
f = focal length of mirror

- **M.K.S. system**

System of units having the fundamental units metre, kilogram and second for the length, mass and time respectively.

- **Mole**

SI unit of quantity of a substance. Amount of a substance that contains as many atoms (molecules, ions etc.) as there are atoms in 0.012 kg. of carbon–12.

- **Monochromatic**

Having only one colour.

- **Moseley's law**

According to it the frequencies in the X–ray spectrum of elements, corresponding to similar transitions are proportional to the square of the atomic number of elements.

- **Multimeter**

An instrument that can be used for measuring various electrical quantities such as resistance, voltage etc.

- **Mutual inductance**

It refers to the phenomenon by which a current is induced in a coil circuit when current in a neighbouring coil circuit is changed. Direction of current in the secondary coil is opposite to battery current in primary coil (Lenz's law)

- **Myopia**

A defect of vision. Any one suffering with this defect fails to see distant objects clearly. The image of distance object is formed in front of retina and not on retina. It can be corrected by use of concave lens.

- **Natural gas**

It is a mixture of hydrocarbons and is found in deposite under the earth's surface. It contains upto 90% Methane. It is used as a fuel both in industry and home.

- **Nautical mile**

It is a unit of distance used for navigation. 1 nautical mile = 6082.66 feet.

- **Negative crystal**

Refers to that crystal in which the velocity of extra ordinary ray is more than the velocity of ordinary ray e.g. calcite.

- **Negative resistance**

  It is characteristic of certain electronic devices in which the current increases with decrease in voltage.

- **Neel temperature**

  The temperature upto which the susceptibility of antiferromagnetic substances increase with increase in temperature and above which the substance becomes paramagnetic.

- **Nernst heat theorem**

  It is also called the third law of thermodynamics. For a chemical change occuring between pure crystalline solids at absolute zero, there is no change in entropy.

- **Neutrino**

  It is an elementary particle having rest-mass zero and is electrically neutral. It has a spin of 1/2.

- **Neutron bomb**

  It is a nuclear bomb. It releases a shower of life destroying neutrons but has practically little blast and contamination.

- **Newton**

  It is S.I. unit of force. It is equal to the force which produces an acceleration of 1 m/s^2 in a mass of 1 kg.

- **Newton's formula for velocity of sound :**

  $u = \sqrt{\frac{E}{\rho}}$ Where u = velocity of sound E = Elasticity of medium

  ρ = density of medium

- **Newton's law of cooling**

  According to it, the rate of loss of heat from a hot body is directly proportional to the excess of temperature over that of its surroundings, provided the excess of temperature is not very large.

- **Newton's law of gravitation n**

  Every body in this universe attracts every other body with a force which is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

  Mathematically $F \propto \frac{m_1m_2}{r^2}$; $F = G\frac{m_1m_2}{r^2}$

Newton's law of motion

- **I[st] Law :** A body continues to remain in its state of rest or of uniform motion in the same direction in a straight line unless acted upon by some external force.
- **II[nd] Law :** The rate of change of momentum of a body is directly proportional to the implied force & takes place in the direction of the force $F = \frac{dp}{dt} = ma$
- **Third Law :** To every action there is equal and opposite reaction. $\vec{F}_{12} = -\vec{F}_{21}$

Newton's ring

Refers to alternately dark and bright fringes (circular) that can be observed around the point of contact of a convex lens and a plane reflecting surface. These are produced due to interference of light waves reflected at the upper and lower surfaces of the air film separating the lens and the plane surface.

Nichrome

An alloy of nickel, chromium and iron. It has high melting point and large resistivity. It is used for electric resistors and heating element.

Nicol prism

A prism made of calcite. It is used for polarizing light and analysing plane polarised light.

Normal temperature and Pressure (N.T.P.)

These are 273 K and 760 mm of mercury respectively.

Nuclear fission

A nuclear reaction in which an atomic nucleus breaks up into two nearly equal fragments and evolution of a large amount of energy.

Nuclear fusion

A nuclear reaction in which two light nuclei combine to form a heavier nuclei and evolution of a large amount of energy.

