CLASS 12 : PHYSICS

FORMULA

ELECTRIC CHARGES AND FIELDS

- Coulomb's law : $F = \frac{k\, q_1 q_2}{r^2} = \frac{1}{4\pi\varepsilon}\frac{q_1 q_2}{r^2}$
- Relative permittivity or dielectric constant :

$$\varepsilon_r \text{ or } K = \frac{\varepsilon}{\varepsilon_0}$$

- Electric field intensity at a point distant r from a point charge q is $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$
- Electric dipole momentm, $\vec{p} = q2\vec{a}$
- Electric field intensity on axial line (end on position) of the electric dipole
  - (i) At the point r from the centre of the electric dipole, $E = \frac{1}{4\pi\varepsilon_0}\frac{2pr}{(r^2 - a^2)^2}$.
  - (ii) At very large distance *i.e.*, $(r >> a)$, $E = \frac{2p}{4\pi\varepsilon_0 r^3}$
- Electric field intensity on equatorial line (board on position) of electric dipole
  - (i) At the point at a distance r from the centre of electric dipole, $E = \frac{1}{4\pi\varepsilon_0}\frac{p}{(r^2 + a^2)^{3/2}}$.
  - (ii) At very large distance *i.e.*, $r >> a$, $E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}$.
- Electric field intensity at any point due to an electric dipole $E = \frac{1}{4\pi\varepsilon_0}\frac{p}{r^3}\sqrt{1 + 3\cos^2\theta}$
- Electric field intensity due to a charged ring
  - (i) At a point on its axis at distance r from its centre, $E = \frac{1}{4\pi\varepsilon_0}\frac{qr}{(r^2 + a^2)^{3/2}}$
  - (ii) At very large distance *i.e.* $r >> a$ $E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$
- Torque on an electric dipole placed in a uniform electric field : $\vec{\tau} = \vec{p} \times \vec{E}$ or $\tau = pE\sin\theta$
- Potential energy of an electric dipole in a uniform electric field is $U = -pE(\cos\theta_2 - \cos\theta_1)$

where θ_1 & θ_1 are initial angle and final angle between $\vec{p}$ and $\vec{E}$.

- Electric flux $\phi = \vec{E} \cdot d\vec{S}$
- Gauss's law : $\oint \vec{E} \cdot d\vec{S} = \frac{q}{\varepsilon_0}$
- Electric field due to thin infinitely long straight wire of uniform linear charge density λ

$$E = \frac{\lambda}{2\pi\varepsilon_0 r},$$

  - (i) At a point outside the shell *i.e.*, $r > R$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$$

  - (ii) At a point on the shell *i.e.*, $r = R$

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2}$$

  - (iii) At a point inside the shell *i.e.*, $r < R$

$$E = 0$$

- Electric field due to a non conducting solid sphere of uniform volume charge density ρ and radius R at a point distant r from the centre of the sphere is given as follows :
  - (i) At a point outside the sphere *i.e.*, $r > R$

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{r^2}$$

  - (ii) At a point on the surface of the sphere *i.e.*, $r = R$

$$E = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{R^2}$$

(iii) At a point inside the sphere *i.e.*, $r < R$

$$E = \frac{\rho r}{3\varepsilon_0} = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{R^3}r$$

- Electric field due to a thin non conducting infinite sheet of charge with uniformly charge surface density σ is $E = \frac{\sigma}{2\varepsilon_0}$
- Electric field between two infinite thin plane parallel sheets of uniform surface charge density σ and – σ is $E = \sigma/\varepsilon_0$.

ELECTROSTATIC POTENTIAL AND CAPACITANCE

- Electric potential $V = \frac{W}{q}$
- Electric potential at a point distant r from a point charge q is $V = \frac{q}{4\pi\varepsilon_0 r}$
- The electric potential at point due to an electric dipole

$$V = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\theta}{r^2}$$

- Electric potential due to a uniformly charged spherical shell of uniform surface charge density σ and radius R at a distance r from the centre the shell is given as follows :

  (i) At a point outside the shell *i.e.*, $r > R$

  $$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

  (ii) At a point on the shell *i.e.*, $r = R$

  $$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$$

  (iii) At a point inside the shell *i.e.*, $r > R$

  $$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$$

- Electric potential due to a non-conducting solid sphere of uniform volume charge density r and radius R distant r from the sphere is given as follows :

  (i) At a point outside the sphere *i.e.* $r > R$

  $$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$$

  (ii) At a point on the sphere *i.e.*, $r = R$

  $$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{R}$$

  (iii) At a point inside the sphere *i.e.*, $r < R$

  $$V = \frac{1}{4\pi\varepsilon_0}\frac{q(3R^2 - r^2)}{2R^3}$$

- Relationship between $\vec{E}$ and $\vec{V}$

  $\vec{E} = -\vec{\nabla}V$

  where $\vec{\nabla} = \left[\hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}\right]$

- Electric potential energy of a system of two point charges is $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$
- Capacitance of a spherical conductor of radius R is $C = 4\pi\varepsilon_0 R$
- Capacitance of an air filled parallel plate capacitor $C = \frac{\varepsilon_0 A}{d}$
- Capacitance of an air filled spherical capacitor

$$C = 4\pi\varepsilon_0\frac{ab}{b-a}$$

- Capacitance of an air filled cylindrical capacitor

$$C = \frac{2\pi\varepsilon_0 L}{\ln\left(\frac{b}{a}\right)}$$

- Capacitance of a parallel plate capacitor with a dielectric slab of dielectric constant K, completely filled between the plates of the capacitor, is given by $C = \frac{K\varepsilon_0 A}{d} = \frac{\varepsilon_r\varepsilon_0 A}{d}$
- When a dielectric slab of thickness t and dielectric constant K is introduced between the plates, then the capacitance of a parallel plate capacitor is given by $C = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{K}\right)}$
- When a metallic conductor of thickness t is introduced between the plates, then capacitance of a parallel plate capacitor is given by

$$C = \frac{\varepsilon_0 A}{d - t}$$

- Energy stored in a capacitor :

$$U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$$

- Energy density : $u = \frac{1}{2}\varepsilon_0 E^2$
- Capacitors in series : $\frac{1}{C_S} = \frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_n}$
- Capacitors in parallel : $C_P = C_1 + C_2 + ... + C_n$

