PHOTON THEORY & DUAL NATURE OF MATTER

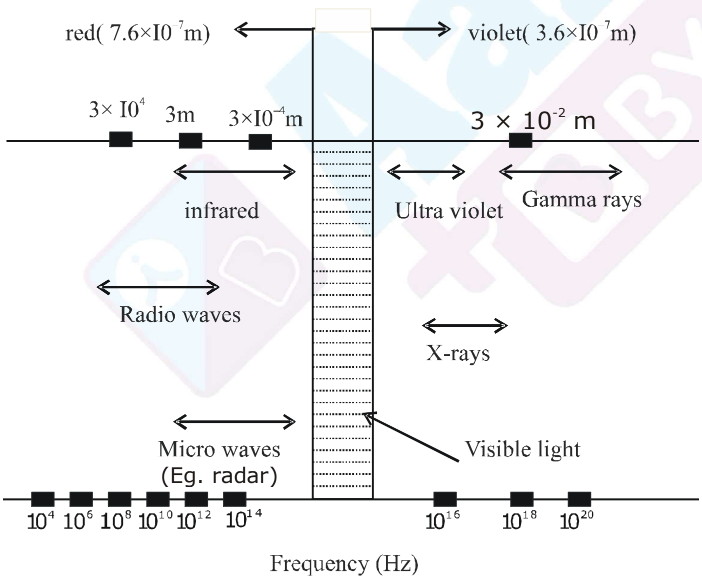
Cathode Rays

- 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 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.

$$E = \frac{hc}{\lambda} = \frac{12400}{\lambda} eV \ (\lambda \text{ in } Å)$$

• 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 = $Nh\nu$
N = no. of photon incident in t time

Intensity $I = \frac{N(h\nu)}{At} = \frac{n(h\nu)}{A}$ ......(ii)

$$\left[\because n = \frac{N}{t} = \text{no. of photon per sec.}\right]$$

Form 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**

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

- **Force exerted on perfectly absorbing surface**

$F = \frac{P}{c}\left(\because n = \frac{P\lambda}{hc}\right)$ 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 $F = \frac{IA\cos\theta}{c}$

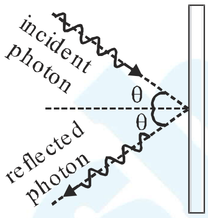


PHOTO ELECTRIC EFFECT

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 $\nu > \nu_0$ (threshold frequency). Emission of electrons is independent of intensity. The wavelength corresponding to ν_0 is called threshold wavelength 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 $\lambda = \frac{h}{p}$ (wave length of a particle).

- **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

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,.. ($n \neq 0$).
- 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 frequencv ν and of energy.

$E = h\nu$

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 Å) $n^2 \Rightarrow r_n \propto n^2$.
- E_n = Energy of the electron in the n^{th} orbit = $\frac{-13.6eV}{n^2} \Rightarrow E_n \propto \frac{1}{n^2}$

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

- **Binding Energy (BE)$_n$** $= -E_n = \dfrac{-13.6\,eV}{n^2}$
- $E_{n_2} - E_{n_1}$ = Energy emitted when an electron jumps from n_2^{th} orbit to n_1^{th} orbit ($n_2 > n_1$).

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

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

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

Where R = Rydberg's constant, for hydrogen = $1.09 \times 10^7\ m^{-1}$.

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

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

$R_Z = RZ^2$; 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 elecron - nucleus system = $\dfrac{mM}{(m+M)}$

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

Spectral series

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

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

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

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

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

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

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

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

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

In far infrared region

$$\bar{v} = R\left[\frac{1}{5^2} - \frac{1}{n_2^2}\right]; n_2 > 5$$

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 = $\frac{n(n-1)}{2}$

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

Excitation potential of atom

Excitation potential for quantum jump from

$n_1 \to n_2$ = $\frac{E_{n_2} - E_{n_1}}{\text{electron charge}}$

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.