Nuclear force

It refers to the strong attractive force that keeps (bind) a large number of nucleons bound together in a very small space. It is a short range attractive force and is charge independent. Its range is a few fermi. (1 fermi = 10^{-15} m)

Nuclear Magnetic Resonance (NMR)

The absorption of electromagnetic radiation at a suitable precise frequency by a nucleus with a nonzero magnetic moment in an external magnetic field. The phenomenon occurs if the nucleus has nonzero "spin, in which case it behaves as a small magnet, In an external magnetic field, the nucleus's magnetic moment vector precesses about the field direction but only certain orientations are allowed by quantum rules. Thus for hydrogens (spin of ½) there are two possible states in the presence of a field, each with a slightly different energy. Nuclear magnetic resonance is the absorption of radiation at a photon energy equal to the difference between these levels causing a transition from a lower to a higher energy state.

- **Nuclear mass**

  It is equal to the sum of masses of protons and neutrons minus the mass defect.

  Mass of nucleus = $Z\ M_p + (A - Z)\ M_n - \Delta m$.

  Z = Atomic number = number of protons

  A = Mass no. or = number of protons + no. of neutrons

  M_p = Mass of proton

  M_n = Mass of neutron Δm = Mass defect

- **Nucleons**

  Refers to protons and neutrons which are present in the nucleus. They are collectively called nucleons.

- **Octave**

  The interval between two musical notes whose frequencies are in the ratio of 2 : 1.

- **Octet**

  Group of eight electrons that constitute the outer electron shell in case of an inert gas (except helium) or any other atom/ion.

- **Odd–Odd nucleus**

  A nucleus which contains the odd number of protons and odd number of neutrons.

- **Oersted**

  A C.G.S. unit for magnetic field strength. $1 \text{ Oersted} = \dfrac{10^3}{4\pi}$ A/m.

- **Ohm's law**

  It states, "current flowing through a conductor is directly proportional to the potential difference across its ends. If temperature and other physical conditions remain unchanged".

- **Opacity**

  It is the reciprocal of the transmittance of a substance. It is a measure of the extent to which a substance is opaque.

- **Opaque**

  A substance that is not transparent or which does not allow light to pass through it.

- **Optical activity**

  It is the property of certain substance to rotate the plane polarized light when it passes through their solution. The substances are classified as dextro–rotatory or leavo rotatory depending on whether they rotate it towards right (dextro) or left (leavo). The rotation produced depends upon the length of the medium and concentration of the solution. It also depends on the wave length of light used.

- **Optical pyrometer**

  A pyrometer where in the luminous radiation from the hot body is compared with the from a known source. The instrument measures the temperature of a luminous source without thermal contact.

- **Optimum**

  Refers to most favourable conditions for obtaining a given result.

- **Oscillation magnetometer**

  It is an instrument where in a freely suspended magnet is made to vibrate in a magnetic field (of earth). The time period of vibration of this instrument is given by $T = 2\pi\sqrt{\frac{I}{MB_H}}$

- **Overtones**

  Refers to the tones or frequencies emitted by a system besides its fundamental frequency are called overtones. Generally the intensity of overtones is lower than that of the fundamental.

- **Packing fraction**

  The algebraic difference between the relative atomic mass of an isotope and its mass number divided by the mass number.

- **Pair production**

  It refers to the simultaneous production of an electron and its anti–particle (positron) from a gamma ray photon. The minimum energy that such a photon must have in 1.02 MeV.

- **Paramagnetic**

  Refers to the magnetic nature of substances. Paramagnetic substances are those substances in which the magnetic moments of the atoms have random directions until placed in a magnetic field. When placed in a magnetic field they possess magnetisation in direct proportion to the magnetic field and are weakly magnetised. If placed in a non–uniform magnetic field, they move from weaker parts to stronger parts of the field.

- **Paraxial rays**

  Refers to those incident rays which are parallel and close to the axis of a lens.

- **Parent nucleus**

  Any nucleus that undergoes radioactive decay to form another nucleus. The nucleus resulting by radioactive decay of the parent nucleus is called daughter nucleus.

- **Parsec**

  It is an astronomical unit of distance 1 parsec = 3.0857×10^{16} m. or 3.2616 light years. It corresponds to a parallel of one second of arc. The distance at which the mean radius of the earth's orbit subtends an angle of one second of arc.