CURRENT ELECTRICITY

- Current, $I = \frac{q}{t}$
- Current density $J = \frac{I}{A}$ ***(Electricity, Class 10)***
- Drift velocity of electrons is given by

$$\vec{v}_d = -\frac{e\vec{E}}{m}\tau$$

- Relationship between current and drift velocity

$$I = nAe\, v_d$$

- Relationship between current density and drift velocity

$$J = nev_d$$

- Mobility, $\mu = \frac{|v_d|}{E} = \frac{qE\tau/m}{E} = \frac{q\tau}{m}$
- Resistance $R = \frac{V}{I}$.
- Conductance : $G = \frac{1}{R}$.
- The resistance of a conductor is

$$R = \frac{m}{ne^2\tau}\frac{l}{A} = \rho\frac{l}{A} \quad \text{where } \rho = \frac{m}{ne^2\tau}$$

- Conductivity :

$$\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m} = ne\mu \qquad \left[\text{As } \mu = \frac{v_d}{E} = \frac{e\tau}{m}\right]$$

- If the conductor is in the form of wire of length l and a radius r, then its resistance is

$$R = \frac{\rho l}{\pi r^2}$$

- If a conductor has mass m, volume V and density d, then its resistance R is

$$R = \frac{\rho l}{A} = \frac{\rho l^2}{Al} = \frac{\rho l^2}{V} = \frac{\rho l^2 d}{m}$$

(Electricity, Class 10)

- A cylindrical tube of length l has inner and outer radii r_1 and r_2 respectively. The resistance between its end faces is

$$R = \frac{\rho l}{\pi\left(r_2^2 - r_1^2\right)}.$$

- Relationship between J, σ and E

$$J = \sigma E$$

- The resistance of a conductor at temperature t°C is given by $R_t = R_0\,(1 + \alpha t + \beta t^2)$
- Resistors in series $R_s = R_1 + R_2 + R_3$
- Resistors in parallel $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$.

(Electricity, Class 10)

- Relationship between ε, V and r

or $r = R\left(\frac{\varepsilon}{V} - 1\right)$

where ε emf of a cell, r internal resistance and R is external resistance

- Wheatstone's bridge $\frac{P}{Q} = \frac{R}{S}$
- Metre bridge or slide metre bridge
  The unknown resistance, $R = \frac{Sl}{100 - l}$.
- Comparison of emfs of two cells by using potentiometer $\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$
- Determination of internal resistance of a cell by potentiometer $r = \left(\frac{l_1 - l_2}{l_2}\right)R$
- Electric power $P = \frac{\text{electric work done}}{\text{time taken}}$

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

(Electricity, Class 10)

MOVING CHARGES AND MAGNETISM

- Force on a charged particle in a uniform electric field $\vec{F} = q\vec{E}$
- Force on a charged particle in a uniform magnetic field $\vec{F} = q\,(\vec{v} \times \vec{B})$ or $F = qvB\sin\theta$
- Motion of a charged particle in a uniform magnetic field
  (i) Radius of circular path is

$$R = \frac{mv}{Bq} = \frac{\sqrt{2mK}}{qB}$$

  (ii) Time period of revolution is $T = \frac{2\pi R}{v} = \frac{2\pi m}{qB}$

  (iii) The frequency is $\upsilon = \frac{1}{T} = \frac{qB}{2\pi m}$

  (iv) The angular frequency is $\omega = 2\pi\upsilon = \frac{qB}{m}$

- Cyclotron frequency, $\upsilon = \frac{Bq}{2\pi m}$
- Biot Savart's law

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2} \quad \text{or} \quad d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,(d\vec{l} \times \vec{r})}{r^3}$$

- The magnetic field B at a point due to a straight wire of finite length carrying current I at a perpendicular distance r is

$$B = \frac{\mu_0 I}{4\pi r}[\sin\alpha + \sin\beta]$$

- The magnetic field at a point on the axis of the circular current carrying coil is

$$B = \frac{\mu_0}{4\pi} \frac{2\pi N I a^2}{(a^2 + x^2)^{3/2}}$$

- Magnetic field at the centre due to current carrying circular arc

$$B = \frac{\mu_0 I \phi}{4\pi a}.$$

- The magnetic field at the centre of a circular coil of radius a carrying current I is

$$B = \frac{\mu_0}{4\pi} \frac{2\pi I}{a} = \frac{\mu_0 I}{2a}$$

If the circular coil consists of N turns, then

$$B = \frac{\mu_0}{4\pi} \frac{2\pi N I}{a} = \frac{\mu_0 N I}{2a}$$

- Ampere's circuital law $\oint \vec{B} \cdot d\vec{l} = \mu_0 I$.
- Magnetic field due to an infinitely long straight solid cylindrical wire of radius a, carrying current I
  - (a) Magnetic field at a point outside the wire *i.e.* $(r > a)$ is $B = \frac{\mu_0 I}{2\pi r}$
  - (b) Magnetic field at a point inside the wire *i.e.* $(r < a)$ is $B = \frac{\mu_0 I r}{2\pi a^2}$
  - (c) Magnetic field at a point on the surface of a wire *i.e.* $(r = a)$ is $B = \frac{\mu_0 I}{2\pi a}$
- Force on a current carrying conductor in a uniform magnetic field

$$\vec{F} = I(\vec{l} \times \vec{B}) \quad \text{or} \quad F = IlB \sin\theta$$

- When two parallel conductors separated by a distance r carry currents I_1 and I_2, the magnetic field of one will exert a force on the other. The force per unit length on either conductor is

$$f = \frac{\mu_0}{4\pi} \frac{2 I_1 I_2}{r}$$

- The force of attraction or repulsion acting on each conductor of length l due to currents in two parallel conductor is $F = \frac{\mu_0}{4\pi} \frac{2 I_1 I_2}{r} l.$
- When two charges q_1 and q_2 respectively moving with velocities v_1 and v_2 are at a distance r apart, then the force acting between them is

$$F = \frac{\mu_0}{4\pi} \frac{q_1 q_2 \, v_1 v_2}{r^2}$$

- Torque on a current carrying coil placed in a uniform magnetic field

$$\tau = NIAB\sin\theta = MB\sin\theta$$

- If α is the angle between plane of the coil and the magnetic field, then torque on the coil is

$$\tau = NIAB \cos\alpha = MB \cos\alpha$$

- Workdone in rotating the coil through an angle θ from the field direction is

$$W = MB\,(1 - \cos\theta)$$

- Potential energy of a magnetic dipole

$$U = -\vec{M} \cdot \vec{B} = -MB\cos\theta$$

- An electron revolving around the central nucleus in an atom has a magnetic moment and it is given by $\vec{\mu}_l = -\frac{e}{2m}\vec{L}$
- Conversion of galvanometer into a ammeter

