KENDRIYA VIDYALAYA SANGATHAN

CHENNAI REGION

तत् त्वं पूषन् अपावृणु

केन्द्रीय विद्यालय संगठन

# CLASS – XII

# PHYSICS

# QUICK REVISION MATERIAL

# FOR HIGH ACHIEVERS

# CHIEF PATRON

**Ms. T.Rukmani**

**Offg.Deputy Commissioner**

**KVS Chennai Region**

# PATRON

**Mr.P I Thanga Raja**

**Assistant Commissioner**

**KVS Chennai Region**

# COURSE DIRECTOR

**Mr. R.N.Senthil Kumar**

**Principal**

**Kendriya Vidyalaya, Nagercoil.**

# CONTENT DEVELOPMENT TEAM

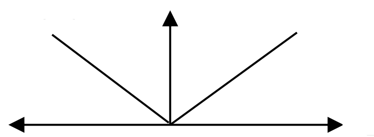
| S.No | NameoftheChapter | NameoftheTeacher | NameoftheKV |
|---|---|---|---|
| 1 | Unit - 1 Electrostatics (Chapters 1 & 2) | MRS. R SUGUNA | CHENNAI AFS AVADI |
| 2 | Unit - II Current Electricity (Chapter-3) & Preparation of Questions Paper for 35 marks from Unit 1 & 2 | MRS. GEETHA RAMESH | CHENNAI ANNANAGAR |
| 3 | Unit - III Magnetic Effects of Current and Magnetism (Chapters 4&5) | MR.T.MURALI | CHENNAI DGQA |
| 4 | Unit - IV Electromagnetic Induction and Alternating (Chapters 6 & 7) | MRS.RADHA MUKUNDAN | CHENNAI MINAMBAKKAM |
| 5 | Unit - V Electromagnetic Waves (Chapter-8) & Preparation of Questions Paper for 35 marks from Unit 3 & 4 | MR.SANKARRAMAN | CHENNAI MINAMBAKKAM |
| 6 | Unit - VI Optics (Chapters 9&10) | MR .V SIVARAMAKRISHNAN | COIMBATORE |
| 7 | Unit - VII Dual Nature of Radiation and Matter (Chapter- 11) & Preparation of Questions Paper for 35 marks from Unit 5 & 6 | MR. K. RENGANATHAN | TRICHY NO.1 |
| 8 | Unit - VIII Atoms and Nuclei (Chapter 12 & 13) | MR. C. MURUGAVEL | PONDICHERRY NO.1 Shift 1 |
| 9 | Unit - IX Electronic Devices (Chapter 14) & Preparation of Questions Paper for 35 marks from Unit 7, 8 & 9 | MR SATYA SURYANARAYANA SURMPUDI | PORT BLAIR NO.2 |

| EDITING AND COMPILATION BY RESOURCE PERSONS |
|---|
| MR.P.SEENIVASAN, K.V No.1, NARIMEDU, MADURAI |
| MR.K V SRINIVASAN, K.V No.1, TAMBARAM, CHENNAI |
| MR.S DHAMODHARAN, KV GILL NAGAR, CHENNAI |
| MR.S KUMAR, KV CRPF AVADI |
| MR.S CHANDRA KUMAR, KV NAGERCOIL |
| MRS.A. BEULAH JASMINE, KV NAGERCOIL |

# Unit - 1 Electrostatics(Chapters 1&2)

## QUICK REVISION NOTES

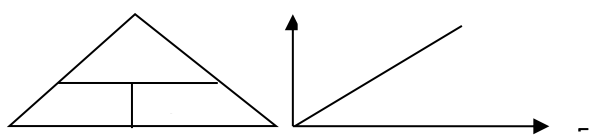
- Study of charges at rest.
- Charging a body can be done by friction, induction and conduction.
- Like charges repel and unlike charges attract.
- Charges are additive in nature i.e., Q=$\sum_{i=1}^{n} q_i$
- Charges are quantized. i.e., Q= $\pm$ ne [n=1,2,3,… & e=1.602 X$10^{-19}$ C]
- Charge in a body is independent of its velocity.
- Charge is conserved.
- To measure charge electroscopes are used.
- Coulomb's law: $\vec{F} = \frac{kq_1q_2}{r^2}\hat{r}$ k=$\frac{1}{4\pi\varepsilon_0}$ = 9X$10^9$ N$m^2$$c^{-2}$
- $\varepsilon_0$= permittivity of free space



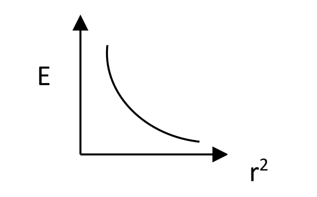
$F_{total} = F_{12} + F_{13} + \ldots$

- Principle of superposition: $Ftotal = \sum_{i=1}^{n} \vec{F_i}$ [vector sum of individual forces]

$$= \frac{1}{4\pi\varepsilon_o}\frac{q_1q_2}{r_{12}^2}\hat{r}_{12} + \frac{1}{4\pi\varepsilon_o}\frac{q_1q_3}{r_{13}^2}\hat{r}_{13} + \ldots$$

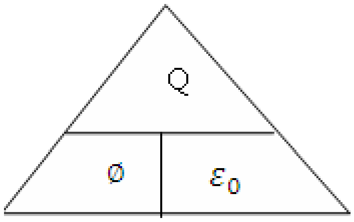


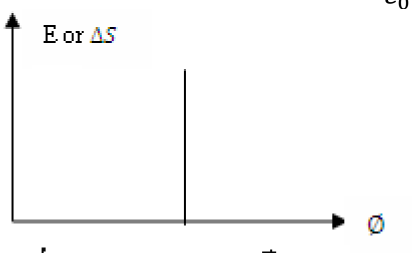
- Electric field: Force per unit positive test charge. It is a vector. SI unitN$C^{-1}$.
- $\vec{E} = \frac{kQ}{r^2}\hat{r}$



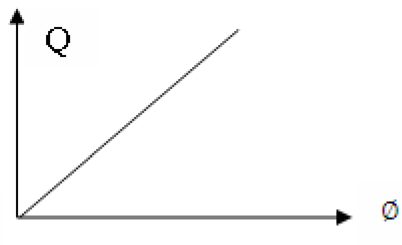

- $\vec{E} = \lim_{q_0 \to 0} \frac{\vec{F}}{q_0}$
- Field due to a point charge:$\vec{E} = \frac{kQ}{r^2}\hat{r}$
- Principle of superposition: $E_{total} = \sum_{i=1}^{n} \vec{E_i}$ [vector sum of individual fields]
- Dipole: Two equal and opposite charges separated by a small distance.
- Dipole moment: Product of magnitude of charge and distance of separation between them. It is a vector. SI unit: Cm $\vec{p}$=Q.2$\vec{a}$ ; direction of $\vec{p}$ is negative to positive charge.
- Dipole in a uniform electric field experiences no net force and instead experiences a torque. $\vec{\tau}=\vec{p} \times \vec{E} \Rightarrow \vec{\tau}=|\vec{p}||\vec{E}| \sin\theta\, \hat{n}$
- If $\theta$= 0° $\Rightarrow$ stable equilibrium; If $\theta$= 180° $\Rightarrow$ unstable equilibrium.

- Electric field due to a dipole **<u>at a point on the axial line</u>**: $\frac{2k\vec{p}}{r^3}$ in the direction of dipole moment
- Electric field due to a dipole **<u>at a point on the equatorial line</u>**: $\frac{k\vec{p}}{r^3}$ against the direction of dipole moment.
- Electric flux: $\emptyset=\overrightarrow{\Delta S}.\vec{E}=|\vec{E}||\overrightarrow{\Delta S}|\cos\theta$ ; It is a scalar; SI unit: $NC^{-1}m^2$ or Vm.
- Gauss' theorem in electrostatics: $\emptyset_{total}=\frac{q_{total}}{\varepsilon_0}$




$\phi$ is independent of $\vec{E}$ & $\vec{\Delta s}$



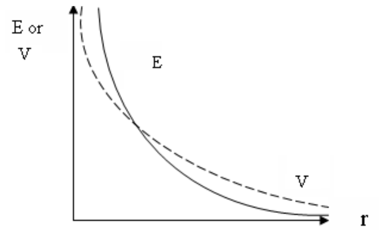

- <u>Uniform Charge distribution</u>:
  - Linear charge distribution: $\lambda=\frac{\Delta q}{\Delta l}$ [$\lambda \Rightarrow$ linear charge density Unit $Cm^{-1}$]
  - Surface charge distribution: $\sigma=\frac{\Delta q}{\Delta S}$ [$\sigma \Rightarrow$ surface charge density Unit $Cm^{-2}$]

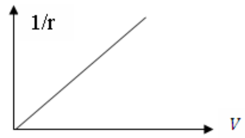
  Volume charge distribution: $\rho=\frac{\Delta q}{\Delta V}$ [$\rho \Rightarrow$ Volume charge density Unit $Cm^3$]
  - Applications of Gauss' theorem for uniform charge distribution:

| Expression for | Infinite Linear | Infinite plane sheet | Thin spherical shell |
|---|---|---|---|
| Flux ∅ | $\frac{\lambda l}{\varepsilon_0}$ | $\frac{\sigma s}{\varepsilon_0}$ | $\frac{\sigma 4\pi r^2}{\varepsilon_0}$ |
| Magnitude of Field E | $\frac{\lambda}{2\pi r\varepsilon_0}$ | $\frac{\sigma}{\varepsilon_0}$ | $\frac{Q}{4\pi r^2\varepsilon_0}$ [for points on/outside the shell] =0 [for points inside the shell] |
| Charge density | $\lambda=\frac{\Delta q}{\Delta l}$ | $\sigma=\frac{\Delta q}{\Delta S}$ | $\frac{\sigma}{4\pi r^2}$ |

  - Properties of electric field lines:
    - Arbitrarily starts from +ve charge and end at –ve charge
    - Continuous, but never form closed loops
    - Never intersect
    - Relative closeness of the field lines represents the magnitude of the field strength.
    - For a set of two like charges – lateral pressure in between
    - For a set of two unlike charges – longitudinal contraction in between.
- Electrostatic Potential: Work done per unit positive Test charge to move it from infinity to that point in an electric field. It is a scalar. SI unit:
  - J/C or V

- V = W / $q_o$
- Electric potential for a point charge: V = kq / r$V = \frac{kq}{r}$

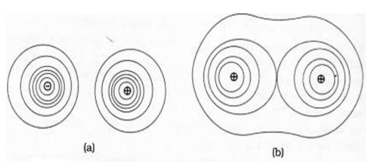



- Electric field is conservative. This means that the work done is the independent of the path followed and the total work done in a closed path is zero.
- Potential due to a system of charges: $V_{total} = \sum_{i=1}^{n} \frac{kq_i}{r_i}$
- Potential due to a dipole at a point **on its axial line**:

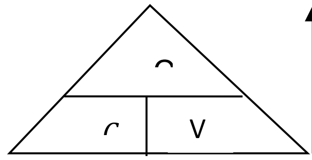
$V_{axial} = \frac{k\,|\vec{p}|}{r^2}$ [or]$\frac{k|\vec{p}|}{r^2}\cos\theta$

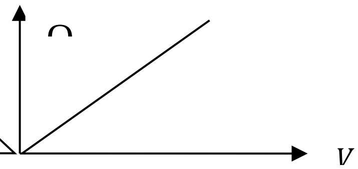
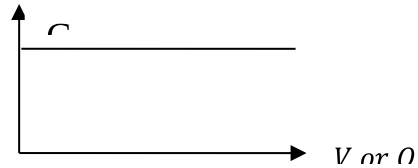
- Potential due to a dipole at a point **on its equatorial line**:$V_{eq}$ = 0
- Potential difference $V_A - V_B = kq\left[\frac{1}{r_A} - \frac{1}{r_B}\right]$
- Potential energy of two charges: U = $\frac{kq_1q_2}{r}$
- Potential energy of a dipole : U = $\vec{p}.\vec{E}$ = p E [$\cos\theta_0$ - $\cos\theta_1$ ]
- Electro static of conductors
  - a. Inside a conductor Electrostatic field is zero
  - b. On the surface E is always Normal t
  - c. No charge inside the conductor
  - d. Potential is constant inside and on the surface
- Equipotential surfaces: The surfaces on which the potential is same everywhere.
  - Work done in moving a charge over a equipotential surfaces is zero.
  - No two equipotential surfaces intersect.
  - Electric field lines are always perpendicular to the equipotential surfaces.



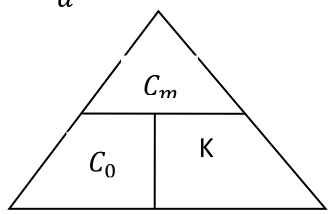
Some equipotential surfaces for (a) a dipole, (b) two identical positive charges.

  - As E= - $\frac{dV}{dr}$If Vis constant, E∝ $\frac{1}{r}$ and if E is constant, V∝ $r$
- Capacitor: An instrument to store charges and electrostatic potential energy.
- Capacitance: $C = \frac{Q}{V}$ , ,Ratio of charge and unit potential difference. Scalar,
- SI unit: farad [F]

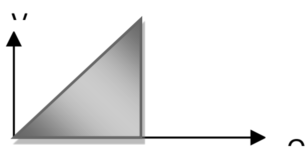


- Capacitance of a parallel plate capacitor: $C = \frac{\varepsilon_0 \times A}{d}$
- Capacitance of a parallel plate capacitor with a dielectric medium in between:
  - ➢ $C_m = \frac{\varepsilon_0}{\left(d - t + \frac{t}{K}\right)} A$
  - ➢ If t =0 $\Rightarrow C_0 = \frac{\varepsilon_0 \times A}{d}$
  - ➢ If t =d $\Rightarrow C_m = \frac{K\varepsilon_0 \times A}{d} \Rightarrow C_m = KC_0$




- Grouping of capacitors:
  - Capacitors in series: $\frac{1}{c} = \sum_{i=1}^{n} \frac{1}{c_i}$
  - Capacitors in parallel : $c = \sum_{i=1}^{n} c_i$
- Energy stored in capacitors: $U = \frac{1}{2} CV^2 = \frac{1}{2} QV = \frac{1}{2} \frac{Q^2}{C}$
- Area shaded in the graph = U $= \frac{1}{2} QV$



- Energy density : $U_d = \frac{1}{2} \varepsilon_0 E^2 = \frac{\sigma^2}{2\varepsilon_0}$
- Introducing dielectric slab between the plates of the charged capacitor with:

| Property⇣ | Battery connected | Battery disconnected |
|---|---|---|
| Charge | K $Q_0$ | $Q_0$ |
| Potential difference | $V_0$ | $V_0$/K |
| Electric field | $E_0$ | $E_0$/K |
| Capacitance | $KC_0$ | $KC_0$ |
| Energy | K times $\frac{1}{2} \varepsilon_0 E^2$ [Energy is supplied By battery] | 1/K times $\frac{1}{2} \varepsilon_0 E^2$ [Energy used for Polarization] |

- On connecting two charged capacitors:

  Common Potential: $V = \frac{C_1V_1+C_2V_2}{V_1+V_2}$

  Loss of energy $\Delta U = \frac{1}{2}\frac{C_1 \times C_2}{C_1+C_2}(V_1 - V_2)^2$

## Unit - II Current Electricity (Chapter-3)

**QUICK REVISION NOTES**

**Current electricity** - The study of electric charges in motion is called current electricity.

**Electric current** - Electric current across an area held perpendicular to the direction of flow of charge is defined as the amount of charge flowing across that area per unit time.

For a steady flow of charge, $I = \frac{q}{t}$

If the rate of flow of charge varies with time, then $I = \frac{dq}{dt}$

Electric current is a scalar quantity. Electric currents do not obey the laws of vector addition.

**Ohm's law** - The potential difference across two ends of a conductor is directly proportional to the current flowing through it, provided the temperature and other physical conditions remain unchanged.

$V \alpha I$ or $V = RI$

**Resistance** – It is the opposition offered by a conductor to flow of charges through it It depends on the length $I$, area of cross-section $A$, nature of material of the conductor and temperature.

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

SI unit of resistance is ohm (Ω). The resistance of a conductor is 1 ohm if a current of I ampere flows through it on applying a potential difference of I volt across its ends.

**Resistivity or specific resistance** - It is the resistance offered by a unit cube of the material of a conductor. It depends on the nature of the material of the conductor and the temperature.

$$\rho = \frac{m}{ne^2\tau} \quad \text{and} \quad \rho = \frac{1}{en\mu_e}$$

**Current density** - It is the amount of charge flowing per second per unit area normal to the flow of charge. It is a vector quantity having the same direction as that of the motion of the positive charge. SI unit - Am. $I = \vec{j} \cdot \vec{A}$ *and*

$$j = nev_d = ne\mu E = \sigma E$$

**Conductance** -It is the reciprocal of resistance. SI unit - mho or siemen.

**Conductivity** - It is the reciprocal of resistivity. SI unit – mho/ m.

$$\sigma = ne\mu = \frac{ne^2}{m}\tau$$

**Carriers of current** – Metal - free electrons, Ionized gases - electrons and positive ions Electrolyte - both positive and negative ions, Semiconductor - electrons and holes.