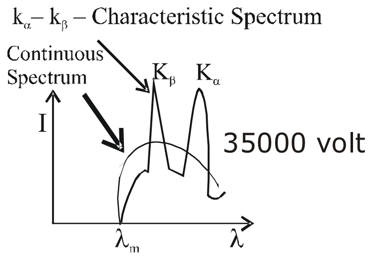
Ionization Potential

Potential difference through which a free electron is moved to gain

ionization energy = $\frac{-E_n}{\text{electron charge}}$

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 of X–rays

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

Moseley's Law for characteristic spectrum

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

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

Z = atomic number of target

ν = frequency of characteristic spectrum

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

a = proportionality constant

Bohr model

1. For single electron species
2. $\Delta E = 13.6Z^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$eV
3. $\nu = RcZ^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$
4. $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$

Moseley's correction

1. For many electron species
2. $\Delta E = 13.6\,(Z-b)^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$eV
3. $\nu = Rc(Z-b)^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$
4. $\frac{1}{\lambda} = R(Z-b)^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$

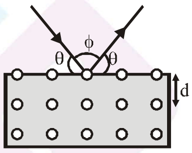
Diffraction of X-rays

Diffraction of X-ray take place according to Bragg's law

$$\boxed{2d\sin\theta = n\lambda}$$

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 wavelength of that series.

NUCLEUS & RADIOACTIVITY

NUCLEAR COLLISIONS

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

a	+	X	$\rightarrow$	Y + b
(bombarding particle)		(at rest)		

We can apply :

(i) Conservation of momentum (ii) Conservation of charge (iii) Conservation of Mass - energy

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

By mass energy conservation :

(i) $K_1 + K_2 + (m_\alpha + m_x)c^2 = K_3 + K_4 + (m_y + m_b)c^2$.

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

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

(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.

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

Nuclear Fission

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).

$A + p \rightarrow$ excited nucleus $\rightarrow B + C + Q$

Nuclear Fusion

It is the phenomenon of fusing two or more lighter nuclei to form a single heavy nucleus.
$A + B \rightarrow C + Q$ (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 $t_{1/2} = \frac{\ell n 2}{\lambda}$

❑ Average life $t_{av} = \frac{1}{\lambda}$

• 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,

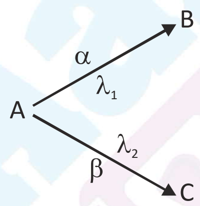
❑ 1 rutherford = 10^6 Bq

• After n half lives Number of nuclei left = $\frac{N_0}{2^n}$

• Probability of a nucleus for survival of time t $= \frac{N}{N_0} = \frac{N_0 e^{-\lambda t}}{N_0} = e^{-\lambda t}$

• **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 $N_0 = N_A + N_B + N_C$



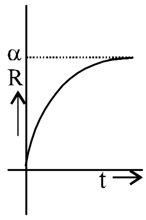
$$\Rightarrow \frac{dN_A}{dt} = \frac{-d}{dt}(N_B + N_C)$$

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

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

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

Radioactive Disintegration with Successive



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

$$\frac{dN_A}{dt} = \alpha - \lambda N_A \ldots\ldots \qquad \textbf{(i)}$$

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 $N_A = \frac{\alpha}{\lambda}(1 - e^{-\lambda t})$

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

Note : 1 u = 1.66×10^{-27} kg = 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**

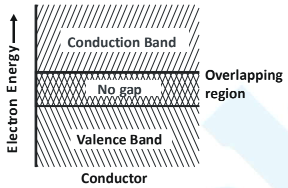
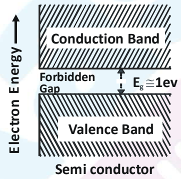
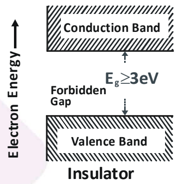
$R = R_0A^{1/3}$ where $R_0 = 1.3\ f_m = 1.3 \times 10^{-15}$ m