$$S = \left(\frac{I_g}{I - I_g}\right) G$$

- Conversion of galvanometer into voltmeter

$$R = \frac{V}{I_g} - G$$

- In order to increase the range of voltmeter n times the value of resistance to be connected in series with galvanometer is $R = (n - 1)G$.
- Magnetic dipole moment

$$\vec{M} = m\,(2\vec{l}\,)$$

- The magnetic field due to a bar magnet at any point on the axial line (end on position) is

$$B_{\text{axial}} = \frac{\mu_0}{4\pi} \frac{2Mr}{(r^2 - l^2)^2}$$

For short magnet $l^2 << r^2$

$$B_{\text{axial}} = \frac{\mu_0 2M}{4\pi r^3}$$

The direction of B_{axial} is along SN.
- The magnetic field due to a bar magnet at any point on the equatorial line (board-side on position) of the bar magnet is

$$B_{\text{equatorial}} = \frac{\mu_0 M}{4\pi (r^2 + l^2)^{3/2}}$$

For short magnet

$$B_{\text{equatorial}} = \frac{\mu_0 M}{4\pi r^3}$$

The direction of $B_{\text{equatorial}}$ is parallel to NS.
- In moving coil galvanometer the current I passing through the galvanometer is directly proportional to its deflection (θ).

$$I \propto \theta \quad \text{or,} \quad I = G\theta.$$

where $G = \frac{k}{NAB}$ = galvanometer constant

- Current sensitivity : $I_s = \frac{\theta}{I} = \frac{NAB}{k}.$
- Voltage sensitivity : $V_s = \frac{\theta}{V} = \frac{\theta}{IR} = \frac{NAB}{kR}.$

MAGNETISM AND MATTER

- Gauss's law for magnetism

$$\phi = \sum_{\substack{\text{all area} \\ \text{elements } \Delta S}} \vec{B} \cdot \Delta \vec{S} = 0$$

- Horizontal component :

$$B_H = B \cos\delta$$

- Magnetic intensity

$$B = \mu H$$

- Intensity of magnetisation

$$I = \frac{\text{Magnetic moment}}{\text{Volume}} = \frac{M}{V}$$

- Magnetic susceptibility

$$\chi_m = \frac{I}{H}$$

- Magnetic permeability

$$\mu = \frac{B}{H}$$

- Relative permeability :

$$\mu_r = \frac{\mu}{\mu_0}$$

- Relationship between magnetic permeability and susceptibility

$$\mu_r = 1 + \chi_m \quad \text{with} \quad \mu_r = \frac{\mu}{\mu_0}$$

- Curie law : $\chi_m = \frac{C}{T}$

$$\chi_m = \frac{C}{T - T_C} \; (T > T_C)$$

ELECTROMAGNETIC INDUCTION

- Magnetic Flux

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

- Faraday's law of electromagnetic induction

$$\varepsilon = -\frac{d\phi}{dt}$$

- When a conducting rod of length l is rotated perpendicular to a uniform magnetic field B, then induced emf between the ends of the rod is

$$|\varepsilon| = \frac{B\omega l^2}{2} = \frac{B(2\pi\upsilon)l^2}{2}$$

$$|\varepsilon| = B\upsilon(\pi l^2) = B\upsilon A$$

- The self induced emf is

$$\varepsilon = -\frac{d\phi}{dt} = -L\frac{dI}{dt}$$

- Self inductance of a circular coil is

$$L = \frac{\mu_0 N^2 \pi R}{2}$$

- Let I_P be the current flowing through primary coil at any instant. If ϕ_S is the flux linked with secondary coil then

$$\phi_S \propto I_P \quad \text{or} \quad \phi_S = MI_P$$

where M is the coefficient of mutual inductance. The emf induced in the secondary coil is given by

$$\varepsilon_S = -M\frac{dI_P}{dt}$$

where M is the coefficient of mutual inductance.

- Coefficient of coupling (K) :

$$K = \frac{M}{\sqrt{L_1 L_2}}$$

- The coefficient of mutual inductance of two long co-axial solenoids, each of length l, area of cross section A, wound on air core is

$$M = \frac{\mu_0 N_1 N_2 A}{l}$$

- Energy stored in an inductor

$$U = \frac{1}{2}LI^2$$

- During the growth of current in a LR circuit is

$$I = I_0(1 - e^{-Rt/L}) = I_0(1 - e^{-t/\tau})$$

where I_0 is the maximum value of current, $\tau = L/R$ = time constant of LR circuit.

- During the decay of current in a LR circuit is

$$I = I_0 e^{-Rt/L} = I_0 e^{-t/\tau}$$

- During charging of capacitor through resistor

$$q = q_0(1 - e^{-t/RC}) = q_0(1 - e^{-t/\tau})$$

where q_0 is the maximum value of charge. $\tau = RC$ is the time constant of CR circuit.

- During discharging of capacitor through resistor

$$q = q_0 e^{-t/RC} = q_0 e^{-t/\tau}$$

ALTERNATING CURRENT

- Mean or average value of alternating current or voltage over one complete cycle

$$I_m \text{ or } \bar{I} \text{ or } I_{av} = \frac{\int_0^T I_0 \sin\omega t \, dt}{\int_0^T dt} = 0$$

$$V_m \text{ or } \bar{V} \text{ or } V_{av} = \frac{\int_0^T V_0 \sin\omega t \, dt}{\int_0^T dt} = 0$$

- Average value of alternating current for first half cycle is

$$I_{av} = \frac{\int_0^{T/2} I_0 \sin\omega t \, dt}{\int_0^{T/2} dt} = \frac{2I_0}{\pi} = 0.637 I_0$$

- Similarly, for alternating voltage, the average value over first half cycle is

$$V_{av} = \frac{\int_0^{T/2} V_0 \sin\omega t dt}{\int_0^{T/2} dt} = \frac{2V_0}{\pi} = 0.637 V_0$$

- Average value of alternating current for second cycle is

$$I_{av} = \frac{\int_{T/2}^{T} I_0 \sin\omega t dt}{\int_{T/2}^{T} dt} = -\frac{2I_0}{\pi} = -0.637\, I_0$$

- Similarly, for alternating voltage, the average value over second half cycle is

$$V_{av} = \frac{\int_{T/2}^{T} V_0 \sin\omega t dt}{\int_{T/2}^{T} dt} = -\frac{2V_0}{\pi} = -0.637\, V_0$$

- Mean value or average value of alternating current over any half cycle

$$I_{av} = \frac{2I_0}{\pi} = 0.637 I_0$$

$$I_{av} = \frac{2I_0}{\pi} = 0.637 I_0$$

- Root mean square (rms) value of alternating current

$$I_{rms} \text{ or } I_v = \frac{I_0}{\sqrt{2}} = 0.707 I_0$$

Similarly, for alternating voltage

$$V_{rms} = \frac{V_0}{\sqrt{2}} = 0.707\, V_0$$

- $\text{Form factor} = \frac{I_{rms}}{I_{av}}$

- Inductive reactance :

$$X_L = \omega L = 2\pi \upsilon L$$

- Capacitive reactance : $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\upsilon C}$

The impedance of the series *LCR* circuit.