- **Pascal (Pa)**

  The S.I. unit of pressure. 1 Pa = 1 Newton/metre^2

- **Pascal's law**

  In a confined fluid, externally applied pressure is transmitted uniformaly in all directions.

- **Pauli's exclusion principle**

  It states, "No two electrons in an atom can have all the quantum numbers same."

- **Peak value of inverse voltage (PIV)**

  It is the maximum instantaneous voltage that is applied to a device, particularly rectifiers, in the reverse direction.

- **Penumbra**

  The partial shadow that surrounds the complete shadow of an opaque body.

- **Perfect gas**

  An ideal gas that obeys the gas laws at all temperatures and pressure. It consists of perfectly elastic molecules. The volume of molecules is zero and the intermolecular forces of attraction between them is also zero.

- **Perigee**

  It is the shortest distance of a satellite from the earth.

- **Perihelion**

  The point in the orbit of a planet, comet, or artificial satellite in solar orbit at which it is nearest to the sun. The earth is at perihelion on about 2 January.

- **Periscope**

  An optical device used to view objects that are above the level of direct sight or are in an obstructed field of vision. In its very simple form it is made up of two mirrors inclined at 45° to the direction being viewed.

- **Permalloys**

  A group of alloys of high magnetic permeability consisting of iron and nickel (usually 40–80%) often with small amounts of other elements (e.g. 3 – 5% molybdenum, copper, chromium or tungsten. They are used in thin foils in electronic transformers, for magnetic shielding and in computer memories.

- **Permanent magnet**

  A magnet that retains its magnetism even after the removal of external magnetic field.

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- **Permeability (μ)**

When a magnetic substance is placed in a uniform magnetic field (where lines of force are parallel) number of lines of force are seen to be crowded through the substance. The conducting power of the substance for the lines of force is called permeability.. It is taken as unity for air. B = μH. It is measured in Henry/metre. The relative permeability of a substance is equal to the ratio of its absolute permeability to the permeability of the free space. Thus $\mu_r = \mu/\mu_0$ where μ_0, the permeability of free space has the value $4\pi \times 10^{-7}$ henry metre

- **Persistence of vision**

The impression of an image on the retina of the eye for some time after its withdrawl is known as persistence of vision. The impression on human eye lasts for $1/16^{th}$ of a second. Successive images at the rate of 16 per second of the same scene give the impression of continuity.

- **Phonon**

The phonon is a quantum of thermal energy. It is given by hf, where h is the Planck constant and f the vibrational frequency. It refers to lattice vibration of crystals.

- **Photodiode**

A Semiconductor diode used to detect the presence of light or to measure its intensity. It usually consists of a p–n junction device in a container that focuses any light in the environment close to the junction. The device is usually biased in reverse so that in the dark the current is small; when it is illuminated the current is proportional to the amount of light falling on it.

- **Photo–electric effect**

When light of suitable wavelength falls on a metal plate, such as ultra violet light on zinc, slow moving electrons are emitted from the metal surface. This phenomenon is known as photoelectric effect and the electrons emitted are known as photoelectrons.

- **Photo fission**

A nuclear fission that is caused by a gamma–ray photon.

- **Photon**

Each quantum of light energy is known as photon. The energy of photon is given by $E = \frac{hc}{\lambda}$, where λ is the wavelength associated with the photon, c is velocity of light and h is Planck's constant.

- **Photonuclear reaction**

A nuclear reaction that is initiated by a (gamma–ray) photon.

- **Photo sphere**

  It refers to highly luminous and visible portion of the sun. The approximate temperature existing in photosphere is estimated to be about 6000 K.

- **Piezo electric effect**

  The production of a small e.m.f. across the opposite faces of non conducting crystals when they are subjected to mechanica stress between their faces external pressure is known as piezoelectric effect or piezoelectricity.

- **Planck's formula for black–body radiation**

  The energy radiated per unit time per unit area at a given wavelength λ, is given by $$E = \frac{2\pi hc^2}{\lambda^5}\frac{1}{\left(e^{\frac{hc}{\lambda kT}}-1\right)}$$

  where c is the speed of light, h is Planck's constant and T is the absolute temperature of the black body, k is the Boltzmann's constant.

