# VIITJEE ACADEMY

## PHYSICS (SR ) IMPORTANT FORMULAE

1.**a)** Phase difference between two points on a wave = $2\pi/\lambda$ (Path difference)

$\Delta\phi = (2\pi/\lambda)\ \Delta x$

**b)** Time difference is the difference of times taken by the vibrating particle in completing one vibration.

$$\Delta\phi = \frac{2\pi}{T} \times \text{time difference}$$

2.**a)** Wave velocity, $V = n\lambda = \lambda/T = \omega/k$; Wave velocity is constant as it doesnot depend on time.

**b) Particle Velocity:** $V = \omega\sqrt{A^2 - y^2}$ • At y = 0, V is maximum, $V_{max} = \pm\omega A$

• At y = $\pm$A, V is minimum, $V_{min} = 0$ • Particle velocity varies with time.

3. a) ***Reflection from rigid surface:***

• Change in phase is $\pi$; change in time is $\frac{T}{2}$. Change in path is $\frac{\lambda}{2}$.

**b)*Reflection from free end :***

• Change in phase = 0, change in time = 0, change in path = 0.

4.• ***Stationary or Standing Waves***

• Distance between two successive nodes or antinodes is $\lambda/2$

• Distance between a node and an immediate antinode is $\lambda/4$

• Total energy confined in a segment (elastic P.E + K.E) always remains the same.

5. ***Equation of Stationary Wave***:

• If the wave is reflected at free boundary ; Y = 2A Cos kx Sin $\omega$t (where 2 A Cos kx is the amplitude)

• If the wave is reflected at fixed boundary; Y = 2A sin kx Cos $\omega$t (where 2 A Sin kx is the amplitude)

6. Interference of two waves, moving in same direction :

• Resultant amplitude

$$A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}$$

• Resultant intensity $I = I_1 + I_2 + 2\sqrt{I_1I_2}\cos\phi$

**Condition for maximum intensity :**

• Phase difference : $\phi = 2n\pi$, where $n = 0,1,2,3,4....$ $\therefore$ path difference $= n\lambda$

$I_{max} = I_1 + I_2 + 2\sqrt{I_1I_2}$

**Condition for minimum intensity :**

• Phase difference : $\phi = (2n-1)\pi$, where $n = 1,2,3,4...$

$\therefore$ path difference $= (2n-1)\frac{\lambda}{2}$ •

$I_{min} = I_1 + I_2 - 2\sqrt{I_1I_2}$

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

• The phenomenon of interference is based on conservation of energy

7. **VIBRATION OF STRETCHED STRINGS**

• Fundamental frequency

$$n_1 = \left(\frac{1}{2l}\right)\sqrt{\frac{T}{m}} = \left(\frac{1}{2l}\right)\sqrt{\frac{T}{A\rho}} = \left(\frac{1}{2l}\right)\sqrt{\frac{T}{\pi r^2\rho}} = \left(\frac{1}{2lr}\right)\sqrt{\frac{T}{\pi\rho}} = \frac{1}{ld}\sqrt{\frac{T}{\pi\rho}}$$

• The ratio of the frequencies of the various modes of vibration is 1: 2: 3: 4: …….

• The difference in the frequencies of successive overtones is equal to the fundamental frequency.

$$n_2 - n_1 = n_3 - n_2 = n_4 - n_3 = n_1 = \left(\frac{1}{2l}\right)\sqrt{\frac{T}{m}}$$

• I If a wire held at the two ends by rigid supports is just taut at $t_1^0$C then the velocity of the transverse wave at $t_2^0$C is given by

$$V = \sqrt{\frac{T}{m}} = \sqrt{\frac{YA\alpha\Delta t}{A\rho}} = \sqrt{\frac{Y\alpha\Delta t}{\rho}}$$

• A wire of uniform cross–section is fixed at one end and is attached to a load M passing over a pulley at the other end. Velocity of the transverse wave, $V = \sqrt{\frac{Mg}{m}}$