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$\therefore$ Admittance $= \frac{1}{\text{Impedance}}$ or $Y = \frac{1}{Z}$

$\therefore$ Susceptance $= \frac{1}{\text{Reactance}}$

- Inductive susceptance $= \frac{1}{\text{Inductive reactance}}$

or $S_L = \frac{1}{X_L} = \frac{1}{\omega L}$

- Capacitive susceptance $= \frac{1}{\text{Capacitive reactance}}$

or $S_C = \frac{1}{X_C} = \frac{1}{1/\omega C} = \omega C$

- The resonant frequency is

$$\upsilon_r = \frac{1}{2\pi\sqrt{LC}}$$

$$\omega_r = \frac{1}{\sqrt{LC}}$$

- Quality factor

$$Q = \frac{X_L}{R} = \frac{\omega_r L}{R}$$

$$Q = \frac{X_C}{R} = \frac{1}{\omega_r CR}$$

$$\therefore Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

- Average power (P_{av}) :

$$P_{av} = V_{rms} I_{rms} \cos\phi = \frac{V_0 I_0}{2} \cos\phi$$

- Apparent power : $P_v = V_{rms} I_{rms} = \frac{V_0 I_0}{2}$

- Efficiency of a transformer,

$$\eta = \frac{\text{output power}}{\text{input power}} = \frac{V_S I_S}{V_P I_P}.$$

ELECTROMAGNETIC WAVES

- The displacement current is given by

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$

- Four Maxwell's equations are :
  - Gauss's law for electrostatics

$$\oint \vec{E} \cdot d\vec{S} = \frac{q}{\varepsilon_0}$$

  - Gauss's law for magnetism

$$\oint \vec{B} \cdot d\vec{S} = 0$$

  - Faraday's law of electromagnetic induction

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d\phi_B}{dt}$$

  - Maxwell-Ampere's circuital law

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 \left[I + \varepsilon_0 \frac{d\phi_E}{dt} \right]$$

- The amplitudes of electric and magnetic fields in free space, in electromagnetic waves are related by

$E_0 = cB_0$ or $B_0 = \frac{E_0}{c}$

- The speed of electromagnetic wave in free space is

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$$

- The speed of electromagnetic wave in a medium is

$$v = \frac{1}{\sqrt{\mu\varepsilon}}$$

- The energy density of the electric field is

$$u_E = \frac{1}{2}\varepsilon_0 E^2$$

- The energy density of magnetic field is

$$u_B = \frac{1}{2}\frac{B^2}{\mu_0}$$

- Average energy density of the electric field is

$$< u_E > = \frac{1}{4}\varepsilon_0 E_0^2$$

- Average energy density of the magnetic field is

$$< u_B > = \frac{1}{4}\frac{B_0^2}{\mu_0} = \frac{1}{4}\varepsilon_0 E_0^2$$

- Average energy density of electromagnetic wave is

$$< u > = \frac{1}{2}\varepsilon_0 E_0^2$$

- Intensity of electromagnetic wave

$$I = < u > c = \frac{1}{2}\varepsilon_0 E_0^2 c$$

- Momentum of electromagnetic wave

$p = \frac{U}{c}$ (complete absorption)

$p = \frac{2U}{c}$ (complete reflection)

- The poynting vector is

$$\vec{S} = \frac{1}{\mu_0}\left(\vec{E}\times\vec{B}\right)$$

RAY OPTICS AND OPTICAL INSTRUMENTS

- When two plane mirrors are inclined at an angle θ and an object is placed between them, the number of images of an object are formed due to multiple reflections.

$n = \frac{360°}{\theta}$	Position of object	Number of images
even	anywhere	$n - 1$
odd	symmetric	$n - 1$
	asymmetric	n

- If $\frac{360°}{\theta}$ is a fraction, the number of images formed will be equal to its integral part.

(Light, Class 8)

- The focal length of a spherical mirror of radius R is given by

$$f = \frac{R}{2}$$

- Transverse or linear magnification

$$m = \frac{\text{size of image}}{\text{size of object}} = -\frac{v}{u}$$

- Longitudinal magnification :

$$m_L = -\frac{dv}{du}$$

- Superficial magnification :

$$m_S = \frac{\text{area of image}}{\text{area of object}} = m^2$$

- Mirror's formula $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$
- Newton's formula is $f^2 = xy$,
- Laws of refraction : $\frac{\sin i}{\sin r} = {}^1\mu_2$
- Absolute refractive index :

$${}^1\mu_2 = \frac{\mu_2}{\mu_1} = \frac{\left(\frac{c}{v_2}\right)}{\left(\frac{c}{v_1}\right)} = \frac{v_1}{v_2}$$

Lateral shift, $d = t\,\frac{\sin(i - r)}{\cos r}$

(Light, Reflection and Refraction, Class 10)

- If there is an ink spot at the bottom of a glass slab, it appears to be raised by a distance

$$d = t - \frac{t}{\mu} = t\left(1 - \frac{1}{\mu}\right)$$

- When the object is situated in rarer medium, the relation between μ_1 (refractive index of rarer medium) μ_2 (refractive index of the spherical refracting surface) and R (radius of curvature) with the object and image distances is given by

$$-\frac{\mu_1}{u} + \frac{\mu_2}{v} = \frac{\mu_2 - \mu_1}{R}$$

- When the object is situated in denser medium, the relation between μ_1, μ_2, R, u and v can be obtained by interchanging μ_1 and μ_2. In that case, the relation becomes

$$-\frac{\mu_2}{u} + \frac{\mu_1}{v} = \frac{\mu_1 - \mu_2}{R} \quad \text{or} \quad -\frac{\mu_1}{v} + \frac{\mu_2}{u} = \frac{\mu_2 - \mu_1}{R}$$

- Lens maker's formula

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

- Thin lens formula

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

- Linear magnification

$$m = \frac{\text{size of image } (I)}{\text{size of object } (O)} = \frac{v}{u}.$$

- Power of a lens

$$P = \frac{1}{\text{focal length in metres}}.$$

- Combination of thin lenses in contact

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + ...$$

- The total power of the combination is given by

$$P = P_1 + P_2 + P_3 + \ldots$$

- The total magnification of the combination is given by

$$m = m_1 \times m_2 \times m_3 \ldots.$$

- When two thin lenses of focal lengths f_1 and f_2 are placed coaxially and separated by a distance d, the focal length of a combination is given by

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}.$$

- In terms of power $P = P_1 + P_2 - dP_1P_2$.