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

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, Micra

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

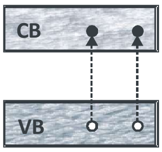
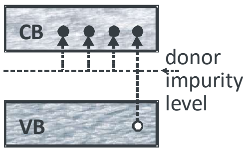
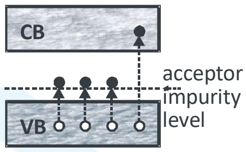
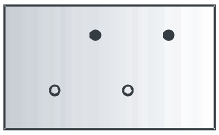
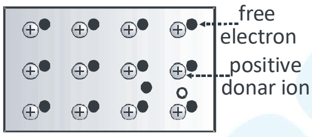
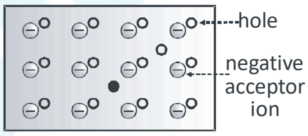
$$n = AT^{3/2}\ e^{-\frac{\Delta Eg}{2kT}}$$

➢ **CLASSIFICATION OF SEMICONDUCTOR**

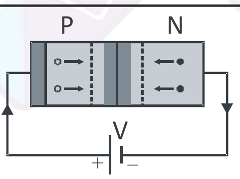
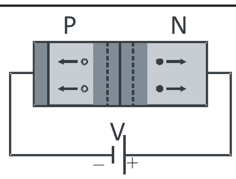
SEMICONDUCTOR

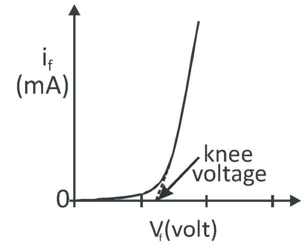
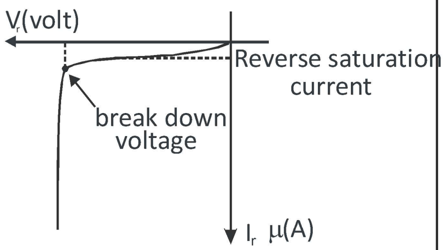
- Intrinsic semiconductor
  - (pure form of Ge, Si)
  - $n_e = n_h = n_i$
- Extrinsic semiconductor (doped semicondutor)
  - N-type
    - pentavalent impurity
    - (P, As, Sb etc.)
    - donar impurity (N_D)
    - $n_e >> n_h$
  - P-type
    - trivalent impurity
    - (Ga, B, In, Al)
    - acceptor 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** $n_i e(\mu_e + \mu_h)$
- **Comparison Study**

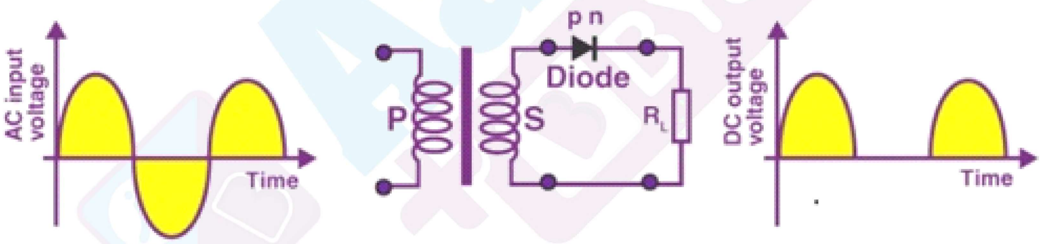
Intrinsic Semiconductor	N-type (pentavalent Impurity)	P-type (Trivalent impurity)
		
		
Current due to electron and hole	Mainly due to electrons	Mainly due to holes
$n_i = n_e = n_h$	$n_h << n_e (N_D \simeq n_e)$	$n_h >> n_e (N_A \simeq n_h)$
$I = I_e + I_h$	$I \simeq I_e$	$I \simeq I_h$
Entirely neutral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

- **Comparison between Forward Bias and Reverse Bias**

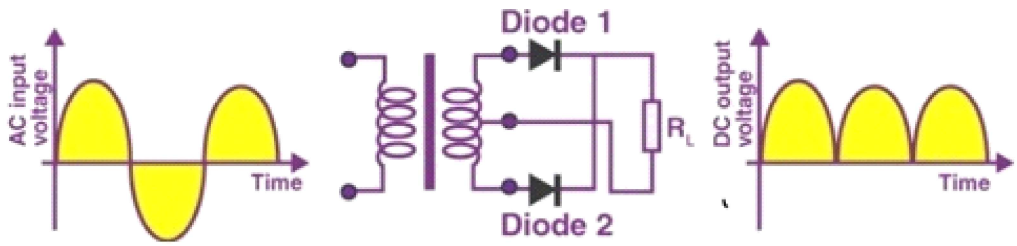
Forward Bias		Reverse Bias	
			
1	Potential Barrier reduces.	1	Potential Barrier increases.
2	Width of depletion layer decreases.	2	Width of depletion layer increases.
3	P-N Jn. provide very small resistance.	3	P-N Jn. provide high resistance.
4	Forward current flows in the circuit.	4	Very small current 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 curves.
			