**Drift velocity** - The average velocity acquired by the free electrons of a conductor in the opposite direction of the applied electric field is called drift velocity. $v_d = \frac{eE}{m}\tau = \frac{eV}{ml}\tau$

**Relaxation time** - The average time interval between the two successive collisions of an electron is called relaxation time (τ).

**Temperature coefficient of resistivity** - It is defined as the change in resistivity per unit original resistivity per degree rise in temperature. $\alpha = \frac{\rho_t - \rho_0}{\rho_0 (T - T_0)} \Rightarrow \rho_T = \rho_0 \left[1 + \alpha\left(T - T_0\right)\right]$

**Effect of temperature on resistivity** - For metals α is positive i.e., resistivity of metals increases with the increase in temperature.For semiconductors and insulators, α is negative i.e., their resistivity decreases with the increase in temperature.For alloys like constantan and manganin, α is very small. So they are used for making standard resistors.

**Mobility of a charge carrier** - The mobility of a charge carrier is the drift velocity acquired by it per unit electric field. $\boldsymbol{\mu} = \frac{v_d}{E} = \frac{e}{m}\boldsymbol{\tau}$

**Ohmic conductors -** The conductors which obey Ohm's law are called Ohmic conductors. For these conductors, V-I graph is a straight line passing through the origin. For example, a metallic conductor for small currents is an Ohmic conductor.

**Non-ohmic conductors** - The conductors which do not obey Ohm's law are called non-ohmic conductors. The Non-ohmic situations –

(i) The straight-line V-I graph does not pass through the origin.
(ii) V-I relationship is non-linear.
(iii) V-I relationship depends on the sign of V.
(iv) V-I relationship is non-unique.

Examples - water voltameter, thyristor, a *p-n* junction, etc.

**Electromotive force (emf) -** It is the energy supplied by the source in taking a unit positive charge once round the complete circuit. It is equal to the terminal p.d. measured in open circuit

**Terminal potential difference (V) -**The potential drop across the terminals of a cell when a current is drawn from it is called its terminal potential difference. It is less than the emf of the cell in a closed circuit. $V=E-Ir$

Terminal p.d. of a cell when it is being charged is $V=E + Ir$

**Internal resistance** -The resistance offered by the electrolyte of a cell to the flow of current between its electrodes is called internal resistance of the cell. It depends on

(v) Nature of the electrolyte, (ii) concentration of the electrolyte, (iii) distance between the electrodes, common area of the electrodes dipped in the electrolyte and (v) temperature of the electrolyte.

$$r=\frac{E-V}{I}=\frac{E-V}{V}R=\left(\frac{E}{V}-1\right)R$$

**Cells in series** - If $n$ cells of emf E and internal resistance $r$ each are connected in series, then current flowing through external resistance $R$ is $I=\frac{nE}{R+nr}$

**Cells in parallel** - If $m$ cells are connected in parallel, then current drawn through external resistance $R$ is $I=\frac{mE}{mR+r}$

**Cells in mixed grouping** - If $n$ cells are connected in series in each row and $m$ such rows are connected in parallel, then current drawn through an external resistance $R$ is

$$I=\frac{mnE}{mR+nr}.$$

For maximum current, the external resistance must be equal to the total internal resistance, *i.e.*,

$$R=\frac{nr}{m}\Rightarrow mR=nr.$$

Heating effect of current - The phenomenon of the production of heat in a resistor by the flow of an electric current through it is called heating effect of current or Joule heating.

$$H=VIt=I^2Rt=\frac{V^2}{R}t$$

Electric power - It is the rate at which an electric appliance converts electric energy into other forms of energy. Or, it is the rate at which work is done by a source of emf in maintaining an electric current through a circuit. $P=VI=I^2R=\frac{V^2}{R}$

Electric energy - It is the total work done in maintaining an electric current in an electric circuit for a given time.

$W = Pt = VI\,t = I^2Rt$ joule

Kirchhoff's laws –

(1) Junction rule: In an electric circuit, the algebraic sum of currents at any junction is zero. Or, at any junction of electrical circuit the sum of currents entering the junction must be equal to the sum of currents leaving it i.e. $\Sigma I = 0$ .

This law is based on the conservation of charge.

(2) Loop Rule: Algebraic sum of changes in the potential around any closed loop must be zero i.e.

$\Sigma V = IR$ . This law is based on the conservation of charge.

Wheatstone bridge – It is an arrangement of four resistances *P*. Q, *R* and S joined to form a quadrilateral *ABCD* with a battery between *A* and C and a sensitive galvanometerbetween *B* and *D.* The resistances are so adjusted that no current flows through the galvanometer.

The bridge is then said to be balanced. In the balanced condition, $\frac{P}{Q} = \frac{R}{S}$

A Wheatstone bridge is most sensitive when the resistances in its four arms are of the same order. Slide wire bridge or metre bridge - It is an application of Wheatstone bridge in which *R* is fixed and a balance point is obtained by varying *P* and *Q i.e.*, by adjusting the position of a jockey on a 100 cm long resistance wire. If the balance point is obtained at length *1,* then

$$\frac{R}{S} = \frac{l}{100-l} \Rightarrow S = \left(\frac{100-l}{l}\right)R$$

## Unit - III Magnetic Effects of Current and Magnetism (Chapters 4&5)

**QUICK REVISION NOTES**

MAGNETIC FIELD:

The region around a magnet or current carrying conductor with in which it influences other magnets or magnetic material. Its SI unit is Tesla (T).

COMPARISON BETWEEN ELECTRIC FIELD AND MAGNETIC FIELD:

| S.NO | | ELECTRIC FIELD | MAGNETIC FIELD |
|---|---|---|---|
| 1. | Source | Charge | Current element (vector) |
| 2. | Field lines | Starts at one point and ends at another point. | Starts and ends at the same point. |

➔BIOT – SAVART LAW:

It states that the magnetic field due to a current element at a particular point is directly proportional to current, length of element, sine of angle between the direction of the current and the line joining the elementary portion to theobservation point and inversely proportional to the square of distance.

(i.e.) dB α I

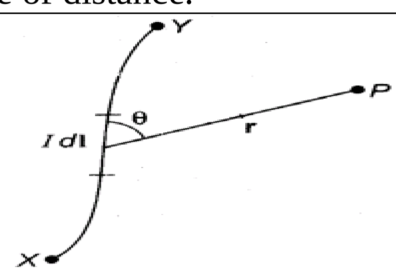
dB α dl

dB α sinθ

dB α $\frac{1}{r2}$

dB = K $\frac{Idlsin\theta}{r2}$

dB = $\frac{\mu 0}{4\pi}\frac{Idlsin\theta}{r2}$[where, $\frac{\mu 0}{4\pi}$= $10^{-7}$ $TA^{-1}m$]




➔MAGNETIC FIELD AT THE CENTRE OF A CURRENT CARRYING CIRCULAR COIL:

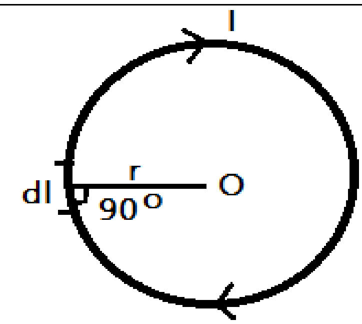
Magnetic field due to a small element,

$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

Since, $\theta = 90$, $\sin 90 = 1$ $\quad dB = \frac{\mu_0}{4\pi}\frac{Idl}{r^2}$

Total magnetic field, $B = \int dB = \frac{\mu_0}{4\pi}\frac{I}{r^2}\int dl$

$$B = \frac{\mu_0 I}{2r}$$




➔<u>MAGNETIC FIELD AT A POINT ON THE AXIS OF CURRENT CARRYING COIL:</u>

Magnetic field due to a small element,

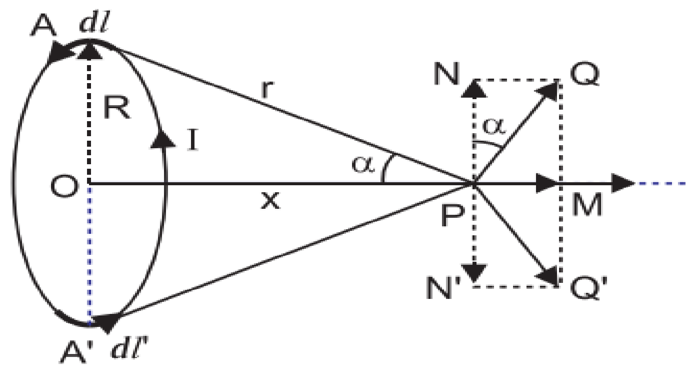
$$dB = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{r^2}$$

since $\theta = 90$, $\sin 90 = 1$

$$dB = \frac{\mu_0}{4\pi}\frac{Idl}{r^2} \qquad \rightarrow 1$$

Resolve $\overrightarrow{dB}$ into dbcosα and dBsinα. Net value of dBcosα is zero and effective component is dBsinα

Total magnetic field, $B = \oint dB\sin\alpha = \frac{\mu_0}{4\pi}\frac{I}{r^2}\sin\alpha \oint dl = \frac{\mu_0}{4\pi}\frac{I}{r^2}\sin\alpha \times 2\pi R$




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

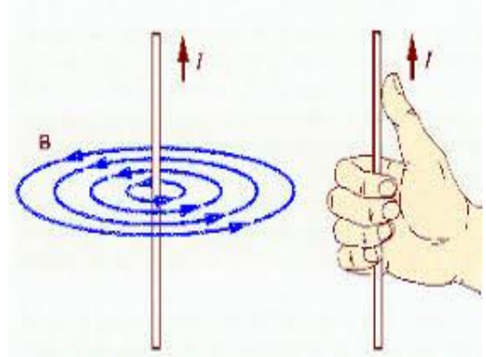
In case of N-turns, $B = \frac{\mu_0 N I R^2}{2(R^2+x^2)^{3/2}}$ $\qquad$ If x = 0, then, $B = \frac{\mu_0 I}{2R}$

➔<u>AMPERE'S CIRCUITAL LAW:</u>

It states that the line integral of magnetic field over any closed surface is $\mu_0$ time the total current threading the loop.

$$\oint \vec{B}.\vec{dl} = \mu_0 I$$

➔<u>MAGNETIC FIELD DUE TO A CURRENT CARRYING STRAIGHT CONDUCTOR:</u>

| | |
|---|---|
| WKT,<br>Line integral of magnetic field,<br>$\oint B.dl = \oint B.dl\cos\theta$ [since, $\theta = 0$]<br>$= B\oint dl = B \times 2\pi r$<br>$\rightarrow 1$<br>According to Ampere's circuital law, $\oint \overrightarrow{B}.\overrightarrow{dl} = \mu_0$ I $\rightarrow 2$<br>Eq. 1 = Eq. 2<br>$B \times 2\pi r = \mu_0 I$ $B = \frac{\mu_0 I}{2\pi r}$ |  |

➔ MAGNETIC FIELD DUE TO A CURRENT CARRYING SOLENOID:

| | |
|---|---|
| Let, n → Number of turns per unit length<br>I → Current through the solenoid<br>L → Length of the solenoid<br>$B = \mu_0 n I$ | Note:<br>If no. of turns is given, then:<br>n → Number of turns<br>$B = \frac{\mu_0 n I}{L}$ |

➔ FORCE ON A MOVING CHARGE [ LORENTZ FORCE]:

Force, F α BF α q F α vsinθ

ie, F α BqvsinθF = K Bqvsinθ In SI unit, K = 1

$$F = Bqv\sin\theta$$

The direction is given by Fleming's left-hand rule.

Note:

| | | |
|---|---|---|
| Two pairs of perpendicular vectors,<br>1. $\vec{F}$ and $\vec{v}$<br>2. $\vec{F}$ and $\vec{B}$ | Special case:<br>If, θ = 0, F = 0<br>θ = 180, F = 0<br>θ = 90, F= Bqv | Lorentz force,<br>$\vec{F} = \vec{F}_e + \vec{F}_m$<br>$\vec{F} = q[\vec{E} + (\vec{V} \times \vec{B})]$ |

➔ RADIUS OF PATH FOLLOWED BYMOVING CHARGE IN THE MAGNETIC FIELD:

$\overrightarrow{V}$ is perpendicular to $\vec{B}$:

| | | |
|---|---|---|
| Radius,<br>Magnetic Lorentz force = Centripetal force<br>$Bqv = \frac{mv2}{r}$ $= \frac{mv}{Bq}$ | Time period,<br>$T = \frac{2\pi r}{v} = \frac{2\pi}{v}\frac{mv}{Bq}$<br>$T = \frac{2\pi m}{Bq}$ | Frequency,<br>$\frac{1}{T} = \frac{Bq}{2\pi m}$ |

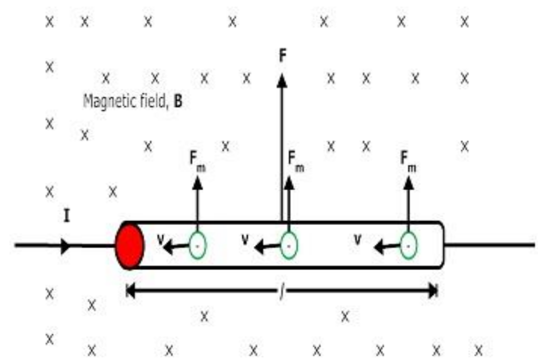
➔ FORCE ON A CURRENT:

B → Mag. Field , $V_d$ → Drift velocity
Il →Current element, l → Length of the conductor
A → Area of cross-section, n → number density
WKT
$I = nAeV_d Il = nAelV_d$
In general form, $\vec{Il} = -nAel\vec{V}_d$
Force experienced by one electron, $\vec{F} = -e(\vec{V}_d \times \vec{B})$
Total no. of electrons, N = nAl
Total force experienced by the conductor,

$$\vec{F} = N\vec{f} = nAl\vec{f}$$

$$\vec{F} = -neAl(\vec{V}_d \times \vec{B})$$

$$\vec{F} = (\vec{Il} \times \vec{B}) \qquad F = BIl\sin\theta$$




Special case:

If θ = 0, F = 0

If θ = 90, F = BIl (maximum)

➔FORCE BETWEEN TWO INFINITELY LONG CURRENT CARRYING PARALLEL CONDUCTORS:

NOTE:

If currents are in same direction the wires will attract each other. If the currents are in opposite directions, they will repel each other.

Mag. Field at 'P' due to current $I_1$,

$$B_1 = \frac{\mu_0}{4\pi}\frac{2I_1}{r} \rightarrow 1$$

Force experienced by CD due to $B_1$,

$$F_1 = B_1 I_2 L\sin\theta \qquad [\theta = 90]$$

$$F_1 = B_1 I_2 [L=1]$$

Force per unit length, $F_1 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r} \rightarrow 2$

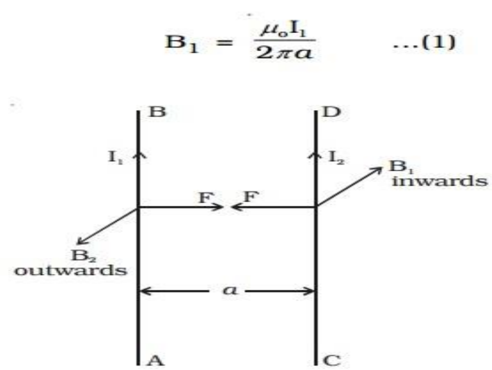



*Fig. 3.23 Force between two long parallel current-carrying conductors*

lll$^y$, $F_2 = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r} \rightarrow 3$

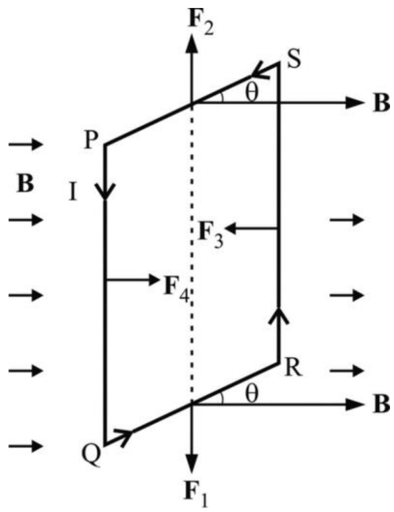
Force per unit length,

$$F = \frac{\mu_0}{4\pi}\frac{2I_1I_2}{r}$$

ONE AMPERE:

The electric current flowing through a conductor is said to be 1 ampere when it is separated by 1 meter from similar conductor carrying same current in the same direction experiences a repulsive for of $2\times10^{-7}$ N per meter length.

➔TORQUE ACTING ON A CURRENT CARRYING CONDUCTOR:




$\vec{F}_1 = \overrightarrow{Ib} \times \vec{B}$= IbBsin (90+θ)
= IbBcosθ → 1

III$^y$,

$\vec{F}_2$= IbBsin (90-θ)
= IbBcosθ→ 2

$\vec{F}_1$ and $\vec{F}_2$is equal, opposite and acting on a same line. Hence, the cancel each other.