(Light, Reflection and Refraction, Class 10)

- If I_1, I_2 are the two sizes of image of the object of size O, then $O = \sqrt{I_1 I_2}$
- The refractive index of the material of the prism is

$$\mu = \frac{\sin\left[\frac{(A+\delta_m)}{2}\right]}{\sin\left(\frac{A}{2}\right)}$$

where A is the angle of prism and δ_m is the angle of minimum deviation.

- Mean deviation $\delta = \frac{\delta_V + \delta_R}{2}$.
- Dispersive power,

$$\omega = \frac{\text{angular dispersion } (\delta_V - \delta_R)}{\text{mean deviation } (\delta)}$$

$$\omega = \frac{\mu_V - \mu_R}{(\mu - 1)},$$

where $\mu = \frac{\mu_V + \mu_R}{2}$ = mean refractive index

- Magnifying power, of simple microscope

$$M = \frac{\text{angle subtended by image at the eye}}{\text{angle subtended by the object at the eye}}$$

$$= \frac{\tan\beta}{\tan\alpha} = \frac{\beta}{\alpha}$$

- When the image is formed at infinity (far point),

$$M = \frac{D}{f}$$

- When the image is formed at the least distance of distinct vision D (near point),

$$M = 1 + \frac{D}{f}$$

- Magnifying power of a compound microscope

$$M = m_o \times m_e$$

- When the final image is formed at infinity (normal adjustment),

$$M = \frac{v_o}{u_o}\left(\frac{D}{f_e}\right)$$

Length of tube, $L = v_o + f_e$

- When the final image is formed at least distance of distinct vision,

$$M = \frac{v_o}{u_o}\left(1 + \frac{D}{f_e}\right)$$

where u_o and v_o represent the distance of object and image from the objective lens, f_e is the focal length of an eye lens.

Length of the tube, $L = v_o + \left(\frac{f_e D}{f_e + D}\right)$

- Astronomial telescope

magnifying power, $M = \frac{f_o}{f_e}$

Length of tube, $L = f_o + \left(\frac{f_e D}{f_e + D}\right)$

WAVE OPTICS

- For constructive interference (i.e. formation of bright fringes)
  - For n^{th} bright fringe,

Path difference $= x_n \frac{d}{D} = n\lambda$

where $n = 0$ for central bright fringe
$n = 1$ for first bright fringe,
$n = 2$ for second bright fringe and so on
d = distance between two slits
D = distance of slits from the screen
x_n = distance of n^{th} bright fringe from the centre.

$\therefore\ x_n = n\lambda \frac{D}{d}$

- For destructive interference (*i.e.* formation of dark fringes).
  - For n^{th} dark fringe,

path difference $= x_n \frac{d}{D} = (2n-1)\frac{\lambda}{2}$

where
$n = 1$ for first dark fringe,
$n = 2$ for 2^{nd} dark fringe and so on.
x_n = distance of n^{th} dark fringe from the centre

$\therefore\ x_n = (2n-1)\frac{\lambda}{2}\frac{D}{d}$

- Fringe width, $\beta = \frac{\lambda D}{d}$
- Angular fringe width, $\theta = \frac{\beta}{D} = \frac{\lambda}{d}$
- If W_1, W_2 are widths of two slits, I_1, I_2 are intensities of light coming from two slits; a, b are the amplitudes of light from these slits, then

$$\frac{W_1}{W_2} = \frac{I_1}{I_2} = \frac{a^2}{b^2}$$

$$\frac{I_{max}}{I_{min}} = \frac{(a+b)^2}{(a-b)^2}$$

- Fringe visibility $V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$
- When entire apparatus of Young's double slit experiment is immersed in a medium of refractive index μ, then fringe width becomes

$$\beta' = \frac{\lambda' D}{d} = \frac{\lambda D}{\mu d} = \frac{\beta}{\mu}$$

- When a thin transparent plate of thickness t and refractive idnex μ is placed in the path of one of the interfering waves, fringe width remains unaffected but the entire pattern shifts by

$$\Delta x = (\mu - 1)\, t\, \frac{D}{d} = (\mu - 1)\, t\, \frac{\beta}{\lambda}$$

- Diffraction due to a single slit
  Width of secondary maxima or minima

$$\beta = \frac{\lambda D}{a} = \frac{\lambda f}{a}$$

where
a = width of slit
D = distance of screen from the slit
f = focal length of lens for diffracted light

- Width of central maximum $= \frac{2\lambda D}{a} = \frac{2f\lambda}{a}$
- Angular width fringe of central maximum $= \frac{2\lambda}{a}$.
- Angular fringe width of secondary maxima or minima $= \frac{\lambda}{a}$
- Fresnel distance, $Z_F = \frac{a^2}{\lambda}$
- Resolving power of a microscope

$$\text{Resolving power} = \frac{1}{d} = \frac{2\mu \sin\theta}{\lambda}$$

- Resolving power of a telescope

$$\text{Resolving power} = \frac{1}{d\theta} = \frac{D}{1.22\,\lambda}$$

DUAL NATURE OF RADIATION AND MATTER

- Energy of a photon $E = h\upsilon = \frac{hc}{\lambda}$
- Momentum of photon is

$$p = \frac{E}{c} = \frac{h\upsilon}{c}$$

- The moving mass m of photon is $m = \frac{E}{c^2} = \frac{h\upsilon}{c^2}$.
- Stopping potential

$$K_{max} = eV_0 = \frac{1}{2} m v_{max}^2$$

- Einstein's photoelectric equation
  If a light of frequency υ is incident on a photosensitive material having work function (ϕ_0), then maximum kinetic energy of the emitted electron is given as

$$K_{max} = h\upsilon - \phi_0$$

For $\upsilon > \upsilon_0$ or $eV_0 = h\upsilon - \phi_0 = h\upsilon - h\upsilon_0$

or $eV_0 = K_{max} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$.