8	Forward resistance : $R_f = \frac{\Delta V_f}{\Delta V_f} \cong 100\ \Omega$	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

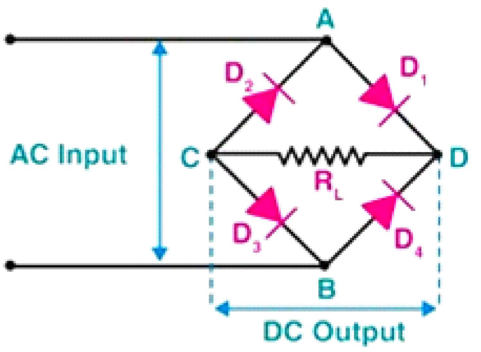
➢ **Half wave rectifier**

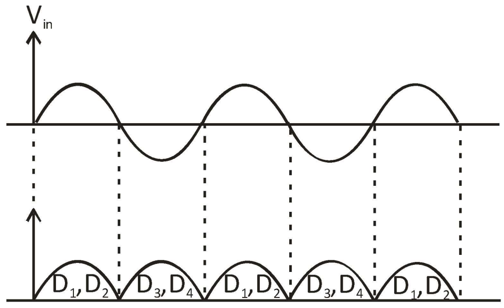


➢ **Full wave rectifier**



➢ Bridge Rectifier





- **Form factor =** $\frac{I_{rms}}{I_{dc}}$

❑ For HWR (Half wave rectifier) form factor $= \frac{\pi}{2}$

❑ For FWR (Full wave rectifier) form factor $= \frac{\pi}{2\sqrt{2}}$

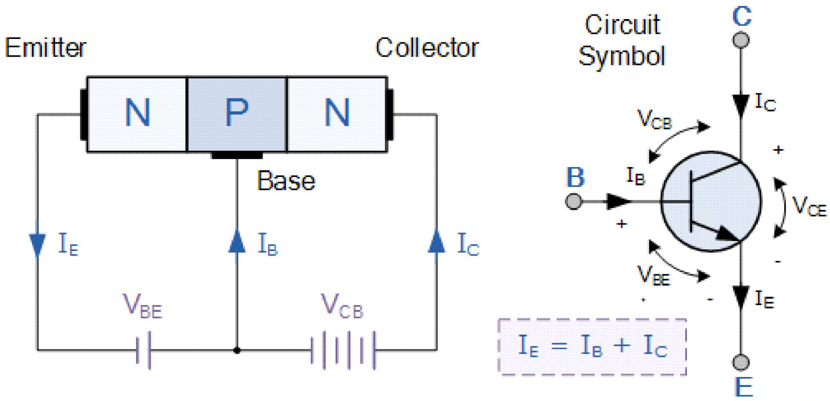
- **Ripple factor r =** $\frac{I_{ac}}{I_{dc}}$

❑ For HWR r = 1.21 For FWR r = 0.48

- **Rectifier efficiency** $\eta = \frac{P_{dc}}{p_{ac}} = \frac{I^2_{dc} R_L}{I^2_{rms}(R_F + R_L)}$

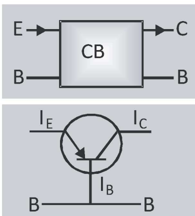
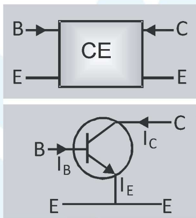
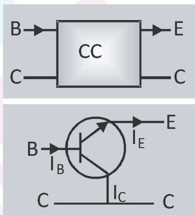
❑ For HWR $\eta\% = \frac{40.6}{1+\frac{R_F}{R_L}}$ & FWR $\eta\% = \frac{81.2}{1+\frac{R_F}{R_L}}$