Force on SR, $\vec{F}_3$ = BILsinθ
= BIL → 3

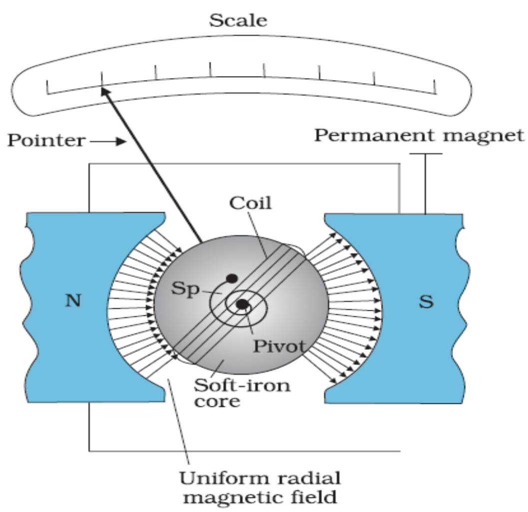
III$^y$,

$\vec{F}_4$ = BIL → 4

$\vec{F}_3$ and $\vec{F}_4$is equal, opposite and not acting on a same line. Hence, they produce torque[τ]. Torque = Force × perpendicular distance

τ = BILbsinθτ = BIAsinθ$\vec{\tau}$= $\overrightarrow{IA} \times \vec{B}$

➔<u>MOVING COIL GALVANOMETER:</u>




Galvanometer: It is a device used to measure small amount of current and potential difference.

Principle: When a current carrying coil is placed in a magnetic field, it experiences torque.

Working:

Deflection torque = Restoring torque

nBIAsinθ = Kϕ (ϕ = Steady angular deflection)

$$I = \frac{K}{nBA}\frac{\phi}{sin\theta}$$

$$= G\frac{\phi}{sin\theta} \quad \rightarrow 1$$

Where, G→ Galvanometer constant

$G = (\frac{K}{nBA})$

K→ Force constant

It implies that the galvanometer cannot read the current in linear scale. To overcome this problem, a radial magnetic field is used. In radial magnetic field the plane of the coil is parallel to the magnetic field. It means that the normal to the plane of the coil is perpendicular to the magnetic field;

(i.e.) I = Gϕ

I α ϕ

- Current sensitivity:

It is defined as the deflection produced in galvanometer on passing unit current through its coil.

(i.e.) $\frac{\phi}{I} = \frac{nBA}{K}$

● Voltage sensitivity: It is defined as deflection per unit potential difference.

i.e.) $\frac{\phi}{IR} = \frac{nBA}{KR} \frac{\phi}{V} = \frac{nBA}{KR}$

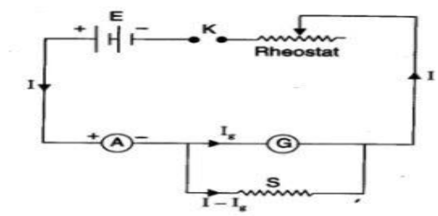
<u>Note:</u> Change in current sensitivity may not necessarily change the voltage sensitivity.

Conditions for sensitivity:

a. n is large b. B is large c. A is large d. K is small (small for phosphor bronze, quartz fiber.

<u>●Ammeter:</u>

It is an instrument used for measuring current in the electrical circuits. Galvanometer can be converted into an ammeter by connecting a shunt resistance in parallel.

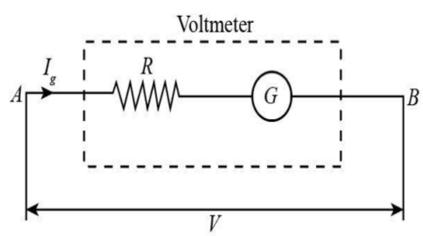



Resistance of the ammeter, $R_a = \frac{R_g S}{R_g + S}$

$S = \frac{I_g R_g}{I - I_g}$

<u>●Voltmeter:</u>

It is the instrument used to measure potential difference across a conductor.




Galvanometer is modified into voltmeter by connecting a large resistance in series.

WKT, $V = IR$ $V = (R_g + R) I_g$

$R_g + R = \frac{V}{I_g}$

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

Resistance of voltmeter, $R_v = R_g + R$

➔<u>MAGNETISM:</u>

Magnetic pole: The preferred regions of attraction near the two ends of a magnet where the magnetic force due to a bar magnet is maximum are called the poles of the magnet.

<u>Characteristics:</u>

1. Attracting property.
2. Directive property.
3. Unlike poles attract each other and like poles repel each other.
4. Magnetic poles exist in pairs.
5. Inductive property.

<u>Key points:</u>

When a magnet having pole strength ‘m’ is cut into equal parts.

a. Longitudinally, the new pole strength is m/2.
b. Vertically/Transversely, the new pole strength will remain same as ‘m’.

<u>Magnetic dipole:</u>

An arrangement of two magnetic poles of equal and opposite separated by a finite distance is called magnetic dipole.

Magnetic dipole moment:

The product of strength of either pole and the magnetic length of the magnet is called magnetic dipole moment.

Current loop as a magnetic dipole:Magnetic dipole moment, M $\alpha$ IM $\alpha$ AM $\alpha$ IA

M = KIAIn SI units, K = 1M = IA

In case of 'n' turns;

M = nIA

Note:

- Torque:$\tau$ = MBsin$\theta$ $\vec{\tau} = \vec{M} \times \vec{B}$
- Potential energy:P.E = MB (cos$\theta_1$– cos$\theta_2$)

➔SOME IMPORTANT TERMS:

1. Magnetic intensity (H):H = $\frac{B0}{\mu 0}$[SI unit = A/m]
2. Intensity of magnetization (I):I = $\frac{M}{V}$ [SI unit = A/m]
3. Magnetic flux ($\phi$):$\phi = \vec{B}.\overrightarrow{\Delta S}$
4. Magnetic induction (B):

No. of mag. field lines of induction crossing the unit area normally through the magnetic substance. Its SI unit is Tesla.

5. Magnetic susceptibility ($\chi_m$):

$$\chi_m = \frac{I}{H} \text{ [Dimensionless physical quantity]}$$

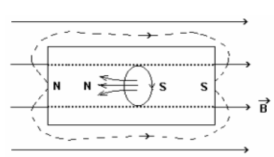
6. Magnetic permeability ($\mu$):

$$M = \frac{B}{H} \text{ [SI unit = Tm/ A]}$$

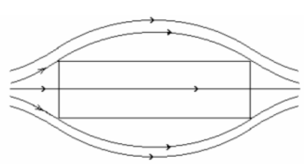
Relation b/w B,H,I three physical quantities is;B = $\mu_0$ (H + I)

➔DIAMAGNETIC MATERIAL;

It consists of only paired electrons.Thus, the magnetic moment due to orbital motion of one electron is cancelled by the magnetic moment due to orbital motion of another electron. It makes the net magnetic moment zero. When a diamagnetic substance is subjected to an external mag. field, the atoms acquire feeble mag. moment due to Lorentz force exerted by external mag. field.

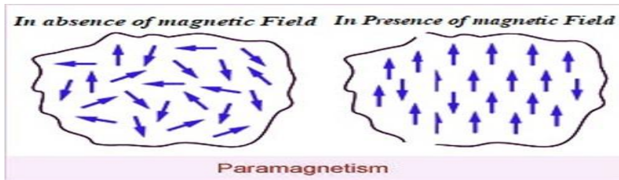


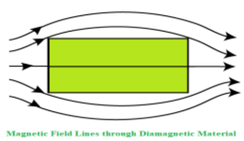
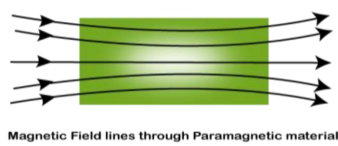
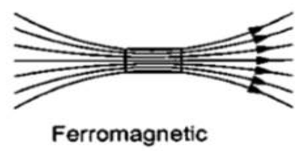
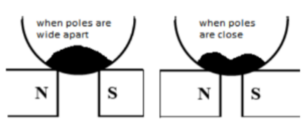
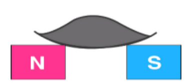
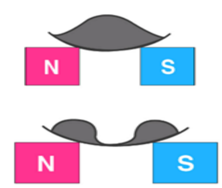

Diamagnetic material in external magnetic field



Field lines in diamagnetic material

➔PARAMAGNETIC MATERIAL:The atom of a paramagnetic substancepossesses mag. moment due to the orbital motion of the unpaired electrons. As the interaction b/w the atomic magnet is very weak, therefore, they may be independent of each other. Due to thermal agitation, the atomic magnets are randomly oriented.

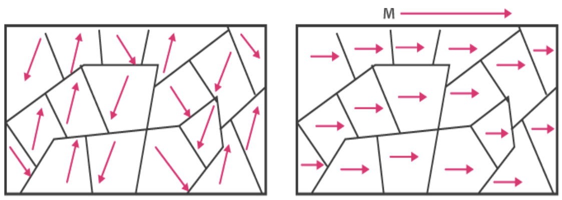



| S. NO | PROPERTIES | DIAMAGNETIC | PARAMAGNETIC | FERROMAGNETIC |
|---|---|---|---|---|
| 1 | Nature | Non-polar dielectric | Polar dielectric | Ferro electric type dielectric |
| 2 | Magnetizing capacity | Feebly magnetized in the opposite direction | Feebly magnetized along the mag. field | Strongly magnetized along the mag. field |
| 3. | Magnetic field inside the specimen | Little less $B < B_0$ | Little more $B > B_0$ | Very strong $B >> B_0$ |
| 4. | Magnetic field lines |   |   |   |
| 5. | Non-uniform | Tends to move from stronger to weaker region slowly. | Tends to move from weaker to stronger region slowly. | Tends to move from weaker to stronger region quickly. |
| 6. | Liquid substance |   |     |   |
| 7. | Intensity of magnetization | **Slightly -ve** | Slightly +ve | Highly +ve |
| 8. | Susceptibility | Small-ve | Small+ve | Highly+ve |
| 9. | Permeability | < 1 | > 1 | >> 1 |
| 10. | Magnetic induction | $B < B_0$ | $B > B_0$ | $B >> B_0$ |

| | | | | |
|---|---|---|---|---|
| **11.** | Examples | Cu, Zn, Ag, Au, Pb, glass, marble, $H_2O$, He, Ar, NaCl | Al, Na, Sb, Pt, $CuCl_2$, Mn, Cr, Liquid $O_2$, Ca etc.. | Ni, Fe, Co, Alnico etc.. |

FERROMAGNETIC MATERIAL:

The atom of ferromagnetic material possesses non-zero mag. effect. Due to exchange interaction, an unpaired electron in one atom interacts strongly with the unpaired electron in the neighboring atom in such a way that they align themselves in a common direction over a small volume of material.




A. Random domain orientation    B. After magnetization

When a ferromagnetic substance is introduced in a magnetic field, the size of domain will increase and the no. of domains will go on decreasing. By this way, the ferromagnetic substance is magnetized strongly along the direction of external mag. field.

➔PROPERTIES OF MAGNETIC SUBSTANCES:

➔RETENTIVITY:

The ability of a substance to retain or resist magnetization, frequently measured as the strength of the magnetic field that remains in a sample after removal of an inducing field.

➔COERCIVITY:

The value of reverse H field required so as to reduce residual magnetism to zero is called coercivity of the material.

➔APPLICATIONS OF FERROMAGNETIC SUBSTANCES:

1. Permanent magnet:
   Ferromagnetic materials should possess high value of retentivity, coercivity.
   Ex: Cobalt steel, carbon steel, alnico
2. Electromagnet:
   It should possess low retentivity, low coercivity and high permeability and the area of the loop should be small. All these requirements are fulfilled by soft iron.
3. Transformer coil:

It should possess high permeability, low hysteresis loss, low coercivity and high resistivity.

## Unit - IV Electromagnetic Induction and Alternating (Chapters 6 & 7)

**QUICK REVISION NOTES**

**Magnetic Flux**

The magnetic flux Φ through any surface held in a magnetic field $\vec{B}$ is measured by the total number of magnetic lines of force crossing the surface.

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

Where, θ is the smaller angle between $\vec{B}$ and $\vec{A}$, which normal to the surface area makes with $\vec{B}$

SI unit of f is weber and magnetic flux is a scalar quantity.

**Faraday's laws of electromagnetic induction**:

**First law** − whenever the amount of magnetic flux linked with a circuit changes, an emf is induced in the circuit. The induced emf lasts as long as the change in magnetic flux continues.

**Second law** − the magnitude of emf induced in a circuit is directly proportional to the rate of change of magnetic flux linked with the circuit.

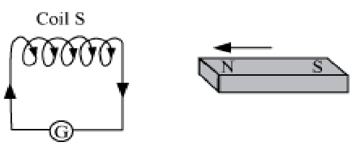
According to Faraday's second law, induced emf

For N turns,

$$\boxed{e = -N\frac{d\phi}{dt}}$$

**Lenz's Law**-The direction of the induced emf or induced current is such that it opposes the change that is producing it.

**Lenz Law and Principle of Conservation of Energy**




**Methods of producing Induced emf:**

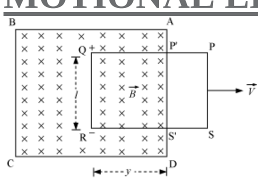
1. **By changing Magnetic Field B:**

**Magnetic fluxΦ can be changed by changing the magnetic field B and hence emf can be induced in the circuit (as done in Faraday's Experiments).**

2. **By changing the area of the coil A available in Magnetic Field:**

**Magnetic flux Φ can be changed by changing the area of the loop A which is acted upon by the magnetic field B and hence emf can be induced in the circuit.**

## MOTIONAL ELECTROMOTIVE FORCE



Consider that at any time *t*, the part $P'Q = S'R = y$ of the coil is inside the magnetic field. Let *l* be the length of the arm of the coil.

Area of the coil inside the magnetic field at time *t*,

$\Delta S = QR \times RS' = ly$

∴Magnetic flux linked with the coil at any time *t*,

Φ =*B*Δ*S*= *Bly*

The rate of change of magnetic flux linked with the coil is given by,

$$\frac{d\phi}{dt} = \frac{d}{dt}(Bly) = Bl\frac{dy}{dt} = Blv$$

Where,

$v \rightarrow$Velocity with the coil pulled out of the magnetic field

If $e$ is the induced *emf*, then according to Faraday's law,

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

$$\therefore \boxed{e = -Blv}$$

From Fleming's Right hand rule, the current due to induced *emf* will flow from the end R to Q i.e., along QPSR in the coil.

**Power**

Current I in the loop is,

$$I = \frac{\varepsilon}{r} = \frac{Blv}{r} \qquad \text{...(i)}$$

Due to the presence of the magnetic field, there is a force on the arm PQ. This force is directed outwards in the direction opposite to the velocity of the rod. The magnitude of this force is,

$$F = IlB = \frac{B^2l^2v}{r}$$

Alternatively, the arm PQ is being pushed with a constant speed v. The power required to do this is,

$$P = Fv = \frac{B^2l^2v^2}{r} \qquad \text{...(ii)}$$

The agent that does this work is mechanical. This mechanical energy is dissipated as joule heat and is given by,

$$P_J = I^2r = \left(\frac{Blv}{r}\right)^2 r = \frac{B^2l^2v^2}{r}$$

This is identical to equation (ii).

Thus, mechanical energy, which was required to move the arm PQ, is converted into electrical energy and then to thermal energy.

**Self Induction:**

Self Induction is the phenomenon of inducing emf in the self coil due to change in current and hence the change in magnetic flux in the coil.

The induced emf opposes the growth or decay of current in the coil and hence delays the current to acquire the maximum value.

Self induction is also called inertia of electricity as it opposes the growth or decay of current.

**Self Inductance:**

$\Phi \propto I$ or $\Phi = LI$ (where L is the constant of proportionality and is known as Self Inductance or co-efficient of self induction)

If $I = 1$, then $L = \Phi$

Thus, self inductance is defined as the magnetic flux linked with a coil when unit current flows through it.

Also, $E = - d\Phi / dt$ or $E = - L (dI / dt)$

If $dI / dt = 1$, then $L = E$

Thus, self inductance is defined as the induced emf set up in the coil through which the rate of change of current is unity.

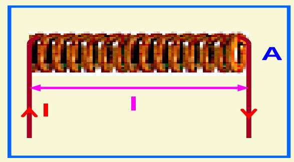
SI unit of self inductance is henry (H).

Self inductance is said to be 1 henry when 1 A current in a coil links magnetic flux of 1 weber.

or

Self inductance is said to be 1 henry when unit rate of change of current (1 A / s) induces emf of 1 volt in the coil.

**Self inductance of a solenoid:**




Magnetic Field due to the solenoid is

$B = \mu_0 nI$

Magnetic Flux linked across one turn of the coil is

$\Phi$ per turn $= B\,A = \mu_0 nIA = \mu_0 NIA / l$

Magnetic Flux linked across N turns of the coil is

$\Phi = \mu_0 N^2 IA / l$

But, $\Phi = LI$ So, $\boxed{L = \mu_0 N^2 A / l = \mu_0 n^2 A l}$

## Mutual Induction

The phenomenon according to which an opposing *emf* is produced in a coil as a result of change in current, hence, the magnetic flux linked with a neighbouring coil is called mutual induction.