- de Broglie wavelength, $\lambda = \frac{h}{p} = \frac{h}{mv}$
- If the rest mass of a particle is m_0, its de Broglie wavelength is given by

$$\lambda = \frac{h\left(1 - \frac{v^2}{c^2}\right)^{1/2}}{m_0 v}$$

- In terms of kinetic energy K, de Broglie wavelength is given by $\lambda = \frac{h}{\sqrt{2mK}}$.
- If a particle of charge q is accelerated through a potential difference V, its de Broglie wavelength is given by $\lambda = \frac{h}{\sqrt{2mqV}}$.

For an electron, $\lambda = \left(\frac{150}{V}\right)^{1/2}$ Å.

- For a gas molecule of mass m at temperature T kelvin, its de Broglie wavelength is given by $\lambda = \frac{h}{\sqrt{3mkT}}$, where k is the Boltzmann constant.

ATOMS

- Rutherford's nuclear model of the atom

$$N(\theta) = \frac{N_i n t Z^2 e^4}{(8\pi\varepsilon_0)^2 r^2 K^2 \sin^4(\theta/2)}$$

The frequency of incident alpha particles scattered by an angle θ or greater

$$f = \pi n t \left(\frac{Ze^2}{4\pi\varepsilon_0 K}\right)^2 \cot^2\frac{\theta}{2}$$

- The scattering angle θ of the α particle and impact parameter b are related as

$$b = \frac{Ze^2 \cot(\theta/2)}{4\pi\varepsilon_0 K}$$

- Distance of closest approach

$$r_0 = \frac{2Ze^2}{4\pi\varepsilon_0 K}$$

- Angular momentum of the electron in a stationary orbit is an integral multiple of $h/2\pi$.

$$i.e., \; L = \frac{nh}{2\pi} \quad \text{or,} \quad mvr = \frac{nh}{2\pi}$$

- The frequency of a radiation from electrons makes a transition from higher to lower orbit

$$\upsilon = \frac{E_2 - E_1}{h}$$

- Bohr's formulae

(i) Radius of n^{th} orbit

$$r_n = \frac{4\pi\varepsilon_0 n^2h^2}{4\pi^2 mZe^2}; \quad r_n = \frac{0.53n^2}{Z}\ \text{Å}$$

(ii) Velocity of electron in the n^{th} orbit

$$v_n = \frac{1}{4\pi\varepsilon_0}\frac{2\pi Ze^2}{nh} = \frac{2.2\times10^6\ Z}{n}\ \text{m/s.}$$

(iii) The kinetic energy of the electron in the n^{th} orbit

$$K_n = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2r_n} = \left(\frac{1}{4\pi\varepsilon_0}\right)^2\frac{2\pi^2me^4Z^2}{n^2h^2}$$

$$= \frac{13.6Z^2}{n^2}\ \text{eV.}$$

(iv) The potential energy of electron in n^{th} orbit

$$U_n = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r_n} = -\left(\frac{1}{4\pi\varepsilon_0}\right)^2\frac{4\pi^2me^4Z^2}{n^2h^2}$$

$$= \frac{-27.2Z^2}{n^2}\ \text{eV.}$$

(v) Total energy of electron in n^{th} orbit

$$E_n = U_n + K_n = -\left(\frac{1}{4\pi\varepsilon_0}\right)^2\frac{2\pi^2me^4Z^2}{n^2h^2} = -\frac{13.6Z^2}{n^2}\ \text{eV.}$$

(vi) Frequency of electron in n^{th} orbit

$$\upsilon_n = \left(\frac{1}{4\pi\varepsilon_0}\right)^2\frac{4\pi^2Z^2e^4m}{n^3h^3} = \frac{6.62\times10^{15}Z^2}{n^3}$$

(vii) Wavelength of radiation in the transition from

$n_2 \rightarrow n_1$ is given by

$$\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

where R is called Rydberg's constant.

$$R = \left(\frac{1}{4\pi\varepsilon_0}\right)^2\frac{2\pi^2me^4}{ch^3} = 1.097\times10^7\ \text{m}^{-1}.$$

- Lyman series

Emission spectral lines corresponding to the transition of electron from higher energy levels ($n_2 = 2, 3, ...,\infty$) to first energy level ($n_1 = 1$) constitute Lyman series.

$$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{n_2^2}\right]$$

where $n_2 = 2, 3, 4, ...,\infty$

- Balmer series

Emission spectral lines corresponding to the transition of electron from higher energy levels ($n_2 = 3, 4, ...\infty$) to second energy level ($n_1 = 2$) constitute Balmer series.

$$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n_2^2}\right]$$

where $n_2 = 3, 4, 5..........,\infty$

- Paschen series

Emission spectral lines corresponding to the transition of electron from higher energy levels ($n_2 = 4, 5, ...,\infty$) to third energy level ($n_1 = 3$) constitute Paschen series.

$$\frac{1}{\lambda} = \frac{1}{R}\left[\frac{1}{3^2} - \frac{1}{n_2^2}\right]$$

- Brackett series

Emission spectral lines corresponding to the transition of electron from higher energy levels ($n_2 = 5, 6, 7,.....,\infty$) to fourth energy level ($n_1 = 4$) constitute Brackett series.

$$\frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{n_2^2}\right]$$

where $n_2 = 5, 6, 7.........,\infty$

- Pfund series

Emission spectral lines corresponding to the transition of electron from higher energy levels ($n_2 = 6, 7, 8,.......,\infty$) to fifth energy level ($n_1 = 5$) constitute Pfund series.

$$\frac{1}{\lambda} = R\left[\frac{1}{5^2} - \frac{1}{n_2^2}\right]$$

where $n_2 = 6, 7,..........,\infty$

- Number of spectral lines due to transition of electron from n^{th} orbit to lower orbit is

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

- Ionization energy $= \frac{13.6Z^2}{n^2}$ eV.

- Ionization potential $= \frac{13.6Z^2}{n^2}$ volt.