•If the load is submerged in a liquid of density $d_L$ then the velocity of wave is,

$$V_1 = \sqrt{\frac{(Mg - vd_Lg)}{m}} = \sqrt{\frac{Mg(1-\frac{d_L}{d_S})}{m}}$$

8. **Intensity of Wave :-**

• It is the average power transmitted by a wave through the given area. $I = \frac{P_{avg.}}{area}$ ;

$I = 2\pi^2 n^2 A^2 \rho v$

- **Laplace's correction** $\therefore V = \sqrt{\frac{\gamma P}{d}}$

$\therefore V = \sqrt{\frac{rRT}{M}}$

☞ Velocity of sound in a gas is directly proportional to the square root of the absolute temperature

$\frac{V_t}{V_o} = \sqrt{\frac{T}{T_o}} = \left(\frac{t+273}{273}\right)^{1/2}$

$\Rightarrow V_t = V_o\left(1 + \frac{t}{546}\right)$

☞ When temperature rises by $1^o C$ then velocity of sound increases by 0.61 m/s

**9. ORGAN PIPES**

- **open pipe :**
- Frequency $= \frac{V}{\lambda} = \frac{nV}{2l}$, where $n = 1, 2, .....$
- **Closed pipe :**
- Frequency $= \frac{(2n-1)V}{4l}$, where $n = 0, 1, 2, .....$

☞ The end correction (e) depends on the internal radius of the pipe. e=0.6 R=0.3d
Where R is radius of the pipe and d is diameter of the pipe

**Velocity of sound (Resonance column apparatus) :**

- If $l_1$ and $l_2$ are the first and second resonating lengths then $l_1 + e = \frac{\lambda}{4}$ $l_2 + e = \frac{3\lambda}{4}$

$\therefore \frac{\lambda}{2} = l_2 - l_1$

- 1) $\lambda = 2(l_2 - l_1)$ • 2) $V = n\lambda = 2n(l_2 - l_1)$ 3) $e = \frac{l_2 - 3l_1}{2}$

10. **BEATS**

- The time period of one beat (or) the time interval between two successive maxima or minima is $\frac{1}{n_1 \sim n_2}$
- The time interval between a minimum and the immediate maximum is $\frac{1}{2(n_1 \sim n_2)}$
- Frequency of variation of amplitude $= \frac{n_1 - n_2}{2}$
- Frequency of resultant wave $= \frac{n_1 + n_2}{2}$

11.**DOPPLER EFFECT**

- Expressions for apparent frequency ($n_1$) in terms of actual frequency (n) :
  V - Velocity of sound in stationary medium
  $V_0$ - Velocity of Listener
  $V_S$ - Velocity of source of sound

$n_1 = \left(\frac{V \pm V_o}{V \mp V_s}\right) n$

- Listener and source at rest. $n_1 = n$
- Listener moving towards stationary source.

$n_1 = \left(\frac{V + V_o}{V}\right) n$

- Listener moving away from stationary source.

$n_1 = \left(\frac{V - V_o}{V}\right) n$

- Source moving towards listener at rest.

$n_1 = \left(\frac{V}{V - V_s}\right) n$

- Source moving away from listener at rest.

$n_1 = \left(\frac{V}{V + V_s}\right) n$

- Source moving towards listener and listener moving away from source. $n_1 = \left(\frac{V - V_o}{V - V_s}\right) n$
- Source moving away from listener and listener moving towards source.

$n_1 = \left(\frac{V + V_o}{V + V_s}\right) n$

- Source and listener moving towards each other.

$n_1 = \left(\frac{V + V_o}{V - V_s}\right) n$

- Source and listener moving away from each other.