Coefficient of mutual induction −

$\Phi \propto I$

$\Phi = MI$… (i)

Where, $M$ is called coefficient of mutual induction

If '$e$' is the induced *emf* produced in the $S$-coil, then

$$e = -\frac{d\phi}{dt} = -\frac{d}{dt}(MI) = -M\frac{dI}{dt}$$

**Mutual inductance of two long co-axial solenoids:**

Magnetic Field due to primary solenoid is

$B_1 = \mu_0 n_1 I_1$

Magnetic Flux linked across one turn of the secondary solenoid is

$\Phi_{21}$ per turn $= B_1 A = \mu_0 n_1 I_1 A = \mu_0 N_1 I_1 A / l$

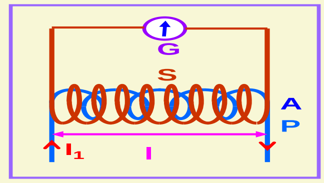
Magnetic Flux linked across N turns of the secondary solenoid is

$$\Phi_{21} = \mu_0 N_1 N_2 I_1 A / l$$

But, $\Phi_{21} = M_{21} I_1$

$$M_{21} = \mu_0 N_1 N_2 A / l = \mu_0 n_1 n_2 A l$$

$|||^{ly}$ $$M_{12} = \mu_0 N_1 N_2 A / l = \mu_0 n_1 n_2 A l$$




∴ For two long co-axial solenoids of same length and cross-sectional area, the mutual inductance is same and leads to principle of reciprocity.

$$M = M_{12} = M_{21}$$

## ALTERNATING CURRENT

An alternating current is that which changes continuously in magnitude and periodically in direction. It can be represented by a sine curve or a cosine curve i.e.,

### ➤ Average or Mean Value of Alternating Current:

**Average or Mean Value of Alternating Current:**

Average or Mean value of alternating current over half cycle is that steady current which will send the same amount of charge in a circuit in the time of half cycle as is sent by the given alternating current in the same circuit in the same time.

$dq = I\,dt = I_0 \sin \omega t\,dt$

$$q = \int_0^{T/2} I_0 \sin \omega t\,dt$$

$$q = 2 I_0 / \omega = 2 I_0 T / 2\pi = I_0 T / \pi$$

Mean Value of AC, $I_m = I_{av} = q / (T/2)$

$$\boxed{I_m = I_{av} = 2 I_0 / \pi = 0.637\, I_0 = 63.7\,\%\, I_0}$$

**Average or Mean Value of Alternating emf:**

$$\boxed{E_m = E_{av} = 2 E_0 / \pi = 0.637\, E_0 = 63.7\,\%\, E_0}$$

Note: Average or Mean value of alternating current or emf is zero over a cycle as the + ve and – ve values get cancelled.

## Root Mean Square or Virtual or Effective Value of Alternating Current:

**Root Mean Square (rms) value of alternating current is that steady current which would produce the same heat in a given resistance in a given time as is produced by the given alternating current in the same resistance in the same time.**

$$dH = I^2R\,dt = I_0^2\,R\sin^2\omega t\,dt$$

$$H = \int_0^T I_0^2\,R\sin^2\omega t\,dt$$

$H = I_0^2\,RT/2$ (After integration, $\omega$ is replaced with $2\pi/T$)

If $I_v$ be the virtual value of AC, then

$H = I_v^{\,2}\,RT$ $\therefore$ $\boxed{I_v = I_{rms} = I_{eff} = I_0/\sqrt{2} = 0.707\,I_0 = 70.7\,\%\,I_0}$

## Root Mean Square or Virtual or Effective Value of Alternating emf:

$\boxed{E_v = E_{rms} = E_{eff} = E_0/\sqrt{2} = 0.707\,E_0 = 70.7\,\%\,E_0}$

**Note:**

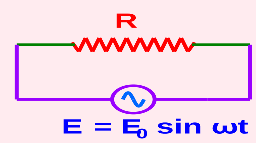
1. Root Mean Square value of alternating current or emf can be calculated over any period of the cycle since it is based on the heat energy produced.

2. *Do not use the above formulae if the time interval under the consideration is less than one period.*

## AC Circuit Containing Resistance only

All a.c. instruments measure virtual values of a.c. The behavior of an ohmic resistance R in a.c. circuit
is the same as in d.c. circuit. Through alternating EMF and alternating current are in same phase.

### AC Circuit with a Pure Resistor:



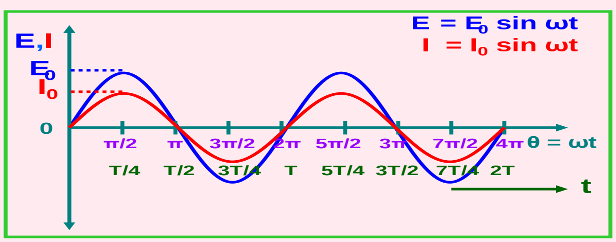

$E = E_0\sin\omega t$

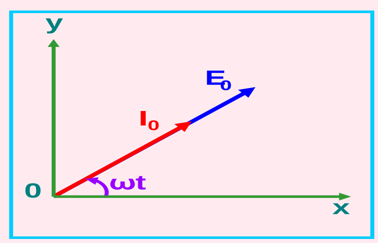
$I = E/R$

$= (E_0/R)\sin\omega t$

$I = I_0\sin\omega t$ (where $I_0 = E_0/R$ and $R = E_0/I_0$)

Emf and current are in same phase.



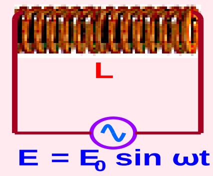

## AC Circuit Containing Pure Inductance only

Through a pure inductor, alternating current lags behind the alternating EMF by phase. angle of $90^o$

## AC Circuit with a Pure Inductor:

$E = E_0 \sin \omega t$

Induced emf in the inductor is $-L\,(dI / dt)$




In order to maintain the flow of current, the applied emf must be equal and opposite to the induced emf.

$\therefore \quad E = L\,(dI / dt)$

$E_0 \sin \omega t = L\,(dI / dt)$

$dI = (E_0 / L) \sin \omega t \, dt$

$\Longrightarrow$

$I = \int (E_0 / L) \sin \omega t \, dt$

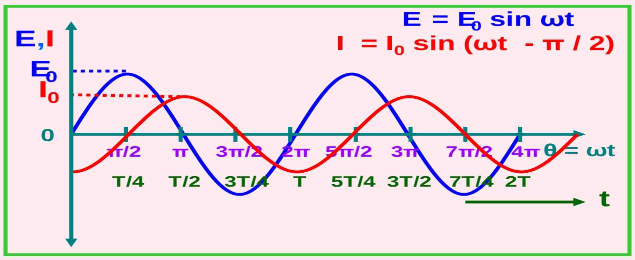
$I = (E_0 / \omega L)\,(-\cos \omega t)$

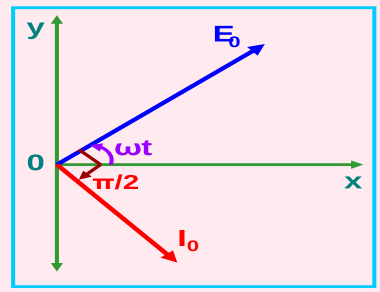
$I = I_0 \sin (\omega t - \pi / 2)$

(where $I_0 = E_0 / \omega L$ and $X_L = \omega L = E_0 / I_0$)

$X_L$ is Inductive Reactance. Its SI unit is ohm.

Current lags behind emf by $\pi/2$ rad.

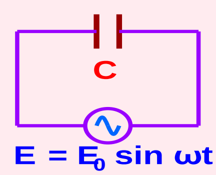



**AC Circuit Containing Pure Capacitance only**

Through a pure capacitor, alternating current leads the alternating EMF by a phase angle of 90°. $X_L$ and $X_c$ both are measured in ohms.

## AC Circuit with a Capacitor:




$E = E_0 \sin \omega t$

$q = CE = CE_0 \sin \omega t$

$I = dq / dt$

$= (d / dt)\,[CE_0 \sin \omega t]$

$I = [E_0 / (1 / \omega C)]\,(\cos \omega t)$

$I = I_0 \sin (\omega t + \pi / 2)$

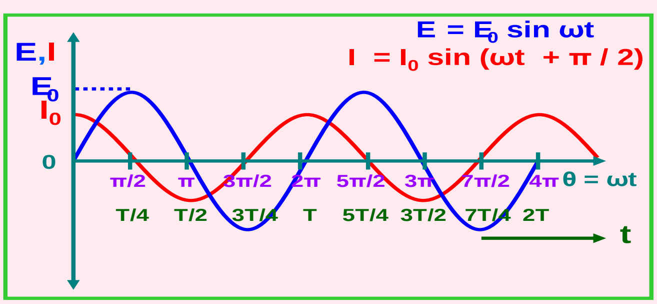
(where $I_0 = E_0 / (1 / \omega C)$ and

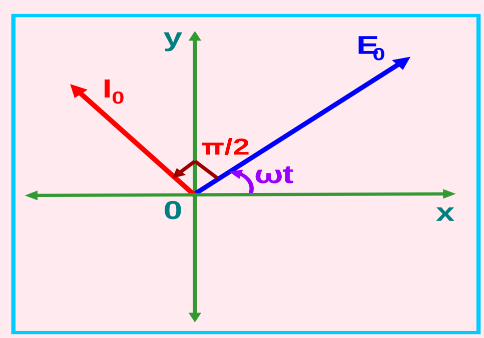
$X_C = 1 / \omega C = E_0 / I_0$)

$X_C$ is Capacitive Reactance.

Its SI unit is ohm.

Current leads the emf by $\pi/2$ radians.



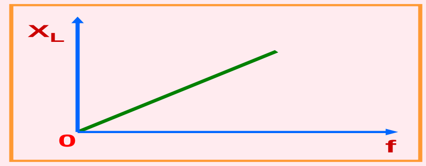



## Variation of $X_L$ with Frequency:

$I_0 = E_0 / \omega L$ and $X_L = \omega L$

$X_L$ is Inductive Reactance and $\omega = 2\pi f$

$X_L = 2\pi f L$ i.e. $X_L \propto f$

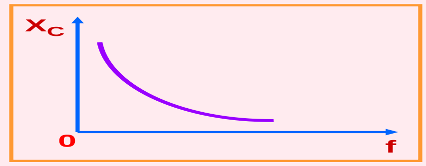



## Variation of $X_C$ with Frequency:

$I_0 = E_0 / (1/\omega C)$ and $X_C = 1 / \omega C$

$X_C$ is Inductive Reactance and $\omega = 2\pi f$

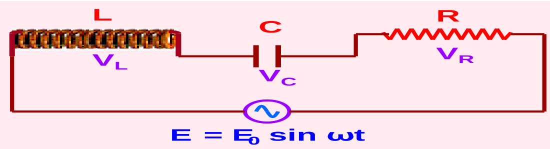
$X_C = 1 / 2\pi f C$ i.e. $X_C \propto 1 / f$




**TIPS:**

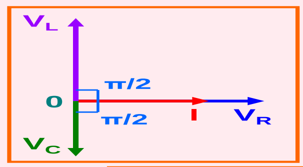
1) Inductance (L) can not decrease Direct Current. It can only decrease Alternating Current.
2) Capacitance (C) allows AC to flow through it but blocks DC.

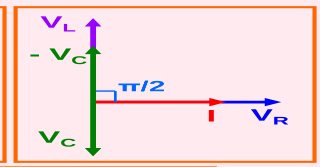
## AC Circuit with L, C, R in Series Combination:

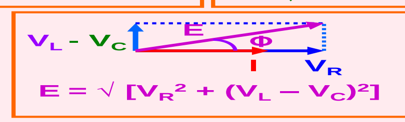



The applied emf appears as Voltage drops $V_R$, $V_L$ and $V_C$ across R, L and C respectively.

1) In R, current and voltage are in phase.
2) In L, current lags behind voltage by $\pi/2$
3) In C, current leads the voltage by $\pi/2$




$E = \sqrt{[V_R^2 + (V_L - V_C)^2]}$

$$I = \frac{E}{\sqrt{[R^2 + (X_L - X_C)^2]}}$$

$Z = \sqrt{[R^2 + (X_L - X_C)^2]}$

$Z = \sqrt{[R^2 + (\omega L - 1/\omega C)^2]}$

$$\tan \Phi = \frac{X_L - X_C}{R} \quad \text{or} \quad \tan \Phi = \frac{\omega L - 1/\omega C}{R}$$

## RESONANCE IN AC CIRCUIT

**When $X_L = X_C$ i.e. $\omega L = 1/\omega C$, $\tan \Phi = 0$ or $\Phi$ is 0° and**

**$Z = \sqrt{[R^2 + (\omega L - 1/\omega C)^2]}$ becomes $Z_{min} = R$ and $I_{0max} = E / R$**

**At resonant angular frequency $\omega_r$,**

**$\omega_r L = 1/\omega_r C$ or $\omega_r = 1 / \sqrt{LC}$ or $f_r = 1 / (2\pi \sqrt{LC})$**

**The impedance offered by the circuit is minimum and the current is maximum. This condition is called resonant condition of LCR circuit and the frequency is called resonant frequency**

**POWER IN AC CIRCUIT: THE POWER FACTOR**

$$i_m = \frac{v_m}{Z} \text{ and } \phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$$

$$p = vi = (v_m \sin \omega t) \times [i_m \sin(\omega t + \phi)]$$

$$= \frac{v_m i_m}{2}[\cos \phi - \cos(2\omega t + \phi)]$$

$$P = \frac{v_m i_m}{2} \cos \phi = \frac{v_m}{\sqrt{2}} \frac{i_m}{\sqrt{2}} \cos \phi$$

$$P = V I \cos \phi$$

$P_{av} = E_v I_v \cos \Phi$

**Power in AC Circuit with R:**

In R, current and emf are in phase.

$\Phi = 0°$

$P_{av} = E_v I_v \cos \Phi = E_v I_v \cos 0° = E_v I_v$

**Power in AC Circuit with L:**

In L, current lags behind emf by π/2.

$\Phi = - \pi/2$

$P_{av} = E_v I_v \cos(-\pi/2) = E_v I_v (0) = 0$

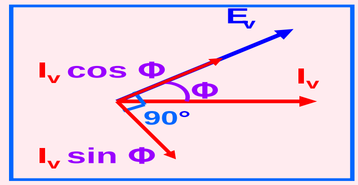
**Power in AC Circuit with C:**

In C, current leads emf by π/2.

$\Phi = + \pi/2$

$P_{av} = E_v I_v \cos(\pi/2) = E_v I_v (0) = 0$

**Wattless Current or Idle Current:**




The component $I_v \cos \Phi$ generates power with $E_v$.

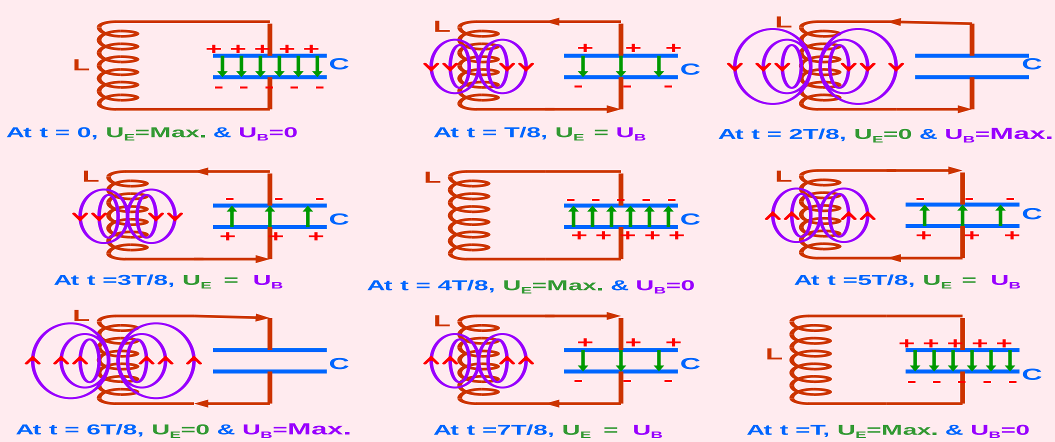
However, the component $I_v \sin \Phi$ does not contribute to power along $E_v$ and hence power generated is zero. This component of current is called wattless or idle current.

$P = E_v I_v \sin \Phi \cos 90° = 0$

Note:

Power (Energy) is not dissipated in Inductor and Capacitor and hence they find a lot of practical applications and in devices using alternating current.

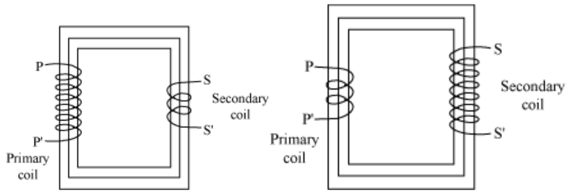
**L C Oscillations:**




TRANSFORMER

**Principle** – It works on the principle of electromagnetic induction. It converts low voltage high current into high voltage low current or vice versa.

**Construction**




Step-down transformer Step-up transformer

**Working**

Alternating *emf* is supplied to the primary coil PP'. The resulting current produces an induced current in secondary.

Magnetic flux linked with primary is also linked with the secondary. The induced *emf* in each turn of the secondary is
equal to that induced in each turn of the primary.