- Energy quantisation

$$E_n = \frac{n^2h^2}{8mL^2}\ \text{where } n = 1, 2, 3, ...$$

NUCLEI

- Nuclear radius, $R = R_0A^{1/3}$

where R_0 is a constant and A is the mass number

- Nuclear density,

$$\rho = \frac{\text{mass nuclear}}{\text{volume of nucleus}}$$

- Mass defect is given by
$\Delta m = [Zm_p + (A - Z)m_n - m_N]$
- The binding energy of nucleus is given by
$E_b = \Delta mc^2 = [Zm_p + (A - Z)m_n - m_N]c^2$
$= [Zm_p + (A - Z)m_n - m_N] \times 931.49$ MeV/u.
- The binding energy per nucleon of a nucleus $= E_b/A$
- Law of radioactive decay
$$\frac{dN}{dt} = -\lambda N(t) \quad \text{or} \quad N(t) = N_0 e^{-\lambda t}$$
- Half-life of a radioactive substance is given by
$$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$
- Mean life or average life of a radioactive substance is given by
$$\tau = \frac{1}{\lambda} = \frac{T_{1/2}}{0.693} = 1.44 T_{1/2}$$
- Activity : $R = -dN/dt$
- Activity law $R(t) = R_0 e^{-\lambda t}$
where $R_0 = \lambda N_0$ is the decay rate at $t = 0$ and $R = N\lambda$.
- Fraction of nuclei left undecayed after n half live is
$$\frac{N}{N_0} = \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^{t/T_{1/2}} \quad \text{or} \quad t = nT_{1/2}$$
- Neutron reproduction factor (K)
$$= \frac{\text{rate of production of neutrons}}{\text{rate of loss of neutrons}}$$

SEMICONDUCTOR ELETRONICS, MATERIALS, DEVICES AND SIMPLE CIRCUITS

- Forbidden energy gap or forbidden band
$$E_g = h\upsilon = \frac{h\upsilon}{\lambda}$$
- The intrinsic concentration n_i varies with temperature T as
$$n_i^2 = A_0 T^3 e^{-E_g/kT}$$
- The conductivity of the semiconductor is given by $\sigma = e(n_e\mu_e + n_h\mu_h)$
where μ_e and μ_h are the electron and hole mobilities, n_e and n_h are the electron and hole densities, e is the electronic charge.
- The conductivity of an intrinsic semiconductor is
$$\sigma_i = n_i e(\mu_e + \mu_h)$$
- The conductivity of n-type semiconductor is
$$\sigma_n = eN_d\mu_e$$
- The conductivity of p-type semiconductor is
$$\sigma_p = eN_a\mu_h$$
- The current in the junction diode is given by
$$I = I_0 (e^{eV/kT} - 1)$$
where k = Boltzmann constant, I_0 = reverse saturation current.
In forward biasing, V is positive and low, $e^{eV/kT} >> 1$, then forward current,
$$I_f = I_0 (e^{eV/kT})$$
In reverse biasing, V is negative and high $e^{eV/kT} << 1$, then reverse current,
$$I_r = -I_0$$
- Dynamic resistance
$$r_d = \frac{\Delta V}{\Delta I}$$

Half wave rectifier
- Peak value of current is
$$I_m = \frac{V_m}{r_f + R_L}$$
where r_f is the forward diode resistance, R_L is the load resistance and V_m is the peak value of the alternating voltage.
- rms value of current is
$$I_{\text{rms}} = \frac{I_m}{2}$$
- dc value of current is
$$I_{\text{dc}} = \frac{I_m}{\pi}$$
- Peak inverse voltage is
$$P.I.V = V_m$$
- dc value of voltage is
$$V_{\text{dc}} = I_{\text{dc}} R_L = \frac{I_m}{\pi} R_L$$

Full wave rectifier
- Peak value of current is
$$I_m = \frac{V_m}{r_f + R_L}$$
- dc value of current is
$$I_{\text{dc}} = \frac{2I_m}{\pi}$$
- rms value of current is
$$I_{\text{rms}} = \frac{I_m}{\sqrt{2}}$$
- Peak inverse voltage is
$$P.I.V = 2V_m$$
- dc value of voltage is
$$V_{\text{dc}} = I_{\text{dc}} R_L = \frac{2I_m}{\pi} R_L$$

Ripple frequency
$$r = \frac{\text{rms value of the components of wave}}{\text{average or dc value}}$$
$$r = \sqrt{\left(\frac{I_{\text{rms}}}{I_{\text{dc}}}\right)^2 - 1}$$

- For half wave rectifier,

$$I_{\text{rms}} = \frac{I_m}{2}, I_{\text{dc}} = \frac{I_m}{\pi}$$

$$r = \sqrt{\left(\frac{I_m/2}{I_m/\pi}\right)^2 - 1}$$

$$= 1.21$$

- For full wave rectifier,

$$I_{\text{rms}} = \frac{I_m}{\sqrt{2}}, I_{\text{dc}} = \frac{2I_m}{\pi}$$

$$r = \sqrt{\left(\frac{I_m/\sqrt{2}}{2I_m/\pi}\right)^2 - 1}$$

$$= 0.482$$

Rectification efficiency

$$\eta = \frac{\text{dc power delivered to load}}{\text{ac input power from transformer secondary}}$$

- For a half wave rectifier,

dc power delivered to the load is

$$P_{\text{dc}} = I_{\text{dc}}^2 R_L = \left(\frac{I_m}{\pi}\right)^2 R_L$$

Input ac power is

$$P_{\text{ac}} = I_{\text{rms}}^2 (r_f + R_L) = \left(\frac{I_m}{2}\right)^2 (r_f + R_L)$$

Rectification efficiency

$$\eta = \frac{P_{\text{dc}}}{P_{\text{ac}}} = \frac{(I_m/\pi)^2 R_L}{(I_m/2)^2 (r_f + R_L)} \times 100\%$$

$$= \frac{40.6}{1 + r_f/R_L}\%$$

- For a full wave rectifier,

dc power delivered to the load is

$$P_{\text{dc}} = I_{\text{dc}}^2 R_L = \left(\frac{2I_m}{\pi}\right)^2 R_L$$

Input ac power is

$$P_{\text{ac}} = I_{\text{rms}}^2 (r_f + R_L) = \left(\frac{I_m}{\sqrt{2}}\right)^2 (r_f + R_L)$$

Rectification efficiency

$$\eta = \frac{P_{\text{dc}}}{P_{\text{ac}}} = \frac{(2I_m/\pi)^2 R_L}{(I_m/\sqrt{2})^2 (r_f + R_L)} \times 100\% = \frac{81.2}{1 + r_f/R_L}\%$$