- **Plane of polarisation**

  It is a plane that is perpendicular to the plane of vibration and containing the direction of propagation of light. It is also the plane containing the direction of propagation and the electric vector of the electromagnetic light wave.

- **Plasma**

  A highly ionized gas in which the number of free electrons is approximately equal to the number of positive ions. Sometimes described as the fourth state of matter, plasmas occurs in interstellar space, in the atmospheres of stars (including the sun), in discharge tubes and in experimental thermonuclear reactors.

- **Poises**

  It is a unit of viscosity in C.G.S. system.

  1 Poise = 0.1 Ns/m^2.

- **Poiseuille's formula**

  It gives the volume per unit time flowing through a cylinderical tube carrying a laminar flow. $Q = \frac{\pi R^4 \Delta P}{8\eta \ell}$

where; Q = Volume per unit of time

R = Radius of pipe

ℓ = Length of the pipe

ΔP = Pressure difference across each end of pipe

η = Coefficient of viscosity

- **Poisson's ratio**

  The ratio of the lateral strain to the longitudinal strain in a stretched rod. If the original diameter of the rod is d and the contractiono f the diameter under stress is Δd, the latral strain $\Delta d/d = s_d$; if the original length is ℓ and the extension under stress $\Delta\ell$, the longitudinal strain is $\Delta\ell/\ell = s_\ell$. Poisson's ratio is then s_d/s_ℓ.

- **Polaroid**

  Synthetic materials that are used for producing polarized light from unpolarised light by dichroism.

- **Positive crystals**

  Doubly refracting crystals in which the ordinary ray travels faster as compared to an extra ordinary ray e.g. quartz.

- **Positron**

  An elementary particle having a mass equal to that of an electron and carrying a unit positive charge.

- **Positronium**

  An unstable assembly of a positron and an electron. It decays into a photon.

- **Potentiometer**

  It is a device that is used for measuring electromotive force or potential difference by comparing it with a known voltage.

- **Pound**

  A unit of mass of FPS system   1 pound = 453.59 g

- **Poundal**

  A unit of force of FPS system   1 poundal = 0.138 N

- **Power of a lens**

  It is the ability of a lens to bend the rays passing through it. Power of convex lens is positive and that of concave lens is negative. Units of power of lens = Diopter. $\text{Power} = \dfrac{1}{\text{Focal length in meters}}$

- **Power reactor**

  A nuclear reactor designed to produce electrical power.

- **Presbyopia**

  It is a defect of vision. Any one suffering with this defect cannot see the near objects. This defect is generally observed in older people. It can be corrected with the help of convex lenses.

- **Pressure gauge**

  It is an instrument that is used for measuring the pressure of a gas or a liquid.

- **Prime meridian**

  The Greenwich meridian. It is used as standard for reckoning longitude east or west.

- **Principle of floatation**

  A body floats as a liquid when the weight of the liquid displaced by it is equal to its weight.

- **Prompt neutrons**

  The neutrons emitted during a nuclear fission process within less than a microsecond of fission.

- **Proton–Proton cycle**

  It refers to a chain of nuclear fusion reactions which are thought to be responsible for production of energy in the sun. Hydrogen gets converted into helium.

$$ {}_1^1H + {}_1^1H + {}_1^1H + {}_1^1H \longrightarrow {}_1^2H + \nu + e^+ $$

$$ {}_1^2H + {}_1^1H \longrightarrow {}_2^3He + \nu $$

$$ {}_2^3He + {}_2^3He \longrightarrow {}_2^4He + 2{}_1^1H $$

- **Pulsar**

  A celestial source of radiation emitted in brief (0.03 second to 4 seconds) regular pulses. First discovered in 1968, a pulsar is believed to be a rotating neutron star. The strong magnetic field of the neutron star concentrates charged particles in two regions and the radiation is emitted in two directional beams. The pulsing effect occurs as the beams rotate. Most pulsars are radio sources (emit electromagnetic radiation of radio frequencies) but a few that emit light or X–rays have been detected. Over 300 pulsars are now known, but is estimated that there are over one million in the Milky way.

- **Pyrometer**

  It is an instrument that is used for measurement of very high temperatures. The measurement is done by observing the colour produced by a substance by heating or by thermoelectric means.