Let,

$E_P$ − Alternating *emf* applied to primary

$n_P$ − Number of turns in the primary

$\frac{d\phi}{dt}$ − Rate of change of flux through each turn of primary coil

$$\therefore E_p = -n_p \frac{d\phi}{dt} \qquad ...(1)$$

$E_s$− Alternating *emf* of secondary

$n_s$ − Number of turns in secondary

$$\therefore E_s = -n_s \frac{d\phi}{dt} \qquad ...(2)$$

Dividing equation (2) by (1),

$$\frac{E_s}{E_p} = \frac{n_s}{n_p} = k$$

- For step-up transformer, $K > 1$

$\therefore E_s > E_p$

- For step-down transformer, $K < 1$

$\therefore E_s < E_p$

- According to law of conservation of energy,

Input electrical power = Output electrical power

$E_pI_p = E_sI_s$

$$\therefore \frac{E_s}{E_p} = \frac{I_p}{I_s}$$

Transformers are used in telegraph, telephone, power stations, etc.

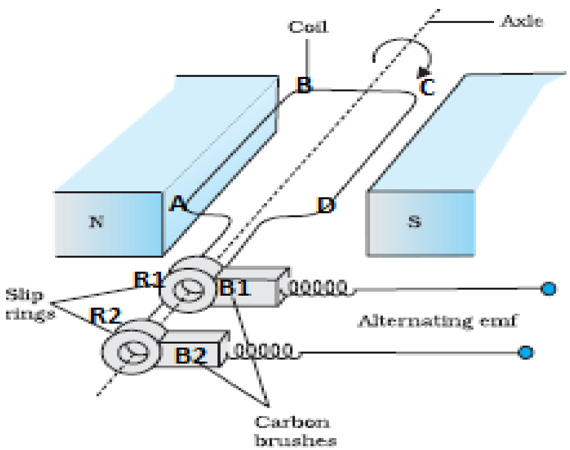
Losses in transformer:

Copper loss − Heat in copper wire is generated by working of a transformer. It can be diminished using thick copper wires.

Iron loss − Loss is in the bulk of iron core due to the induced eddy currents. It is minimized by using thin laminated core.

Hysteresis loss − Alternately magnetizing and demagnetizing, the iron core cause loss of energy. It is minimized
using a special alloy of iron core with silicon.
Magnetic loss − It is due to the leakage of magnetic flux.

**AC Generator**




Principle − Based on the phenomenon of electromagnetic induction
It converts mechanical energy into electrical energy.
**Construction**
Main parts of an ac generator:
Armature − Rectangular coil ABCD
Field Magnets − Two pole pieces of a strong electromagnet
Slip Rings − The ends of coil ABCD are connected to two hollow metallic rings R1 and R2.
Brushes − B1 and B2 are two flexible metal plates or carbon rods. They are fixed and are kept in tight contact with R1
and R2 respectively.
**Theory and Working** − As the armature coil is rotated in the magnetic field, angle $\theta$ between the field and normal to the
coil changes continuously. Therefore, magnetic flux linked with the coil changes. An *emf* is induced in the coil. According
to Fleming's right hand rule, current induced in AB is from A to B and it is from C to D in CD. In the external circuit,
current flows from $B2$ to $B1$.
To calculate the magnitude of *emf* induced:
Suppose
$A \rightarrow$ Area of each turn of the coil
$N \rightarrow$ Number of turns in the coil
$\vec{B} \rightarrow$ Strength of magnetic field
$\theta \rightarrow$ Angle which normal to the coil makes with $\vec{B}$ at any instant $t$
∴ Magnetic flux linked with the coil in this position:

$\phi = N(\vec{B}\cdot\vec{A})$ = $NBA$ cos$\theta$= $NBA$ cos$\omega t$ …(i)

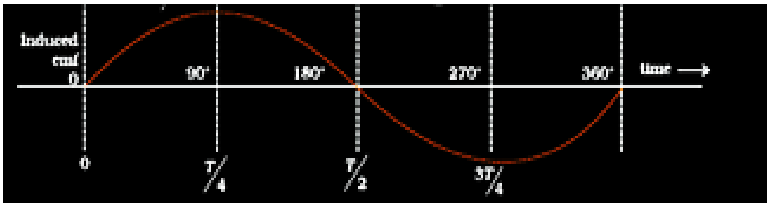
Where, '$\omega$' is angular velocity of the coil

$$e = -\frac{d\theta}{dt} = -\frac{d}{dt}(NAB\cos\omega t)$$

$$= -NAB\frac{d}{dt}(\cos\omega t)$$

$$= -NAB(-\sin\omega t)\omega$$

$\therefore e$ = NAB $\omega$ sin$\omega t$




## Unit - V Electromagnetic Waves (Chapter-8)

**QUICK REVISION NOTES**

INTRODUCTION

- Electromagnetic waves are one of the predictions of Maxwell's equations.
- Electromagnetic waves are time varying electric and magnetic fields that propagate in space.
- Hertz experimentally confirmed the existence of electromagnetic waves with the help of spark gap oscillator.
- J C Bose produced electromagnetic waves of smaller wavelength (5mm 25mm).
- Marconi discovered that electromagnetic wave can radiate up to several kilometers.

DISPLACEMENT CURRENT

· From Maxwell's correction to Ampere's circuital law , the total current *i is the sum of the conduction current* denoted by $i_c$, *and the displacement current denoted by* $i_d$.

$$i = i_c + i_d = i_c + \varepsilon_0 \frac{d\Phi_E}{dt} \qquad I_d = \varepsilon_0 \frac{d\phi_E}{dt}$$

· The current due to changing electric field (or electric *displacement*) is called *displacement current or Maxwell's displacement current.*

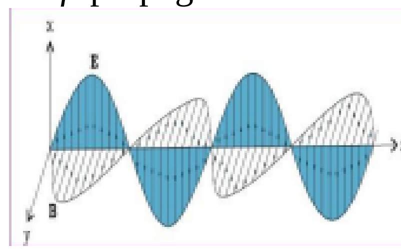
· The current carried by conductors due to flow of charges is called *conduction current.*

· Thus the generalized Ampere's circuital law (Ampere-Maxwell law ) is given by

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\Phi_E}{dt}$$

Nature of electromagnetic waves

· An electric charge oscillating with a frequency produces em waves of the same frequency.
• The electric and magnetic fields in an electromagnetic wave are perpendicular to each other, *and to the direction of* propagation.




· The electric and magnetic fields are represented by

$$E_x = E_0 \sin(kz - \omega t)$$
$$B_y = B_0 \sin(kz - \omega t)$$

• Here *k is related to the wave length λ of the wave by the* equation,

$$k = \frac{2\pi}{\lambda}$$

• The speed of propagation of the wave is ($\omega/k$).
• The magnitude of the electric and the magnetic fields in an electromagnetic wave are related as

$$B_0 = (E_0/c)$$

· Pressure exerted by em wave is called radiation pressure

Properties of EM waves

• They are self-sustaining oscillations of electric and magnetic fields in free space, or vacuum.
• Shows transverse wave nature.
• No material medium is needed for its propagation.
• EM waves are not deflected in electric field and magnetic field.
• The velocity of em waves in any media is given by

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

· EM waves are polarised.

· Electromagnetic waves carry energy and momentum like other waves.

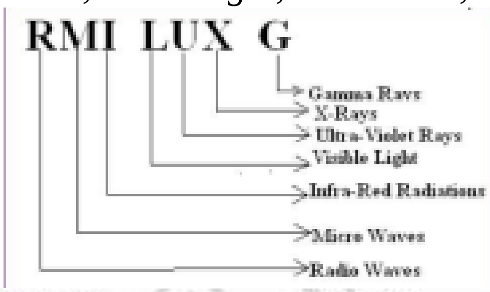
· If the total energy transferred to a surface in time *t is U,* the magnitude of the total momentum delivered to this surface (*for complete absorption) is,*

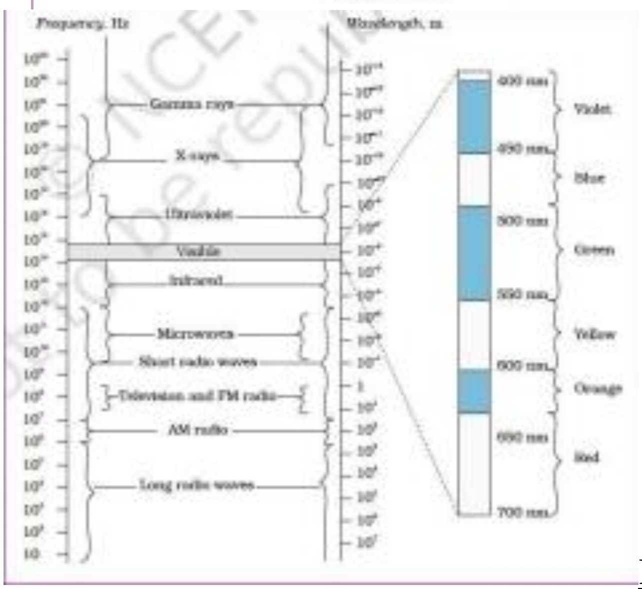
$$p = \frac{U}{c}$$

ELECTROMAGNETIC SPECTRUM

· An arrangement of electromagnetic radiations according to their wavelength or frequency. · Some of the waves in the increasing order of frequency (decreasing order of wavelength) are :

*Radio waves, microwaves, infra red, visible light, ultra violet, x-rays, Gamma rays*




Radio waves

• Radio waves are produced by the accelerated motion of charges in conducting wires.

• They are used in radio and television communication systems.

• They are generally in the frequency range from 500 kHz to about 1000 MHz.

• The AM (amplitude modulated) band is from 530 kHz to 1710 kHz.

• Higher frequencies up to 54 MHz are used for *short wave bands. TV waves range* from 54 MHz to 890 MHz.

• The FM (frequency modulated) radio band extends from 88 MHz to 108 MHz.

• Cellular phones use radio waves to transmit voice communication in the ultrahigh frequency (UHF) band.

Microwaves

• Microwaves are produced by special vacuum tubes such as klystrons, magnetrons and Gunn diodes.

- Microwaves are used for the radar systems used in aircraft navigation. Radar also provides the basis for the speed guns used to time fast balls, tennis serves, and automobiles.
- Used in Microwave ovens.
- In such ovens, the frequency of the microwaves is selected to match the resonant frequency of water molecules so that energy from the waves is transferred efficiently to the kinetic energy of the molecules. This raises the temperature of any food containing water.
- Also used in satellite communication.

Infrared waves

- Infrared waves are produced by hot bodies and molecules.
- Infrared waves are referred to as *heat waves. This i*s because water molecules present in most materials readily absorb infrared waves (many other molecules, for example, $CO_2$, $NH_3$, also absorb infrared waves). After absorption, their thermal motion increases, that is, they heat up and heat their surroundings.
- Infrared radiation plays an role in maintaining the earth's warmth or average temperature through the greenhouse effect.
- Incoming visible light is absorbed by the earth's surface and reradiated as infrared radiations. This radiation is trapped by greenhouse gases such as carbon dioxide and water vapour.
- Infrared detectors are used in Earth satellites, both for military purposes and to observe growth of crops.
- Electronic devices (for example semiconductor light emitting diodes) also emit infrared and are widely used in the remote switches of household electronic systems such as TV sets, video recorders and hi-fi systems.
- Used in secret signaling and burglar alarms.
- Used in the treatment of dislocations, paralysis etc.
- Used to take the photographs of distant objects.
- Used in physiotherapy
- Used for determination of molecular structure.

Visible rays

- It is the part of the spectrum that is detected by the human eye.
- It runs from about a wavelength range of about 700 – 400 nm.
- Visible light emitted or reflected from objects around us provides us information about the world. Our eyes are sensitive to this range of wavelengths.

• Different animals are sensitive to different range of wavelengths. For example,
snakes can detect infrared waves, and the 'visible' range of many insects extends well into the ultraviolet.

Ultraviolet rays

• Ultraviolet (UV) radiation is produced by special lamps and very hot bodies
• The sun is an important source of ultraviolet light. But most of it is absorbed in the ozone layer in the atmosphere at an altitude of about 40 – 50 km.
• UV light in large quantities has harmful effects on humans. Exposure to UV
radiation induces the production of more melanin, causing tanning of the skin.
• UV radiation is absorbed by ordinary glass. Hence, one cannot get tanned or sunburn through glass windows.

• Welders wear special glass goggles or face masks with glass windows to protect their eyes from large amount of UV produced by welding arcs.

• Due to its shorter wavelengths, UV radiations can be focused into very
narrow beams for high precision applications such as LASIK (*Laser assisted in situ keratomileusis) eye surgery*.
• *UV lamps are used to kill* germs in water purifiers.
• Ozone layer in the atmosphere plays a protective role.
• Used in the manufacture of fluorescent tubes
• Used in the determination of age of written documents
• Used in the detection of finger prints. • Helps to produce vitamin D in our skin.

X-rays

• Beyond the UV region of the electromagnetic spectrum lies the X-ray region.
• W Roentgen discovered x-rays
• One common way to generate X-rays is to bombard a metal target by high energy electrons.
• X-rays are used as a diagnostic tool in medicine and as a treatment for certain forms of cancer.
• Because X-rays damage or destroy living tissues and organisms, care must be taken to avoid unnecessary or over exposure.

• Used to study structure of atoms
molecules and crystals
• Used to detect cracks and holes inside a sheet of metal.

• Used to detect hidden materials.

Gamma rays

- They lie in the upper frequency range of the electromagnetic spectrum.
- This high frequency radiation is produced in nuclear reactions and also emitted by radioactive nuclei.
- They are used in medicine to destroy cancer cells.
- Used to study structure of nuclei of atom.
- Used to sterilize surgical Instruments, • Used to detect cracks in underground metal pipes etc

Production and detection of em waves

| Type | Wavelength range | Production | Detection |
|---|---|---|---|
| Radio | > 0.1 m | Rapid acceleration and decelerations of electrons in aerials | Receiver's aerials |
| Microwave | 0.1m to 1 mm | Klystron valve or magnetron valve | Point contact diodes |
| Infra-red | 1mm to 700 nm | Vibration of atoms and molecules | Thermopiles Bolometer, Infrared photographic film |
| Light | 700 nm to 400 nm | Electrons in atoms emit light when they move from one energy level to a lower energy level | The eye Photocells Photographic film |
| Ultraviolet | 400 nm to 1nm | Inner shell electrons in atoms moving from one energy level to a lower level | Photocells Photographic film |
| X-rays | 1nm to $10^{-3}$ nm | X-ray tubes or inner shell electrons | Photographic film Geiger tubes Ionisation chamber |
| Gamma rays | $<10^{-3}$ nm | Radioactive decay of the nucleus | -do- |

# Unit - VI Optics (Chapters 9&10)

## QUICK REVISION NOTES

### RAY OPTICS

$$\mu = \frac{\sin i}{\sin r}$$

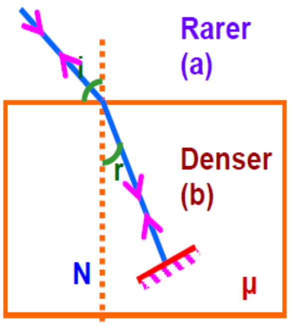
TIPS:

- For optically rarer medium μ is lower and that of a denser medium μ is higher.
- μ of denser medium w.r.t. rarer medium is more than 1 and that of rarer medium w.r.t. denser medium is less than 1. ($\mu_{air} = \mu_{vacuum} = 1$)
- In refraction, the velocity and wavelength of light change.
- In refraction, the frequency and phase of light do not change.
- $_a\mu_m = c_a / c_m$ and $_a\mu_m = \lambda_a / \lambda_m$

**Principle of Reversibility of Light:**

$$_a\mu_b = \frac{\sin i}{\sin r} \qquad _b\mu_a = \frac{\sin r}{\sin i}$$

$$\boxed{_a\mu_b \times {_b\mu_a} = 1} \quad \text{or} \quad \boxed{_a\mu_b = 1 / {_b\mu_a}}$$




If a ray of light, after suffering any number of reflections and/or Refractions has its path reversed at any stage, it travels back to The source along the same path in the opposite direction.

A natural consequence of the principle of reversibility is that the image and object positions can Be interchanged. These positions are called conjugate positions.