➢ NPN Transistor



Comparative study of transistor configurations

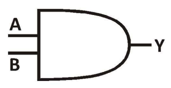
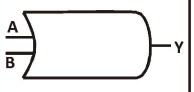
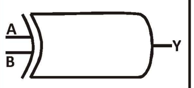
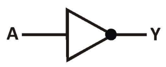
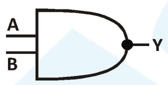
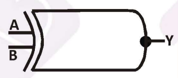
1. Common Base (CB)
2. Common Emitter (CE)
3. Common Collector (CC)

	CB	CE	CC
			
Input Resistance	Low (100Ω)	High (750Ω)	Very High ≅ 750kΩ
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	$A_V = \frac{V_0}{V_i} = \frac{I_C R_L}{I_E R_i}$	$A_V = \frac{V_0}{V_i} = \frac{I_C R_L}{I_B R_i}$	$A_V = \frac{V_0}{V_i} = \frac{I_E R_L}{I_B R_i}$
	$A_V = \alpha \frac{R_L}{R_i} \cong 150$	$A_V = \beta \frac{R_L}{R_i} \cong 500$	$A_V = \gamma \frac{R_L}{R_i} < 1$
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 : $\beta=\frac{\alpha}{1-\alpha}$, $\gamma=1+\beta$, $\gamma=\frac{1}{1-\alpha}$

➢ Logic Gates

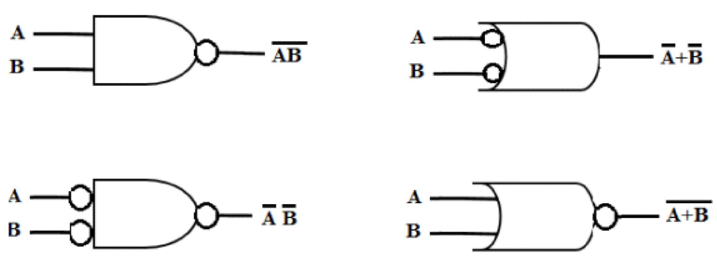
Basic Logic Gates

Logic	Schematic	Boolean Expression	A	B	Y
AND		A•B=Y	0	0	
			0	1	
			1	0	
			1	1	
OR		A+B=Y	0	0	
			0	1	
			1	0	
			1	1	
XOR		A⊕B=Y	0	0	
			0	1	
			1	0	
			1	1	
NOT		$\bar{A}$ = Y	0	0	
			0	1	
			1	0	
			1	1	
NAND		A • B = Y	0	0	
			0	1	
			1	0	
			1	1	
NOR		A + B = Y	0	0	
			0	1	
			1	0	
			1	1	
XNOR		A⊕B = Y	0	0	
			0	1	
			1	0	
			1	1	

➢ De Morgan's theorem

$\overline{A+B}=\bar{A}.\bar{B}$

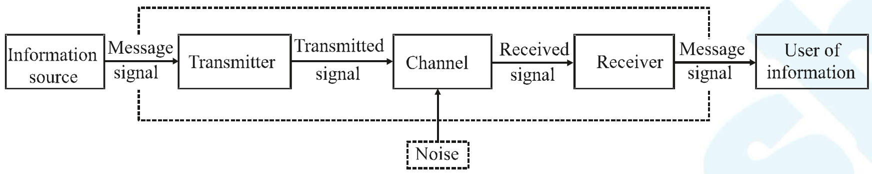
$\overline{A.B}=\bar{A}+\bar{B}$



COMMUNICATION SYSTEM

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

Basic components of a communication system



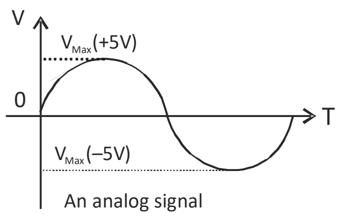
● **Transmitter:** Transmitter converts the message signal produced by information source into a form (e.g. electrical signal) that is suitable for transmission through the channel to the receiver.