- **Quality of sound**

  Majority of musical notes contain more than one frequency. Quality of sound is a characteristic of a musical note that depends on frequencies present in the note. In each note there is one fundamental frequency and a number of overtones. The frequencies of overtones are integral multiples of the fundament frequency but intensity is much low. The quality of sound changes with the number of overtones present and their intensity.

- **Quark**

  Hypothetical fundamental particles which are postulated to be building blocks of elementary particles.

- **Quartz**

  The most abundant and common mineral, consisting of crystalline silica (sillicon dioxide, SiO_2).

- **Quartz clock**

  A clock based on a piezoelectric crystal of quartz.

- **Quasars**

  A class of astronomical objects that appear on optical photographs as star like but have large redshifts quite unlike those of stars.

- **Quenching**

  The rapid cooling of a metal by immersing it in a bath of liquid in order to improve its properties.

- **Q–Value**

  It is the amount of energy produced in a nuclear reaction. It is expressed in MeV.

- **Rad**

  The unit of absorbed radiation. One rad = absorption of 10^{-2} joule of energy in one kilogram of material.

- **Radiology**

  It is the branch of science that deals with X-rays or rays from radioactive substances.

- **Radioscopy**

  It involves the examination of opaque objects with the help of X-rays.

- **Radius of curvature (R)**

  In case of a mirror or a lens it is the radius of the sphere of which a mirror or lens surface is a part.

- **Radius of gyration (K)**

  It is the distance, from the axis of rotation of a body to a point where the whole mass of a body may be considered to be concentrated.

  It is given by $K = \sqrt{\frac{I}{m}}$ Where I is the moment of inertia of body of mass m about the axis of rotation.

- **Rainbow**

  An arc of seven colours that appears in the sky due to splitting of sunlight into its constituent colours by the water droplets present in air because of refraction and internal reflection of sunlight by them.

- **Raman effect**

  When monochromatic light is allowed to pass through a transparent medium it gets scattered and the scattered light contains original wave length as well as lines of larger wave length than the original lines. These lines of larger wave lengths are known as Raman lines and this effect is known as Raman effect. This is quite useful in the study of molecular energy levels of liquids.

- **Rayleigh's criterion**

  Two sources are just resolvable by an optical instrument if the central maximum of the diffraction pattern of one coincides in position with the first minimum of the diffraction pattern of the other.

- **Receiver**

  Any device or apparatus that receives electric signals, waves etc.

- **Recoil**

  Means to fly back

- **Rectifier**

  A device that allows the current to flow through it in one direction only. It can convert a.c. into d.c. The commonly used rectifiers are a p-n junction, a diode valve etc.

- **Red giant**

  It is a type of cool giant star that emits light in red region of the spectrum. A normal star expands to red giant as it exhausts its nuclear fuel.

- **Red shift :**

  Because of **Doppler effect** a shift of spectrum lines in the spectra of some celestial objects towards the red end of the visible spectrum with an increase in wave length of the lines.

- **Reflectance**

  It is the ratio of the reflected light to the incident light on a surface.

- **Reflecting power**

  It is the ratio of the quantity of energy reflected to the quantity of energy falling on a body per unit time.

- **Refrigerator**

  It is the device that is used for producing low temperature and keeping items at low temperature.

- **Relative humidity**

  The amount of water vapour in the air, expressed as a percentage of the maximum amount that the air could hold at a given temperature.

- **Relativistic mass**

  It is the mass of an object which is moving with a velocity v.

  It is given by the relation $m = \dfrac{m_0}{\sqrt{1-\dfrac{v^2}{c^2}}}$

  where m_0 is the rest mass of the same object.

- **Relativistic particle**

  A particle moving with a velocity close to the velocity of light, say greater than 0.1 c, c being the velocity of light.

- **Remanence**

  The magnetic flux which remains in a magnetic circuit even after the applied magnetomotive force is removed.

- **Remote sensing**

  The gathering and recording of information concerning the earth's surface by techniques that do not involve actual contact with the object or area under study. These techniques include photography (e.g. aerial photography), multispectral imagery, infrared imagery, and radar. Remote sensing is generally carried out from aircraft and increasingly, satellites. The techniques are used, for example, in cartography (map making).