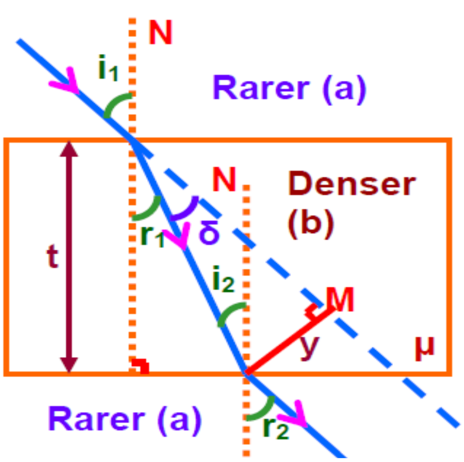
**Refraction through a Parallel Slab:**

$$_a\mu_b = \frac{\sin i_1}{\sin r_1} \qquad _b\mu_a = \frac{\sin i_2}{\sin r_2}$$

But $_a\mu_b \times {_b\mu_a} = 1$

$$\therefore \frac{\sin i_1}{\sin r_1} \times \frac{\sin i_2}{\sin r_2} = 1$$

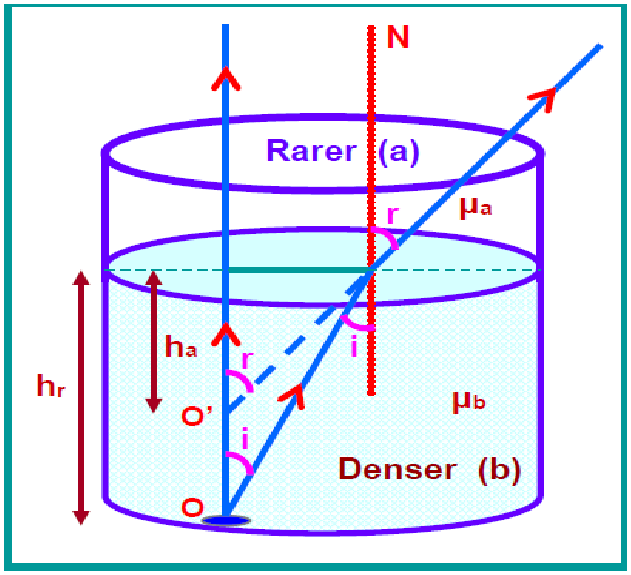
It implies that $i_1 = r_2$ and $i_2 = r_1$ since $i_1 \neq r_1$ and $i_2 \neq r_2$.



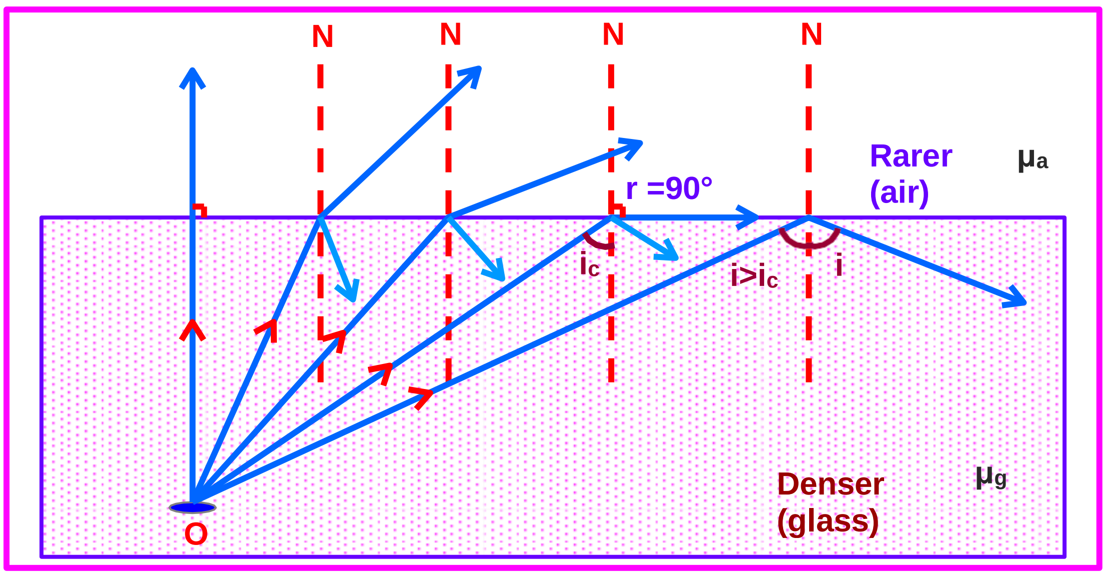

**Apparent Depth of a Liquid:**

$${}_b\mu_a = \frac{\sin i}{\sin r} \quad \text{or} \quad {}_a\mu_b = \frac{\sin r}{\sin i}$$

$${}_a\mu_b = \frac{h_r}{h_a} = \frac{\text{Real depth}}{\text{Apparent depth}}$$




**Total Internal Reflection:**




**Conditions for TIR:**

1. Incidentraymustbein opticallydenser medium.
2. Theangleofincidence in thedenser medium mustbegreater than thecriticalanglefor thepair ofmediaincontact.

**RelationbetweenCriticalAngleandRefractive Index:**

Critical angle is theangle ofincidence in thedensermediumforwhichthe angle ofrefractioninthe rarermediumis 90°.

$$_g\mu_a = \frac{\sin i}{\sin r} = \frac{\sin i_c}{\sin 90^\circ} = \sin i_c$$

$$\text{or} \quad _a\mu_g = \frac{1}{_g\mu_a} \quad \therefore \quad \boxed{_a\mu_g = \frac{1}{\sin i_c}} \quad \text{or} \quad \boxed{\sin i_c = \frac{1}{_a\mu_g}} \quad \text{Also} \quad \boxed{\sin i_c = \frac{\lambda_g}{\lambda_a}}$$

**Refraction at Convex Surface:**

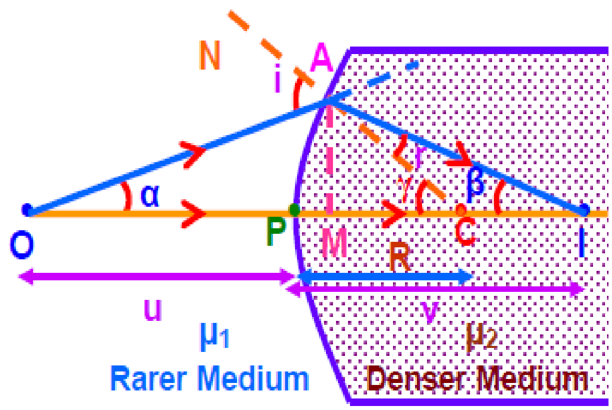
(From Rarer Medium to Denser Medium - Real Image)

$i = \alpha + \gamma \qquad \gamma = r + \beta \quad \text{or} \quad r = \gamma - \beta$

$\tan \alpha = \frac{MA}{MO} \quad \text{or} \quad \alpha = \frac{MA}{MO}$

$\tan \beta = \frac{MA}{MI} \quad \text{or} \quad \beta = \frac{MA}{MI}$

$\tan \gamma = \frac{MA}{MC} \quad \text{or} \quad \gamma = \frac{MA}{MC}$




$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \quad \text{or} \quad \frac{i}{r} = \frac{\mu_2}{\mu_1} \quad \text{or} \quad \boxed{\mu_1 i = \mu_2 r}$$

Substituting for i, r, α, β and γ, replacing M by P and rearranging,

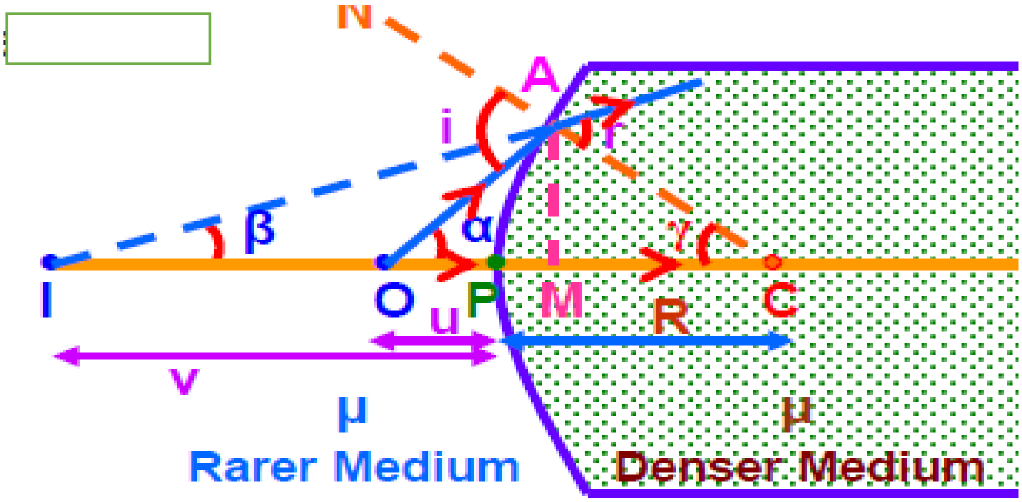
$$\frac{\mu}{PO} + \frac{\mu}{PI} = \frac{\mu_2 - \mu_1}{PC}$$

Applying sign conventions with values,
PO = - u, PI = + v and PC = + R

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

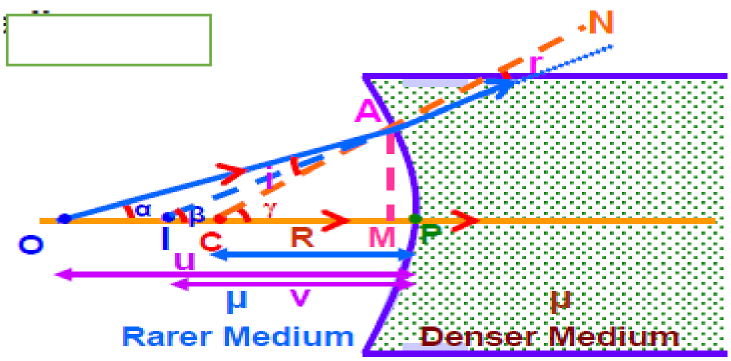
**Refraction at Convex Surface:**
(From Rarer Medium to Denser Medium
-Virtual Image)

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

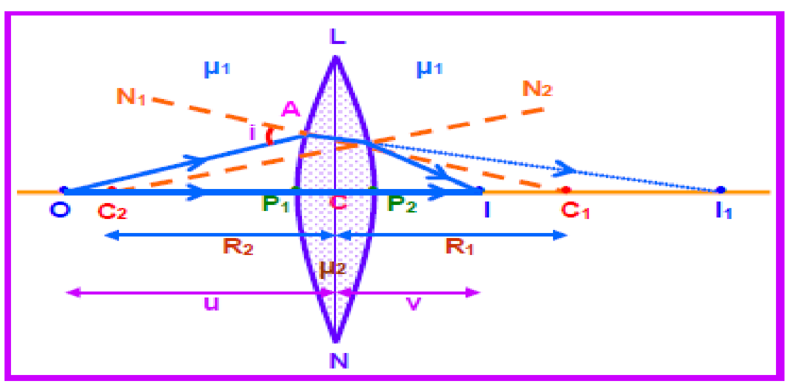



**Refraction at Concave Surface:**
(From Rarer Medium to Denser Medium
- Virtual Image)

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




**Lens Maker's Formula:**




For refraction at $LP_1N$,

$$\boxed{\frac{\mu}{C}+\frac{\mu}{CI_1}=\frac{\mu_2-\mu_1}{CC}}$$

(as if the image is formed in the denser medium)

For refraction at $LP_2N$,

$$\boxed{\frac{\mu}{-CI_1}+\frac{\mu}{C}=\frac{-(\mu_1-\mu_2)}{CC}}$$

(as if the object is in the denser medium and the image is formed in the rarer medium)

Combining the refractions at both the surfaces,

$$\frac{\mu}{C}+\frac{\mu}{C}=(\mu_2-\mu_1)\left(\frac{1}{CC}+\frac{1}{CC}\right)$$

Substituting the values with sign conventions,

$$\boxed{\frac{1}{-u}+\frac{1}{v}=\frac{(\mu_2-\mu_1)}{\mu}\left(\frac{1}{R_1}-\frac{1}{R_2}\right)}$$

Since $\mu_2 / \mu_1 = \mu$

$$\frac{1}{-u} + \frac{1}{v} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

or

$$\frac{1}{-u} + \frac{1}{v} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

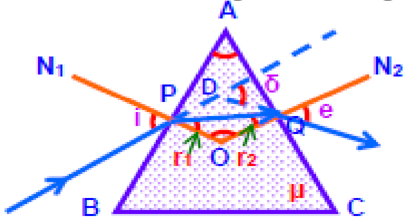
When the object is kept at infinity, the image is formed at the principal focus.
i.e. $u = -\infty$, $v = +f$.

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

This equation is called 'Lens Maker's Formula'.

Also, from the above equations we get, $$\boxed{\frac{1}{-u} + \frac{1}{v} = \frac{1}{f}}$$

**Refraction of Light through Prism:**




In quadrilateral APOQ,

$A + O = 180°$ .......(1)

(since $N_1$ and $N_2$ are normal)

In triangle OPQ,

$r_1 + r_2 + O = 180°$ .......(2)

In triangle DPQ,

$\delta = (i - r_1) + (e - r_2)$

$\delta = (i + e) - (r_1 + r_2)$ .......(3)

From (1) and (2),

$A = r_1 + r_2$

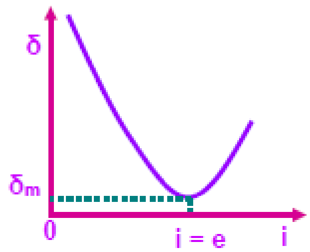
From (3),

$\delta = (i + e) - (A)$

or $\boxed{i + e = A + \delta}$

**Variation of angle of deviation with angle of incidence:**

When angle of incidence increases,
The angle of deviation decreases.
At a particular value of angle of incidence
The angle of deviation becomes minimum
And is called 'angle of minimum deviation'.
At $\delta m$, $i = e$ and $r1 = r2 = r$ (say)
After minimum deviation, angle of deviation Increases with angle of incidence




**Refractive Index of Material of Prism:**

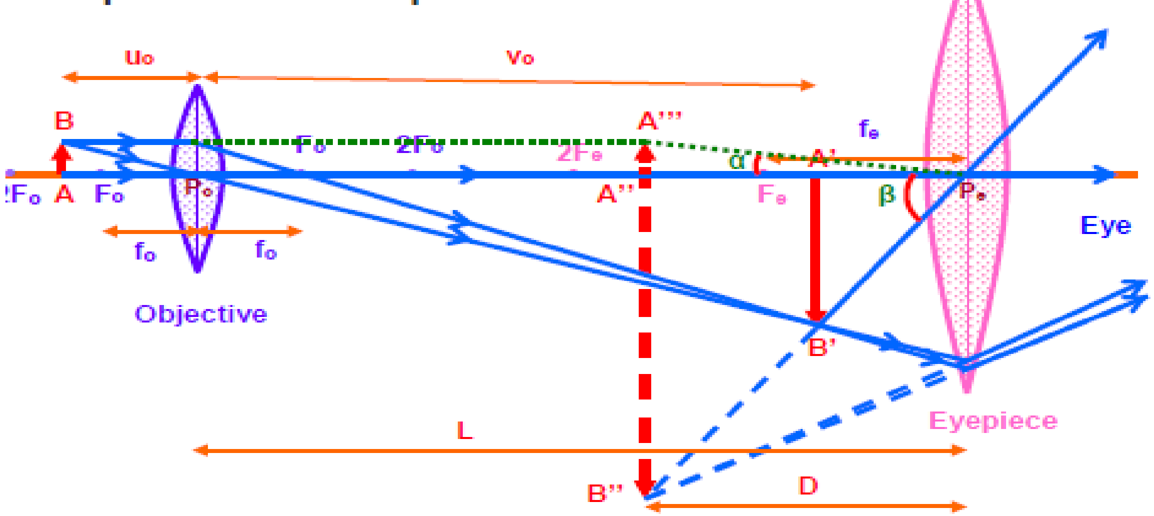
$A = r_1 + r_2$
$A = 2r$
$r = A / 2$
$i + e = A + \delta$
$2\,i = A + \delta_m$
$i = (A + \delta_m) / 2$

According to Snell's law,

$$\mu = \frac{\sin i}{\sin r_1} = \frac{\sin i}{\sin r}$$

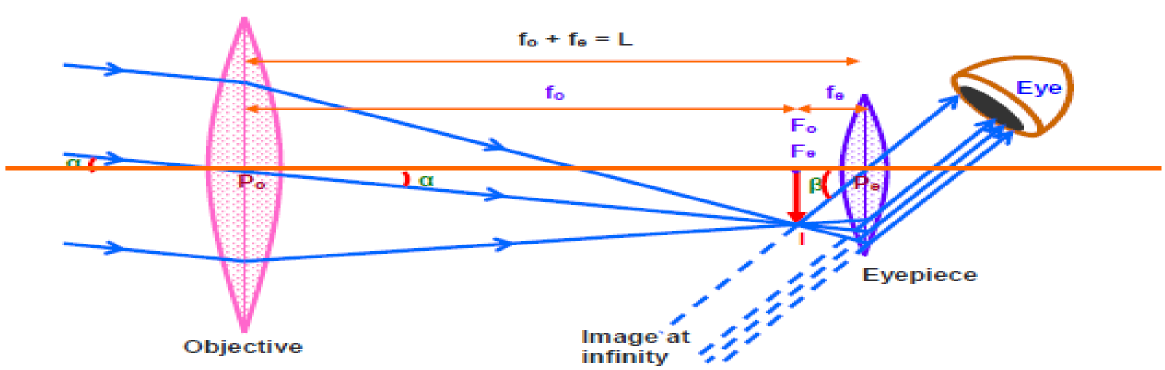
$$\therefore \quad \boxed{\mu = \frac{\sin \frac{(A + \delta_m)}{2}}{\sin \frac{A}{2}}}$$

**Compound Microscope:**




Objective: The converging lens nearer to the object.
Eyepiece: The converging lens through which the final image is seen.
Both are of short focal length.
Focal length of eyepiece is slightly greater than that of the objective.