$n_1 = \left(\frac{V - V_o}{V + V_s}\right) n$

- **Consider a source of sound of frequency 'n'Hz is moving rapidly towards a wall with a velocity of $V_s$ m/s.**
  **Case (i): If the observer is in between source and wall.** No.of beats = 0 (As the wall (source) and observer both are at rest)
  **Case (ii): If the source is in between observer**

**and wall** No. of beats = $\frac{2V_s n}{V}$

**Case (iii): If the observer and source are moving together towards a wall** No.of beats = $\frac{2V_s n}{V - V_s}$

☞ When source is in motion and observer is at rest, apparent wavelength of the wave is given by

$\lambda_1 = \lambda\left(\frac{V \pm V_s}{V}\right)$; '+' for source moving away observer '–' for source moving towards observer

☞ When observeris in motion and source is at rest, apparent wavelength of the wave doesn't change

12.☞ Conductivity of conductors decreases and that of semi conductors increase with increase in temperature.

• Semi conductors behave as insulators at absolute zero temperature.

☞ The ratio of free electrons to holes is 1 : 1 and even with increase of temperature the ratio remains same i.e., 1 : 1.

☞ The width and the resistance of junction decreases in forward bias

☞ The width and resistance of the junction increases in reverse bias

☞ in half wave rectifier the ripple frequency is same as that of the input frequency.

☞ In full wave rectifier the ripple frequency is double that of the input frequency.

☞ 1. Avalanche Break Down: At high reverse bias voltages, the minority charge carriers acquire high velocity and diffuse across the depletion layer, breaking down the covalent linkages between different atoms. The free electrons liberated further are responsible for breakage of other covalent bonds. Thus there is an unexpected rise (multiplication) of electrons and hence current. This high current produces heat and the device is damaged. It takes place in a lightly doped diode.

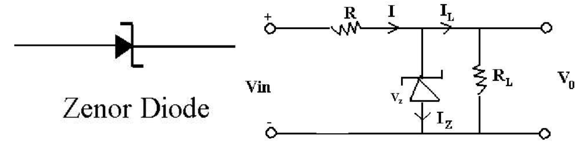
☞13 . Zener Break Down: Even at low high reverse bias voltages, there is the direct breakage of covalent bonds due to very strong electric field which gives rise to unexpected increase in electron number, current value and hence heat energy. It take place in a heavily doped diode.

☞ Zener diodes are used for voltage regulation.

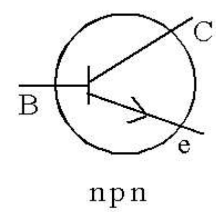
ii) Zener diode is used as a voltage regulator. It's circuit diagram is

1) $I = I_Z + I_L$ 2) $V_{in} = IR + V_Z$

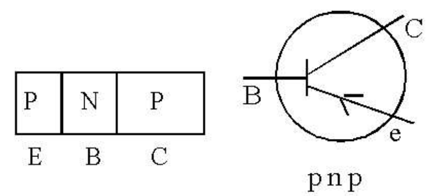
3) $V_0 = V_Z = I_L \times R_L$




14. **In an n-p-n Transistor:**




● **In a p-n-p Transistor:**




● The emitter curret ($I_E$) is the sum of base curret ($I_B$) and collector current ($I_C$), $I_E = I_B + I_C$

● Current amplification factor of common base configuration $\alpha = \left(\frac{\Delta I_C}{\Delta I_E}\right)_{\text{constant } V_{CB}}$

● Current amplification factor of common emitter configuration $\beta = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{\text{constant } V_{CE}}$.

● Values of $\alpha$ range from 0.95 to 0.99. ● Values of $\beta$ range from 20 to 500.

● $\alpha$ and $\beta$ of a transistor is related as $\beta = \frac{\alpha}{1-\alpha}$ ; $\alpha = \frac{\beta}{1+\beta}$

● Input resistance of transistor in CE configuration is $R_{in} = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$

● Output resistance of transistor in CE configuration is $R_{out} = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$

● Voltage gain = current gain x resistance gain.

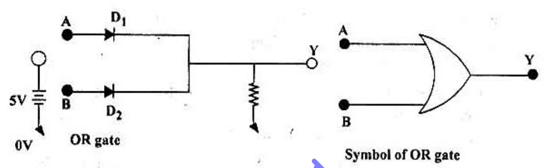
- Power gain = $\left(\frac{\Delta I_C}{\Delta I_B}\right)^2 \times \frac{R_{out}}{R_{in}} = \beta^2 \times$ resistance gain.