- **Resistance**

  It is the property of a material by virtue of which it opposes the flow of current through it. $R = V/I$

- **Resistance box**

  It is a box containing a set of combination of resistance coils arranged in such a way that any desired value of resistance may be obtained using one or a combination of these.

- **Resistivity (ρ)**

  It is also known as specific resistance. It is defined as the resistance offered by 1 m length of the conductor having an area of cross-section of 1 square meter.

  Units of ρ are ohm-meter or ohm-cm.

- **Resolving power:**

  It gives the measure of the ability of an optical instrument to form separate and distinguishable images of two objects very close to each other. The resolving power of a telescope is given by

  $$\text{Resolving power} = \frac{1.22\,\lambda}{a}$$

  Where λ is the wavelength of light used and a is the aperture.

- **Retentivity**

  It is the ability to retain magnetisation even after the magnetising force is removed.

- **Reverberation**

  Refers to the persistence of sound even after the source has stopped emitting the sound.

- **Reverberation time**

  It is the time taken by a sound made in a room to diminish by 60 decibels.

- **Reynold number**

  It determines the state of flow of liquid through a pipe. According to Reynold number the critical velocity (v_c) is given by $v_c = \frac{R_n \eta}{\rho D}$ where ρ is the density of liquid, R_n is Reynold number and D is the diameter of the pipe thorugh which liquid is flowing –

  If R_n is upto 1000 the flow is streamline or laminar.

  If R_n lies between 1000-2000, flow is unstable.

  If R_n is more than 2000, flow is turbulant.

- **Richter scale**

  A logarithmic scale devised in 1935 by C.F. Richter (1900) to compare the magnitude of earthquakes. The scale ranges from 0 to 10. On this scale a value of 2 can just be felt as a tremor and damage to buildings occurs for values in excess of 6. The largest shock recorded hand a magnitude of 8.9.

- **Roentgen (R)**

  It is a unit of ionising radiation. One, Roengten induces 2.58×10^{-4} C of charge per kilogram of dry air.

- **Roentgen rays**

  X-rays

- **Rutherford**

  It is defined as the amount of radioactive substance which gives rise to 10^6 disintegrations per sec.

  $$1 \text{ curie} = 3.7 \times 10^4 \text{ Rutherford.}$$

- **Rydberg constant**

  The wavelengths of lines of an atomic spectra are given by $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$

  where n_1 and n_2 are integers, R is called Rydberg's constant $R = \frac{2\pi^2 me^4}{ch^3}$

- **Scattering**

  It is the phenomenon of spreading out or diffusion of a beam of radiation when it is incident on some matter surface. The intensity of scattered light varies as $1/\lambda^4$ (Rayleigh scattering)

- **Schwartzchild radius**

  It is equal to $2GM/c^2$, where G is the gravitational constant, c is the speed of light, and M is the mass of the body. If the body collapse to such an extent that its radius is less than the Schwartzchild radius the escape velocity becomes equal to the speed of light and the object becomes a black hole.

- **Scintillated**

  To twinkle like stars

- **Scintillation**

  Refers to the twinkling effect of the light of stars.

- **Second pendulum**

  A simple pendulum having a time period of two seconds.

- **Seeback effect**

  When the juctions of two metallic conductors are maintained at different temperatures and e.m.f. is produced across these junctions. The production of such an e.m.f. is known as seeback effect.

- **Segre chart**

  A graph wherein the number of protons in nuclides is plotted against the number of neutrons

- **Seismograph**

  An instrument that records ground oscillations. e.g. those caused by earthquakes, volcanic activity, and explosions.

- **Semi–conductor**

  A substance having conductivity more than an insulator but less than that of a conductor. The conductivity of a semiconductor increases with temperature. Pure semi–conductors are also known as intrinsic semi–conductors. It is possible to increase the conductivity of a semi–conductor by adding suitable impurities in them. Such semi–conductors are known as extrinsic semi–conductors.

- **Semipermeable membrane**

  A membrane that is permeable to molecules of the solvent but not the solute in osmosis. Semipermeable membranes can be made by supporting a film of material (e.g. cellulose) on a wire gauze of porous pot.