**Astronomical Telescope: (Image formed at infinity – Normal Adjustment)**

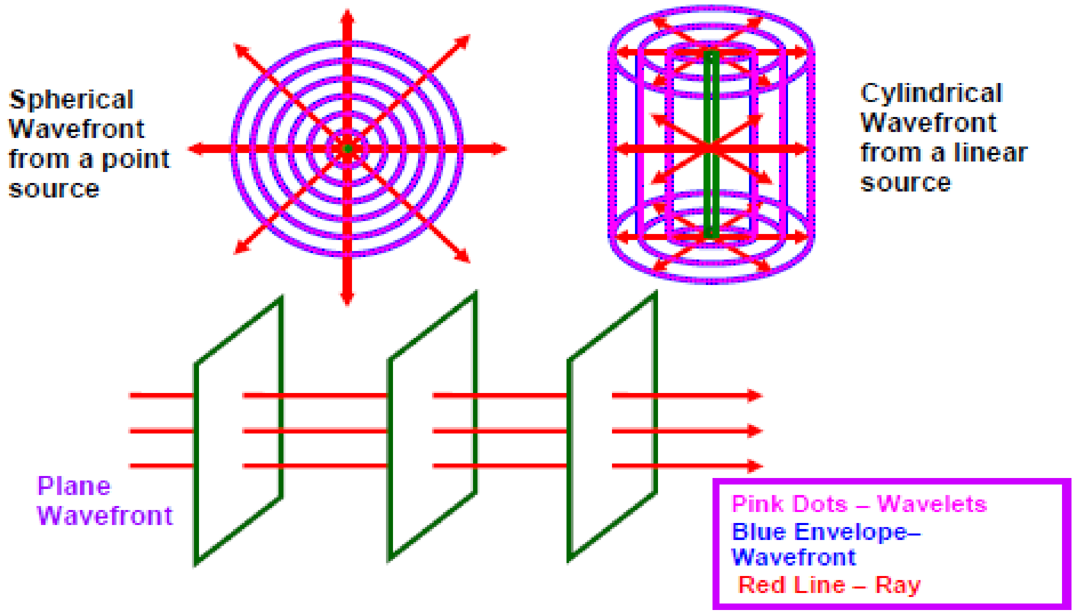


Focal length of the objective is much greater than that of the eyepiece.
Aperture of the objective is also large to allow more light to pass through it.

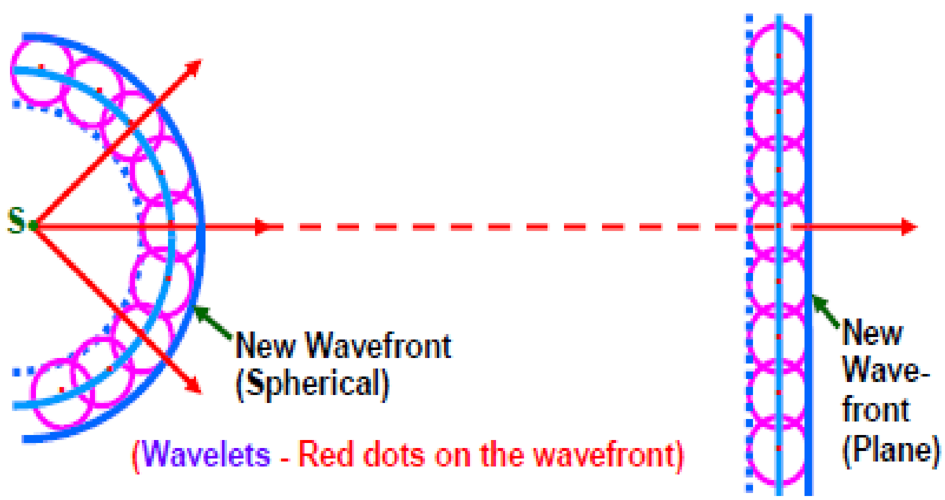
## WAVE OPTICS

**Wavefront:**

A wavelet is the point of disturbance due to propagation of light.
A wavefront is the locus of points (wavelets) having the same phase of oscillations.
A line perpendicular to a wavefront is called a **'ray'.**




**Huygens' Construction or Huygens' Principle of Secondary Wavelets:**

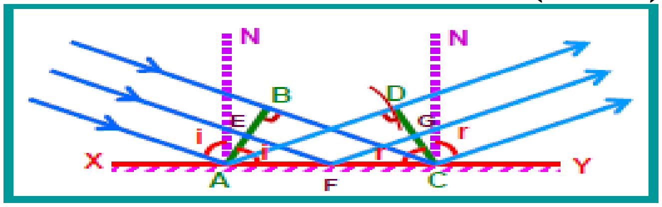



•Each point on a wavefront acts as a fresh source of disturbance of light.
• The new wavefront at any time later is obtained by taking the forward Envelope of all the secondary wavelets at that time.

**Note: Backward wavefront is rejected. Why?**

**Laws of Reflection at a Plane Surface (On Huygens' Principle):**

**Amplitude of secondary wavelet is proportional to % (1+cos0). Obviously, for the backward wavelet 0= 180° and (1+cose) is 0**.




**AB – Incident wavefront**
**CD – Reflected wavefront**
**XY – Reflecting surface**

If c be the speed of light, t be the time taken by light to go from B to C or A to D or E to G through F, then

$$t = \frac{EF}{c} + \frac{FG}{c}$$

$$t = \frac{AF \sin i}{c} + \frac{FC \sin r}{c}$$

$$t = \frac{AC \sin r + AF (\sin i - \sin r)}{c}$$

For rays of light from different parts on the incident wavefront, the values of AF are Different. But light from different points of the incident wavefront should take the Same time to reach the corresponding points on the reflected wavefront.
So, t should not depend upon AF. This is possible only if sin i – sin r = 0.
i.e. sin i = sin r or i = r

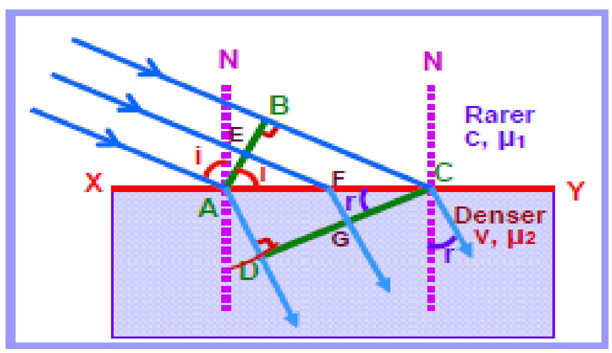
## Laws of Refraction at a Plane Surface (On Huygens' Principle):

If c be the speed of light, t be the time taken by light to go from B to C or A to D or E to G through F, then

$$t = \frac{EF}{c} + \frac{FG}{v}$$

$$t = \frac{AF \sin i}{c} + \frac{FC \sin r}{v}$$

$$t = \frac{AC \sin r}{v} + AF \left( \frac{\sin i}{c} - \frac{\sin r}{v} \right)$$

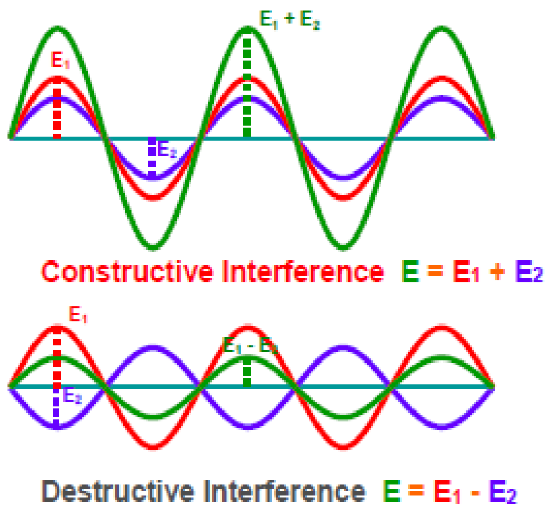


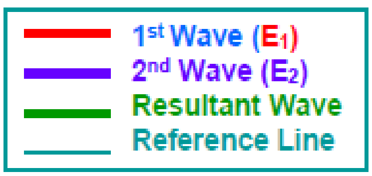

AB – Incident wavefront
CD – Refracted wavefront
XY – Refracting surface

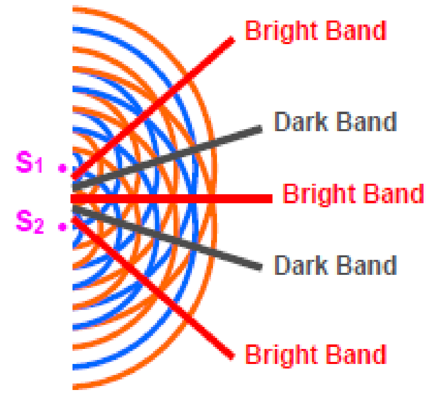
For rays of light from different parts on the incident wavefront, the values of AF are different. But light from different points of the incident wavefront should take the same time to reach the corresponding points on the refracted wavefront.
So, t should not depend upon AF. This is possible only if

$$\frac{\sin i}{c} - \frac{\sin r}{v} = 0 \quad \text{or} \quad \frac{\sin i}{c} = \frac{\sin r}{v} \quad \text{or} \quad \frac{\sin i}{\sin r} = \frac{c}{v} = \mu$$

## Interference of Waves:





**The phenomenon of one wave interfering with another and the resulting redistribution of energy in the space around the two sources of disturbance is called interference of waves.**

**Condition for Constructive Interference of Waves:**

For constructive interference, I should be maximum which is possible only if cos $\Phi = +1$.

**i.e. $\Phi = 2n\pi$ where n = 0, 1, 2, 3, …….**

Corresponding path difference is $\Delta = (\lambda / 2\pi) \times 2n\pi$

$\boxed{\Delta = n\lambda}$ $\boxed{I_{max} \propto (a + b)^2}$

**Condition for Destructive Interference of Waves:**

For destructive interference, I should be minimum which is possible only if cos $\Phi = -1$.

$\boxed{\text{i.e. } \Phi = (2n + 1)\pi}$ where n = 0, 1, 2, 3, …….

Corresponding path difference is $\Delta = (\lambda / 2\pi) \times (2n + 1)\pi$

$\boxed{\Delta = (2n + 1)\lambda / 2}$ $\boxed{I_{min} \propto (a - b)^2}$

### Comparison of intensities of maxima and minima:

$\boxed{I_{max}\ \alpha\ (a + b)^2}$

$\boxed{I_{min}\ \alpha\ (a - b)^2}$

$$\frac{I_{max}}{I_{min}} = \frac{(a + b)^2}{(a - b)^2} = \frac{(a/b + 1)^2}{(a/b - 1)^2}$$

$$\frac{I_{max}}{I_{min}} = \frac{(r + 1)^2}{(r - 1)^2}$$ where $r = a / b$ (ratio of the amplitudes)

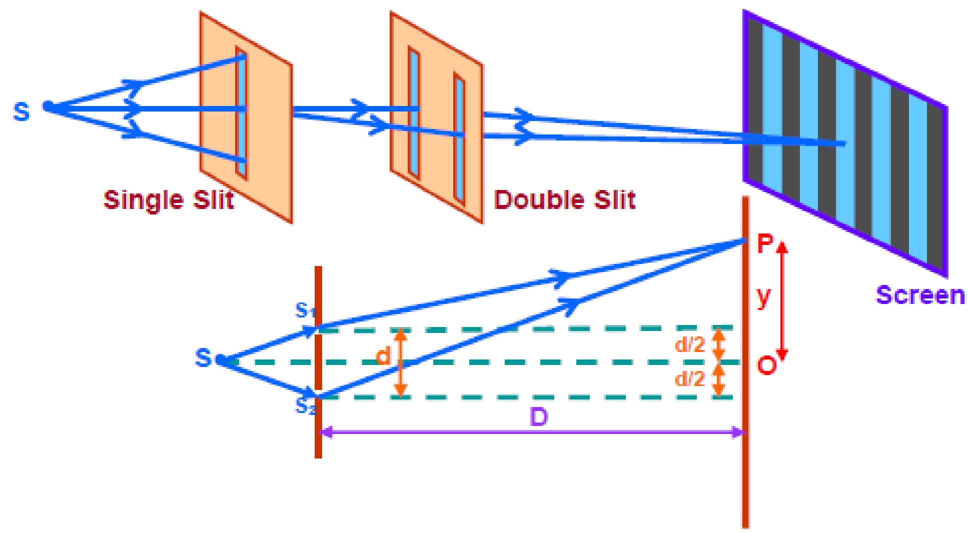
### Relation between Intensity (I), Amplitude (a) of the wave and Width (w) of the slit:

$I\ \alpha\ a^2$

$a\ \alpha\ \sqrt{w}$

$$\boxed{\frac{I_1}{I_2} = \frac{(a_1)^2}{(a_2)^2} = \frac{w_1}{w_2}}$$

## Young's double slit Experiment:




The waves from $S_1$ and $S_2$ reach the point P with some phase difference and hence path difference $\Delta = S_2P - S_1P$

$S_2P^2 - S_1P^2 = [D^2 + \{y + (d/2)\}^2] - [D^2 + \{y - (d/2)\}^2]$

$(S_2P - S_1P)\ (S_2P + S_1P) = 2\ yd$

$\Delta\ (2D) = 2\ yd$ $\boxed{\Lambda = yd / D}$

**Expression for Dark Fringe Width:**

$\beta_D = y_n - y_{n-1}$
$= n\ D\ \lambda / d - (n - 1)\ D\ \lambda / d$
$= D\ \lambda / d$

**Expression for Bright Fringe Width:**

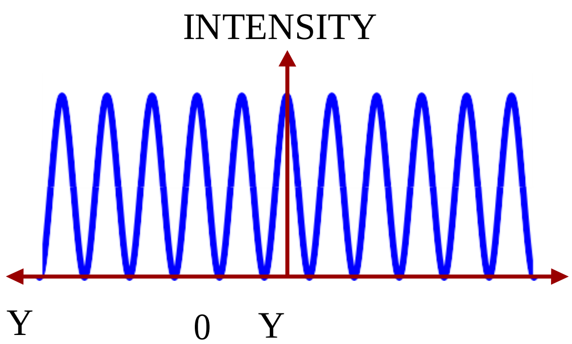
$\beta_B = y_n' - y_{n-1}'$
$= (2n+1)\ D\ \lambda / 2d - \{2(n-1)+1\}\ D\ \lambda / 2d$
$= D\ \lambda / d$

The expressions for fringe width show that the fringes are equally spaced on the screen.

### Distribution of Intensity:

Suppose the two interfering waves have same amplitudes 'a',then $I_{max}\alpha(a+a)^2$ i.e. $I_{max}\alpha 4a^2$

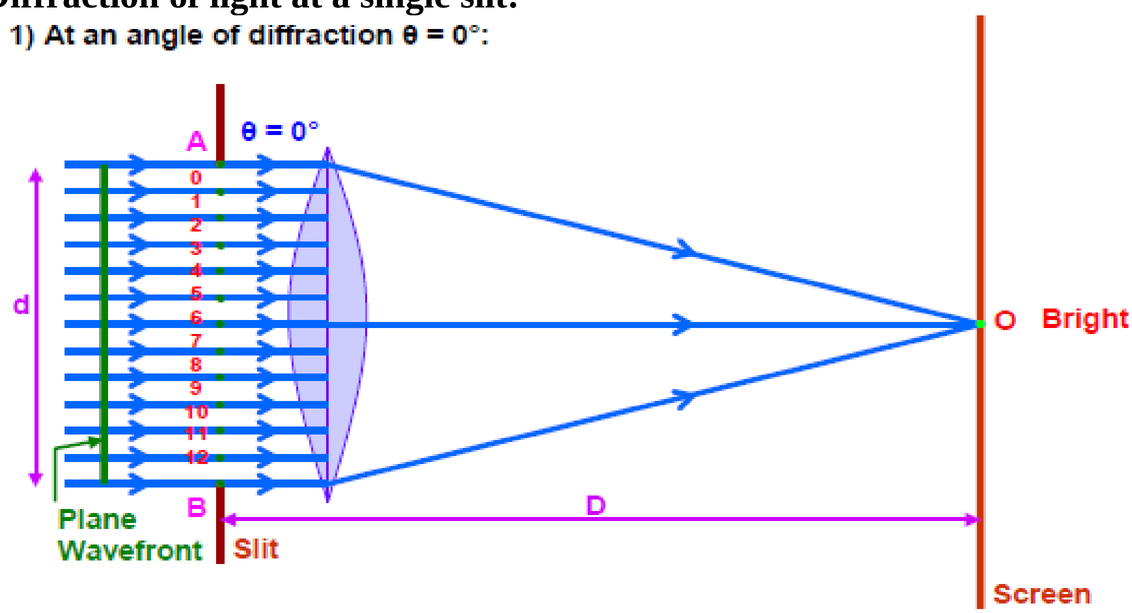
All the bright fringes have this same intensity.
Imin=0
All the dark fringes have zero intensity.