● **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.

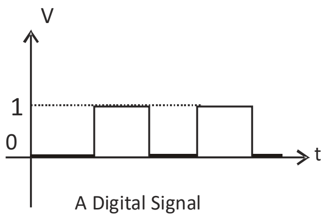
● **Receiver** : It receives and decode the signal into original form.

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 signals.



An analog signal



A Digital Signal

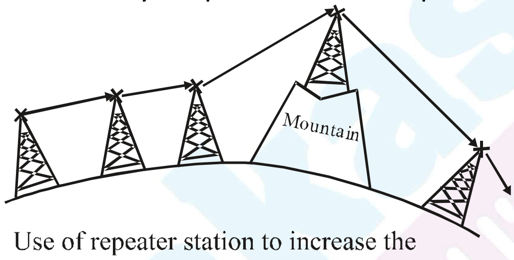
● **Noise :** There are unwanted signals that tend to disturb the transmission and processing of message signals. The source of noise can be inside or outside the system.

● **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 υ_0, $2\upsilon_0$, $3\upsilon_0$, $4\upsilon_0$, $n\upsilon_0$, 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	540kHz -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 high 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 1500kHz).

(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 ionospheric 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 $f_e = 9\sqrt{N_{max}}$ 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.

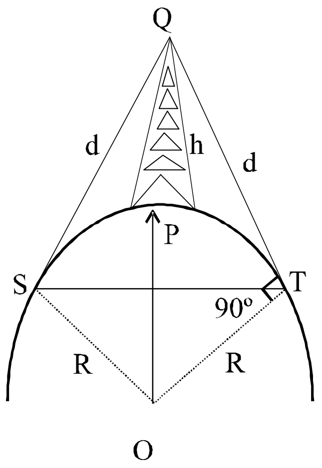
(c) The range of communication of space wave propagation can be increased by increasing the heights of transmitting and receiving antenna.

(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 $h^2 + 2Rh = d^2 \Rightarrow d = \sqrt{2Rh}$

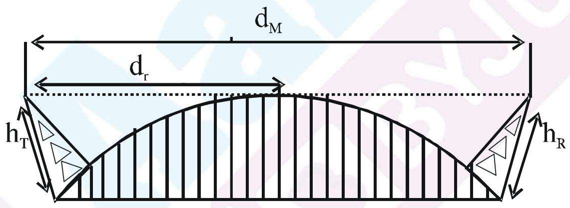


Area covered for TV transmission : $A = \pi d^2 = 2\pi Rh$

Population covered = population density × area covered

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

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



Line of sight communication by space waves

where;

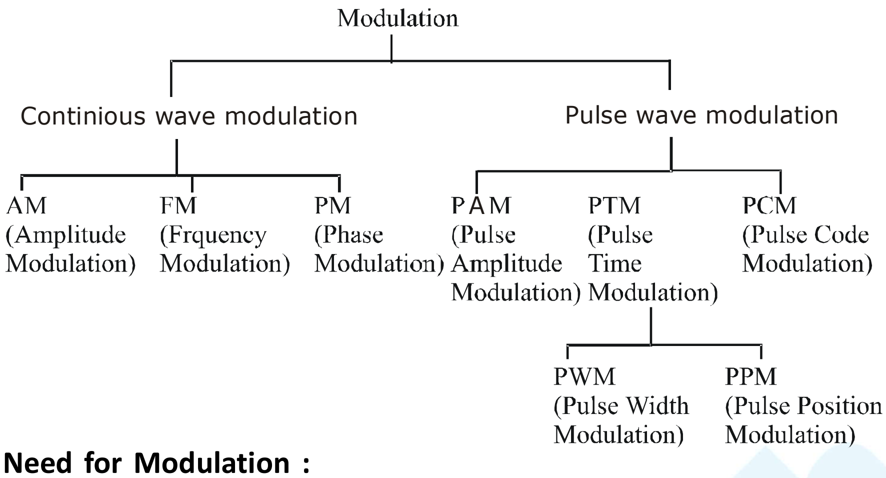
R = radius of earth (approximately 6400 km)

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 aviod interference :

If many modulating signals travel directly through the same transmission channel, they will interfere with each other and result in distortion.