- **Sextant**

  It is an optical instrument. It is used for the determination of the dimensions and distances of distant objects. It is based on the principle that if the angle subtended by two ends of an object at the observer's eye is known (measured by the sextant), the distance and dimensions of the object can be determined with the help of a trignometric formula.

- **Shadow**

  It refers to the dark shape cast on a surface by an object through which light, a form of radiation, can not pass, as radiations, travel in a straight line through a given medium. If one of the sources of radiations is small and the object is large, a sharp shadow is formed.However if the sources is larger than the object the shadow formed is not sharp and shows two distinct regions. The umbra, or full shadow, at the centre, surrounded by penumbra or partial shadow, no radiation reaches umbra but some radiation reaches penumbra.

- **Short wave**

  Refers to an electromagnetic wave of 60 meters or less.

- **Side band**

  Range of frequencies on either side of the carrier frequency of a modulated signal. The width of a side–band both above and below the modulated wave is equal to the highest modulating frequency.

- **Siemens (Mho)**

  It is S.I. unit of electrical conductance 1 Siemen (1 Mho) = 1 A/V.

- **Significant figures**

  The number of digits used in a number specify its accuracy. The number 6.532 is a value taken to be accurate to four significant figures. The number 7320 is accurate only to three significant figures. Similarly 0.0732 is also only accurate to three significant figure. In these cases the zeros only indicate the order of magnitude of the number, whereas 7.065 is accurate to four significant figures as the zero in this case is significant in expressing the value of the number.

- **Silicon chip**

  A single crystal of a semiconducting silcon material, typically having micrometer dimensions, fabricated in such a way that it can perform a large number of independent electronic functions.

- **S.I. units**

This is international system of units comprising of seven basic units. These are:

Physical Quantity	Unit	Symbol
Length	Metre	m
Mass	Kilogram	kg
Time	Second	s
Temp.	Kelvin	K
Electric current	Ampere	A
Light Intensity	Candela	cd
Amount of substance	mole	mol

- **Skin effect**

It is the phenomenon wherein an alternating current tends to concentrate in the outer layer of a conductor.

- **Skip distance**

The minimum distance at which a sky wave can be received. This arises due to a minimum angle of incidence at the ionosphere below which a sky wave is not reflected. This minimum angle is a function of the frequency.

- **Sky wave**

Refers to a radio wave that is propagated upwards from the earth and such a wave reaches a point after reflection from the ionosphere and not directly from the transmitter.

- **Snell's law**

$$\mu = \frac{\sin i}{\sin r} \text{ (or } \mu\sin\theta = \text{constant)}$$

- **Soft iron** It refers to iron that contains small quantities of carbon. Since it can be easily magnetised and demagnetised easily so it is used in transformers, electric bells etc.

- **Solar battery**

It is device for converting solar energy into electricity by means of photo voltaic cells.

- **Solar constant**

It refers to the average rate at which solar energy is received from the sun by the earth. It is equal to 1.94 small calories per minute per square centimeter of area perpendicular to the sun's rays. It is equal to 1400 J/s–m^2.

- **Solar day**

The time interval that elapses between two successive appearances of the sun at the meridian.

- **Solar system**

The sun, the nine major planets (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto) and their natural satellites, the asteroids, the comets and meteoroids. Over 99% of the mass of the system is concentrated in the sun. The solar system as a whole moves in an approximately circular orbit about the centre of the galaxy, taking about 2.2×10^8 years to complete its orbit.

- **Solar wind**

A continuous outward flow of charged particles, mostly protons and electrons, from the sun's corona into interplanetary space. The particles are controlled by the sun's magnetic field and are able to escape from the sun's magnetic field and are able to escape from the sun's gravitational field because of their high thermal energy. The average velocity of the particles in the vicinity of the earth is about 450 km s^{-1} and their density at this range is about 8×10^6 protons per cubic metre.

- **Solenoid**

It refers to a coil of wire wound over a cylinderical frame uniformly. Its diameter is small as compared to its length. When a current is passed through it, a magnetic field is produced inside the coil and parallel to its axis. It can also be used as an electromagnet by introducing a core of soft iron inside it.

- **Sonic boom:**

Refers to a loud noise.