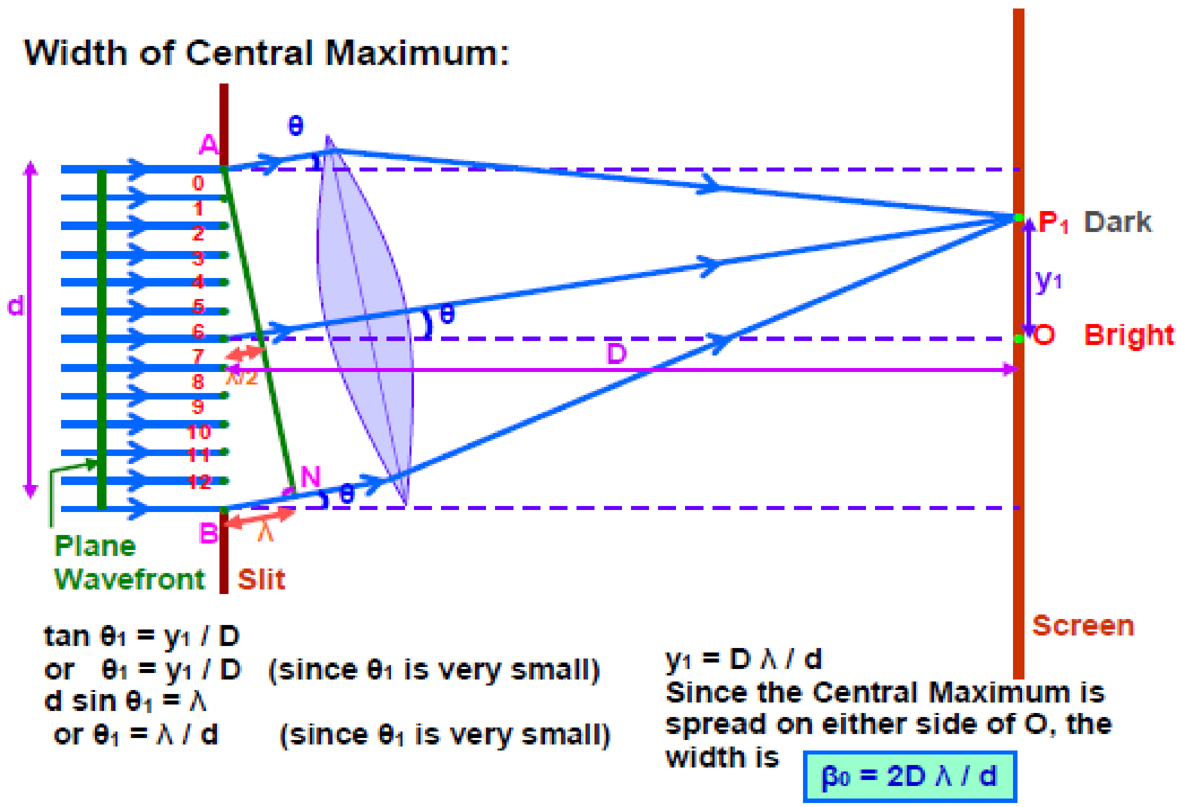



### Conditions for sustained interference:

- The two sources producing interference must be coherent.
- The two interfering wave trains must have the same plane of polarisation.
- The two sources must be very close to each other and the pattern must be observed at a larger distance to have sufficient width of the fringe.(Dλ/ d)
- The sources must be monochromatic. Otherwise, the fringes of different colours ill overlap.
- The two waves must be having same amplitude for better contrast between bright and dark fringes.

**Diffraction of light at a single slit:**






## Unit - VII Dual Nature of Radiation and Matter (Chapter- 11)

**QUICK REVISION NOTES IN POINTS**

1) WORK FUNCTION - The minimum energy needed by an electron to come out from a metal surface ($\phi_0$).
2) ELECTRON EMISSION - The electrons from a metal surface can be emitted by supplying energy greater than $W_0$ by suitably heating (thermionic emission) or applying strong electric field (field emission) or irradiating it by light of suitable frequency (photoelectric emission).
3) K.E GAINED BY AN ACCELERATED ELECTRON - An electron accelerated from rest through a p.d. of V volts. Gain in K. E = 1/2 x m x v $^2$ = eV
4) ELECTRON VOLT - Kinetic energy gained by an electron when accelerated through a p.d. of V volts. 1eV = 1.6 x 10 $^{-19}$ J , 1 MeV = 1.6 x 10$^{-3}$ J
5) PARTICLE NATURE OF LIGHT - THE PHOTONS - According to Planck's quantum theory of radiation, an electromagnetic wave travels in the form of discrete packets of energy called quanta. One of quantum of light radiation is called a photon.
6) PHOTON PICTURE OF ELECTROMAGNETIC RADIATION –
1. In its interaction with matter, radiation behaves as if it is made of particles, called photons.
2. Each photon carries an energy (E = hv) and momentum p (= h / λ ) , which depend on the frequency of radiation and not on its intensity.
3. Photons are electrically neutral not deflected by electric and magnetic fields.

4. In a photon-electron collision, total energy and total momentum are conserved but the number of photons may not be conserved. 5. The rest mass of a photon is zero.
6. The equivalent mass of a photon is given by
$E = mc^2 = hv$ or $m = (hv)/(c^2)$

**7) PHOTOELECTRIC EFFECT** - The phenomenon of emission of electrons from a metal surface, when electromagnetic radiations of sufficiently high frequency are incident on it. Metals like Li, Na, K, Ce show photoelectric effect with visible light while metals like Zn, Cd, Mg respond to ultraviolet light.

**8) PHOTOELECTRIC CURRENT** - The current constituted by photoelectrons. It depends on (i) the intensity of incident light, (ii) p.d. applied between the two electrodes, and (iii) the nature of emitter material.

**9) CUT OFF OR STOPPING POTENTIAL** - The minimum value of negative potential applied to the anode of a photocell to make the photoelectric current zero. It depends on (i) frequency of incident light, and (ii) the nature of emitter material. For a given frequency of incident light, it is independent of its intensity. It is related to the maximum K.E. of the emitted electrons as , $K_{max}$ $1/2\ mv^2_{max} = eV_o$

**10) THERSHOLD FREQUENCY** - The minimum value of the frequency of incident radiation below which the photoelectric emission stops altogether. It is a characteristic of the metal.

**11) LAWS OF PHOTOELECTRIC EMISSION -**

1. For a given metal and a radiation of fixed frequency, the rate of emission of photo electrons is proportional to the intensity of incident radiation.
2. For every metal, there is a certain minimum frequency below which no photoelectrons are emitted, howsoever high is the intensity of incident radiation. This frequency is called threshold frequency.
3. For the radiation of frequency higher than the threshold frequency, the maximum kinetic energy of the photoelectrons is directly proportional to the frequency of incident radiation and is independent of the intensity of incident radiation.
4. The photoelectric emission is an instantaneous process.

**12) FAILURE OF WAVE THEORY TO EXPLAIN PHOTOELECTRIC EFFECT** - The picture of continuous absorption of energy from the radiation could not explain

1. the independent of $K_{max}$ on intensity,
2. the existence of threshold frequency $v_0$ , and
3. the instantaneous nature of photoelectric emission.

**13) EINSTEIN'S THEORY OF PHOTOELECTRIC EFFECT -**
When a radiation of frequency v is incident on a metal surface, it is absorbed in the form of discrete photons each of energy hv. Photoelectric emission occurs because of single collision of a photon with a free electron. The energy of the photon is used to

1. free the electron from the metal surface. It is equal to the work function $W_0$, of the metal.
2. provide kinetic energy to the emitted electron.

$hv = K_{max} + W_0$

or $K_{max}=1/2\ mv^2_{max} = hv-W_0$

This is Einstein's photoelectric equation.

**14) EXPLANATION OF PHOTOELECTRIC EMISSION ON THE BASIS OF EINSTEIN'S PHOTOELECTRIC EMISSION -**

1. Clearly, above the threshold frequency $v_0$, $K_{max} \propto v$ i.e., the maximum K.E. of the emitted electrons depends linearly on the frequency of incident radiation.

2. When $v < v_0$ $K_{max}$ becomes negative. The kinetic energy becomes negative which has no physical meaning. Hence there is no photo electric emission below the threshold frequency $v_0$.

3. It is obvious from the photo-electric equation that the maximum K.E. of photo-electrons does not depend on the intensity of incident light.

**15) DUAL NATURE OF RADIATION** - Light has dual nature. It manifests itself as a wave in diffraction, interference, polarisation, etc., while it shows particle nature in photoelectric effect, Compton scattering, etc.

**16) DUAL NATURE OF MATTER** - According to de-Broglie hypothesis, material particles in motion display wave like properties. This hypothesis was based on (i) de-Broglie concept of nature loves symmetry, and (ii) matter can be converted into energy and vice versa. So moving particles like protons, neutrons, electrons, etc. are associated with de-Broglie waves and their wavelength is given by $\lambda = h/p = h/mv$

**17) DAVISSION AND GERMER EXPERIMENT** - This electron diffraction experiment has verified and confirmed the wave-nature of electrons.

**18) DE-BROGLIE WAVELENGTH OF AN ELECTRON** - The wavelength associated with an electron beam accelerated through a potential difference of V volts is given by,

$\boldsymbol{\lambda}=\sqrt{2mev} = 1.227/\sqrt{V}$ nm

## Unit - IX Electronic Devices (Chapter 14)

**QUICK REVISION NOTES**

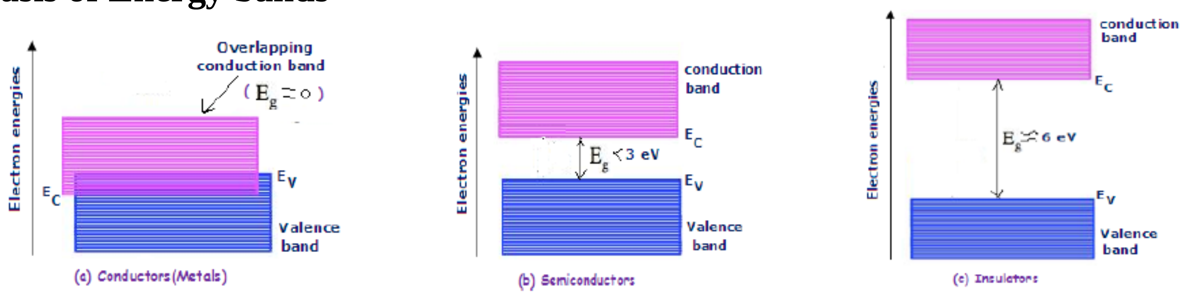
**Classification of solids:Solids can be classified as metals, insulators and semiconductors basing on conductivity (or) band theory**

- **Classification according to conductivity is as follows**
- **Metals have high conuctivity** $\left(10^{8} to 10^{2}\ Sm^{-1}\right)$ **(or) low resistivity**
- **Insulators have low conductivity** $\left(10^{-19} to 10^{-11} Sm^{-1}\right)$ **(or) high resistivity** $\left(10^{5}\ to 10^{-6}\ Sm^{-1}\right)$
- **Semiconductors have conductivity** $\left(10^{+11} to 10^{+19}\ \Omega m\right)$ **(or) resistivity , intermediate to metals and insulators** $\left(10^{-5} to 10^{6}\ \Omega m\right)$

**Energy Band theory in solids:An isolated atom has well defined energy levels and energy of an electron depends on its orbit (Principal quantum number)**

- But in solids atoms are so close such that outer orbits are very close (or) overlaped to form energy band.
- Inside the crystal each electron has a unique position and no two electrons see exactly same pattern of surrounding charges and each electron has different energy level.
- Different energy level with continuous energy variation form energy bands (According to Pauli's principle)
- The energy band formed by a series of energy bands containing valance electrons is valance band.
- At 0 K, electrons start filling energy level in valance band starting from the lowest one.
- The highest energy level, occupied by an electron in the valance band at 0K is called Fermi level.
- The lowest unfilled energy band formed just above valance band is called conduction band.
- Depending on the forbidden energy gap between valance band and conduction band, the solids are classified as conductors, insulators and semiconductors.

**Distinction between Conductors (metals), insulators and semiconductors on the basis of Energy bands**




- **Conductors (Metals) :**

In conductors either conduction and valence band partly overlap each other or the conductionband is partially filled. Forbidden energy gap does not exists ( . This makes a large number of free electrons available for electrical conduction. So the metals have high conductivity.

- **Semiconductors :**

In semiconductors, conduction band is empty and valance band is totally filled. is quite small ( 3 eV). At , electrons are not able to cross this energy gap and semiconductor behaves as an insulator. But at room temperature, some electrons are able to jump to conduction band and semiconductor acquires small conductivity

- **Insulators**

In insulators, conduction band is empty and valance band is totally filled. is very large ( 6 eV). It is not possible to give such large amount of energy to electrons by any means. Hence conduction band remains total empty and the crystal remains as insulator

- **Intrinsic Semiconductor -**

  **1. It is a pure semiconductor**

  **2.** $n_e = n_h$

  **3. Low conductivity at room temperature**

  **4. Its electrical conductivity depends on temperature only.**

**Extrinsic Semiconductor-**

**1.It is a semiconductor with added impurity**

**2.** $n_e \neq n_h$

**3. High conductivity at room temperature**

**4. Its electrical conductivity depends on temperature and the amount of doping.**

- **n-type semiconductor-**

  **1.It is obtained by adding controlled amount of pentavalent impurity to a pure semiconductor**

  **2.** $n_e >> n_h$

  **3. Its electrical conductivity is due to free electrons**

- **p-type semiconductor-**

  **1.It is obtained by adding controlled amount of trivalent impurity to a pure semiconductor**

  **2.** $n_h >> n_e$

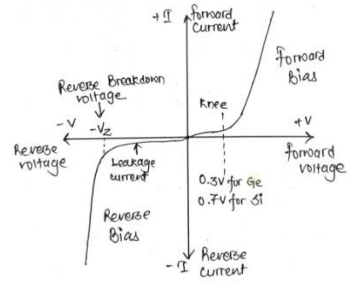
  **3. Its electrical conductivity is due to holes**

- **In semi conductors the total current I is the sum of electron current $I_e$ and holes current $I_h$**

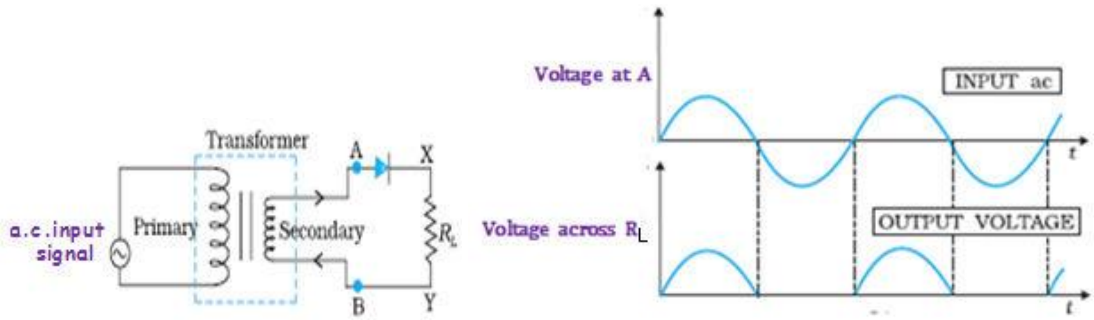
  **I = Ie + Ih**

- **Electrical conductivity** $\sigma = \sigma_e + \sigma_h = n_e \mu_e e + n_h \mu_h e$
- **p-n junction : When a semiconductor crystal is so prepared that, it's one half is p-type and other is n-type, then the contact surface dividing the two halves, is called p-n junction**
- **Due to different concentration gradient of the charge carriers on two sides of the junction, electrons from n-side starts moving towards p-side and holes start moving from p-side to n-side. This process is called Diffusion.**
- **Due to diffusion, positive space charge region is created on the n-side of thejunction and negative space charge region is created on the p-side of the junction. Hencean electric field called Junction field is set up from n-side to p-side which forces the minority charge carriers to cross the junction. This process is called Drift.**
- **Forward biasing :When the positive terminal of external battery is connected to p-side and negative terminal to the n-side, then the p-n junction is said to be forward biased**
- **Reverse biasing :When the positive terminal of external battery is connected to n-side and negative terminal to the p-side, then the p-n junction is said to be reverse biased**

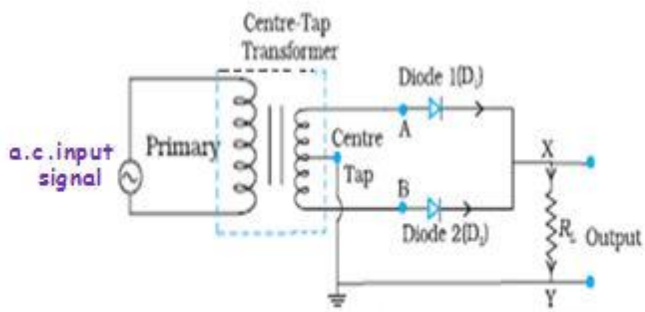
- **V-I characteristics : A graph showing the variation of current through a p-n junction with the voltage applied across it, is called the voltage – current (V-I) characteristics of that p-n junction.**




- **Half wave rectifier :**




- **Full wave rectifier**




-