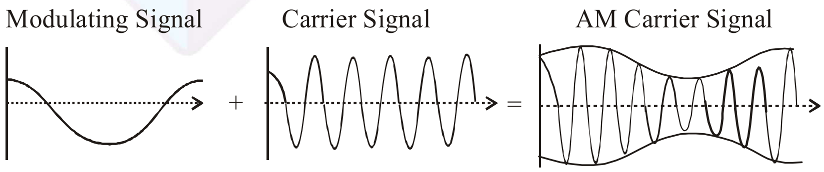
(ii) To design antennas of practical size :

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

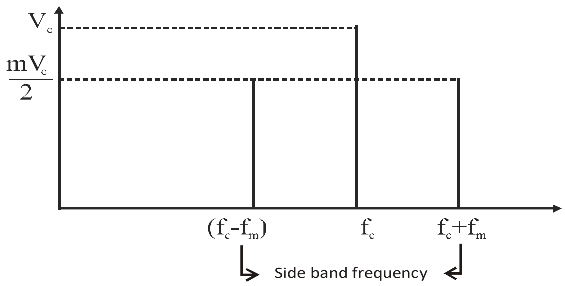
if $V_m = V_m \cos \omega_m t$ and $v_c = V_c \cos\omega_c t$ then $m = \dfrac{V_m}{V_c}$

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 = $\frac{\omega_c}{2\pi}$

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

$$\Rightarrow V = V_c \cos \omega_c t + \frac{mV_c}{2} \cos (\omega_c + \omega_m) t + \frac{mV_c}{2} \cos (\omega_c - \omega_m)t$$

Frequency spectrum of AM wave



Power in AM wave

- Power of carrier wave : $P_c = \frac{V_c^2}{2R}$ where R = resistance of antenna in which power is disspated

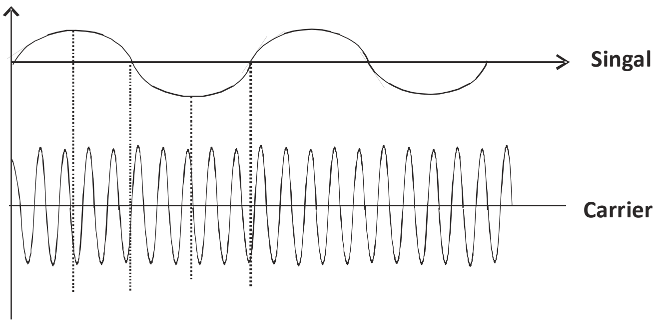
- Total power of side bands : $P_{sidebands} = 2 \times \frac{1}{2R}\left(\frac{mV_c}{2}\right)^2 = \frac{m^2}{2} p_c$

- 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 instantneous value of the modulating signal, it is called frequency modulation.



MODULATION FACTOR OR INDEX AND CARRIER SWING (CS)

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

$\Delta f = f_{max} - f_c = f_c - f_{min}$: $v_{FM} = V_c \cos[\omega_c t + m_f \cos\omega_m t]$

- **Carrier Swing (CS)**

The total variation in frequency from the lowest to the highest is called the carrier swing

$\Rightarrow$ CS = $2 \times \Delta f$

- **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	The amplitude of AM singal varies depending on modulation index
2. It require much wider channel (Band width) [7 to 15 times] as Compared to AM	Band width is very small (One of the biggest advantage)
3. Transmitters are complex and hence expensive.	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)	Area of reception is large.
5. Noise can be easily minimized amplitude variation can be eliminated by using limiter.	It is difficult to eliminate effect to noise
6. Power contained in the FM wave is useful. Hence full transmitted power is useful.	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.	The average power in modulated wave is greater than carrier power.
8. No restriction is placed on modulation index (m).	Maximum m = 1, otherwise over modulation (m > 1) would result in distortion
9. It is possible to operate several independent transmitter on same	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 distance place is called Fax.