- **Sonometer**

It is an instrument that is used for studying the vibrations of a fixed wire or string. It consists of a hollow wooden box with a wire stretched across its top. The wire is fixed at one end while the other end passes over a pulley and a load can be suspended from it. Any length of wire can be set into vibration by placing two inverted v–shaped bridges at the ends, by placing vibrating tunning fork on the sonometer. resonance is produced when the natural frequency of the vibrating wire given by $\left(f = \frac{1}{2\ell}\sqrt{\frac{T}{m}}\right)$ is equal to the frequency of the tunning fork. T is the tension in the wire and m is its mass per unit length.

- **Space–charge**

A region in a vacuum tube or semi–conductor having some net electric charge because of excess or deficiency of electrons.

- **Specific gravity**

It is the ratio of density of any substance to the density of some other substance taken as standard. e.g. the density of water at 4°C is taken as 1.

- **Specific heat**

  It is the amount of heat required to raise the temperature of 1 kg of substance by 1°C or 1 K.

  It is expressed in J/g/K or J Kg^{-1} K^{-1}.

  The specific heat of water is maximum.

- **Spectrograph**

  An instrument where in a photograph of the spectrum can be obtained.

- **Spectrometer**

  It is an instrument that is used for analysing the spectrum of a source of light.

- **Spherical aberration**

  A defect of image due to the paraxial and marginal rays which are coming to focus at different point on the axis of the lens. It can be corrected by using parabolic surfaces as reflectors and refractors.

- **Spontaneous fission**

  Nuclear fission that occurs independently of external circumstances and is not initiated by the impact of a neutron, an energetic particles or a photon.

- **Spring balance**

  Any instrument with which a force is measured by the extension produced in a helical spring. It is used in weighing. The extension produced is directly proportional to the force (weight).

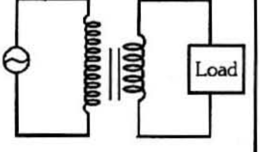
- **Stable equilibrium**

  A body is said to be in stable equilibrium if it tends to return to its original state when it is slightly disturbed from its state.

- **Steam point**

  It is the temperature at which water boils under a pressure of one atmosphere.

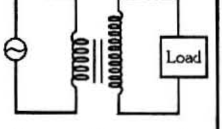
- **Step–down transformer**



  It helps in stepping down the voltage. In it $N_S < N_P$ and so $\frac{N_S}{N_P} < 1$.

  The e.m.f. of secondry coil is less than that of primary $E_S < E_P$.

- **Step–up transformer**



  It helps in stepping up the voltage.

  In it $N_S > N_P$ and the ratio $\frac{N_S}{N_P} > 1$ The e.m.f. of secondary coil is greater than that of primary $E_S > E_P$.

- **Stokes (St)**

  It is a unit of viscosity in C.G.S. system.

- **Stoke's law**

  When a spherical body falls through a viscous medium, it drags the layer of fluid in contact. Due to relative motion between layers, the falling body feels a viscous force F given by $F = 6\pi\eta rv$

  Where r = radius of body

  v = velocity of body

  η = Coefficienat of viscosity

- **Sublimation**

  Change from solid to gaseous state without passing through liquid state.

- **Subsonic**

  Speed less than the speed of sound.

- **Sunspots**

  Dark patches observed on the sun's surface that are regions of cool gas. Their presence is connected with local changes in the sun's magnetic field. They appear in cycles having a period of about 11 years.

- **Super conductivity**

  Refers to complete disappearance of electrical resistance. It has been observed in some substances when they are cooled to very low temperatures (very close to absolute zero). This phenomenon can be used for producing large magnetic fields.

- **Surface tension**

  It is the force per unit length of an imaginary line drawn in the liquid surface in equilibrium acting perpendicular to it at every point and tending to pull the surface apart along the line. It can also be defined as the work done in increasing the surface area of a liquid film by unity. Units of surface tension are dynes/cm or N/m.

- **Susceptibility**

  If a bar of iron is placed in a magnetic field, it gets magnetised and the pole strength or magnetisation depends upon the strength of magnetic field. Thus if $\vec{H}$ is magnetic intensity or magnetizing field intensity and $\vec{I}$ is intensity of magnetization then $\frac{I}{H} = \chi$ is the susceptibility of the specimen. The value of χ (susceptibility) and μ (permeability) are high for ferromagnetic substances.