If $r_f << R_L$,

Maximum rectification efficiency, $\eta = 81.2\%$

Form factor

- Form factor $= \dfrac{I_{\text{rms}}}{I_{\text{dc}}}$
- For half wave rectifier,

$$I_{\text{rms}} = \frac{I_m}{2}, \ I_{\text{dc}} = \frac{I_m}{\pi}$$

$$\text{Form factor} = \frac{I_m/2}{I_m/\pi} = \frac{\pi}{2} = 1.57$$

- For full wave rectifier,

$$I_{\text{rms}} = \frac{I_m}{\sqrt{2}}, \ I_{\text{dc}} = \frac{2I_m}{\pi}$$

$$\text{Form factor} = \frac{I_m/\sqrt{2}}{2I_m/\pi} = \frac{\pi}{2\sqrt{2}} = 1.11$$

Common emitter amplifier

- dc current gain

$$\beta_{\text{dc}} = \frac{I_C}{I_B}$$

- ac current gain

$$\beta_{\text{ac}} = \frac{\Delta I_C}{\Delta I_B}$$

- Voltage gain

$$A_v = \frac{V_o}{V_i} = -\beta_{\text{ac}} \times \frac{R_o}{R_i}$$

- Power gain

$$A_p = \frac{\text{output power } (P_o)}{\text{input power } (P_i)}$$

- Voltage gain (in dB) $= 20 \log_{10} \dfrac{V_o}{V_i}$

$$= 20 \log_{10} A_v$$

- Power gain (in dB) $= 10 \log \dfrac{P_o}{P_i}$

Common base amplifier

- dc current gain

$$\alpha_{\text{dc}} = \frac{I_C}{I_E}$$

- ac current gain

$$\alpha_{\text{ac}} = \left(\frac{\Delta I_C}{\Delta I_E}\right)$$

- Voltage gain

$$A_v = \frac{V_o}{V_i} = \alpha_{\text{ac}} \times \frac{R_o}{R_i}$$

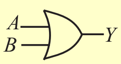
- Power gain

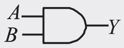
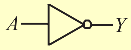
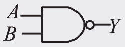
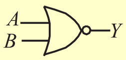
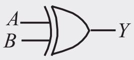
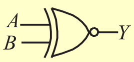
$$A_p = \frac{\text{output power } (P_o)}{\text{input power } (P_i)}$$

$$= \alpha_{\text{ac}} \times A_v$$

- Relationship between α and β

$$\beta = \frac{\alpha}{1-\alpha}; \alpha = \frac{\beta}{1+\beta}$$

Name of gate	Symbol	Truth Table	Boolean expression
OR		A B Y 0 0 0 0 1 1 1 0 1 1 1 1	$Y = A + B$

AND		A B Y 0 0 0 0 1 0 1 0 0 1 1 1	$Y = A \cdot B$
NOT		A Y 0 1 1 0	$Y = \overline{A}$
NAND		A B Y 0 0 1 0 1 1 1 0 1 1 1 0	$Y = \overline{A \cdot B}$
NOR		A B Y 0 0 1 0 1 0 1 0 0 1 1 0	$Y = \overline{A + B}$
XOR (also called exclusive OR gate)		A B Y 0 0 0 0 1 1 1 0 1 1 1 0	$Y = A \cdot \overline{B} + \overline{A} \cdot B$
XNOR		A B Y 0 0 1 0 1 0 1 0 0 1 1 1	$Y = A \cdot B + \overline{A} \cdot \overline{B}$

COMMUNICATION SYSTEM

- Critical frequency, $\upsilon_c = g(N_{\max})^{1/2}$
  where $N_{\max}$ the maximum number density of electron/m^3.
- Maximum usable frequency

$$\text{MUF} = \frac{\upsilon_c}{\cos i} = \upsilon_c \sec i$$

- The skip distance is given by

$$D_{\text{skip}} = 2h\sqrt{\left(\frac{\upsilon_0}{\upsilon_c}\right)^2 - 1}$$

  where h is the height of reflecting layer of atmosphere, υ_0 = maximum frequency of electromagnetic waves used and υ_c is the critical frequency for that layer.
- If h is the height of the transmitting antenna, then the distance to the horizon is given by

$$d = \sqrt{2hR}$$

  where R is the radius of the earth.
  For TV signal,
  area covered = $\pi d^2 = \pi 2hR$
  Population covered = population density × area covered
- The maximum line of sight distance d_M between two antennas having heights h_T and h_R above the earth is given by

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

  where h_T is the height of the transmitting antenna and h_R is the height of the receiving antenna and R is the radius of the earth.
- The amplitude modulated signal contains three frequencies, viz. υ_c, $\upsilon_c + \upsilon_m$ and $\upsilon_c - \upsilon_m$. The first frequency is the carrier frequency Thus, the process of modulation does not change the original carrier frequency but produces two new frequencies ($\upsilon_c + \upsilon_m$) and($\upsilon_c - \upsilon_m$) which are known as sideband frequencies.

$$\upsilon_{SB} = \upsilon_c \pm \upsilon_m$$

- Frequency of lower side band

$$\upsilon_{LSB} = \upsilon_c - \upsilon_m$$

- Frequency of higher side band

$$\upsilon_{USB} = \upsilon_c + \upsilon_m$$

- Bandwidth of AM signal = $\upsilon_{USB} - \upsilon_{LSB} = 2\upsilon_m$
- Average power per cycle in the carrier wave is

$$P_c = \frac{A_c^2}{2R}$$

  where R is the resistance
- Total power per cycle in the modulated wave

$$P_t = P_c\left(1 + \frac{\mu^2}{2}\right)$$

- If I_t is rms value of total modulated current and I_c is the rms value of unmodulated carrier current, then

$$\frac{I_t}{I_c} = \sqrt{1 + \frac{\mu^2}{2}}$$

- For detection of AM wave, the essential condition is $\frac{1}{\upsilon_c} << RC$
- The instantaneous frequency of the frequency modulated wave is

$$\upsilon(t) = \upsilon_c + k\frac{V_m}{2\pi}\sin\omega_m t$$

  where k is the proportionality constant.
- The maximum and minimum values of the frequency is

$$\upsilon_{\max} = \upsilon_c + \frac{k\,V_m}{2\pi} \text{ and } \upsilon_{\min} = \upsilon_c - \frac{k\,V_m}{2\pi}$$

- Frequency deviation

$$\delta = \upsilon_{\max} - \upsilon_c = \upsilon_c - \upsilon_{\min} = \frac{k\,V_m}{2\pi}$$