@ In a common -base amplifier, the phase difference between the input signal voltage and output voltage is 0

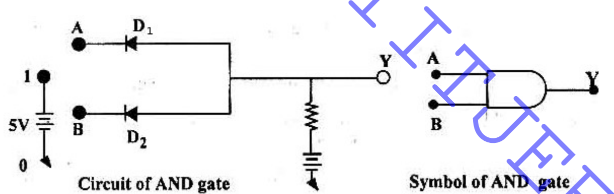
@ In a common -emitter amplifier, the phase difference between the input signal voltage and output voltage is $\pi$

**15. LOGIC GATES :**

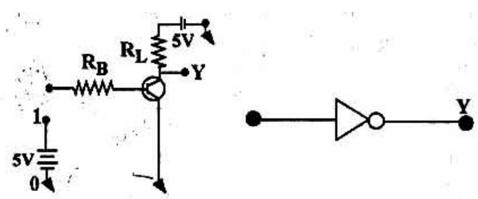
**OR gate**




**AND gate**




**NOT gate**




**16.MOTION OF A CHARGED PARTICLE IN A UNIFORM MAGNETIC FIELD:**

- Force acting on a charged particle in a uniform magnetic field of induction B is F = Bq $v$ sin$\theta$.
- If the charged particle enters into the magnetic field parallel to the direction of the magnetic field it follows a straight line path with no change in its velocity as F = 0. ($\because$ $\theta$ = 0°)
- If the charged particle enters normally into the magnetic field, the force F = Bq $v$ and its direction is perpendicular to both the directions of the velocity of the charged particle and the magnetic field as given by Fleming's left hand rule. Hence the charged particle follows a circular path of radius r for which the necessary centripetal force $\frac{mv^2}{r}$ is given by the magnetic force Bq $v$. Hence radius of the circular path $r = \frac{mv}{Bq}$
- The ratio of the radii of the charged particles that enter into the same magnetic field with the same velocity is $\frac{r_1}{r_2} = \left(\frac{m_1}{m_2}\right)\left(\frac{q_2}{q_1}\right)$

  Ratio of the deflections is $\frac{r_2}{r_1}$ as deflection is proportional to $\frac{1}{r}$
- The radius of the circular path in terms of momentum is r = $\frac{p}{Bq}$.

  The ratio of the radii of two charged particles entering into the same magnetic field with the same momentum is $\frac{r_1}{r_2} = \frac{q_2}{q_1}$
- The radius of the circular path in terms of K.E. is r = $\sqrt{2m \times K.E.}/Bq$

  The ratio of the radii of two charged particles entering into the same magnetic field with the same K.E. is $\frac{r_1}{r_2} = \sqrt{\frac{m_1}{m_2} \times \frac{q_2}{q_1}}$.
- The angular velocity of the charged particle in the circular path is $\omega = \frac{v}{r} = \frac{Bq}{m}$.
- The time period of revolution of the charged particle in the circular path is T= $\frac{2\pi}{\omega} = \frac{2\pi m}{Bq}$.

  It is independent of velocity and radius.

  The frequency of revolution of the charged particle in the circular path is n= $\frac{1}{T} = \frac{Bq}{2\pi m}$.
- If a charged particle enters into a magnetic field at any angle other than 0°, 90° and 180°, the charged particle follows a helical path.

**17.PHOTOELECTRIC EFFECT :**

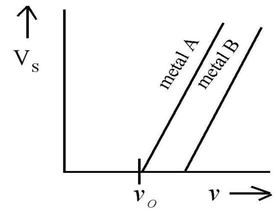
- The energy of each photon E = h $\nu$ = $\frac{hc}{\lambda}$ where $\nu$ is frequency and $\lambda$ is wavelength of light.
- The momentum of a photon

$p = mc = \frac{h\nu}{c^2} \times c = \frac{h\nu}{c} = \frac{h}{\lambda}$

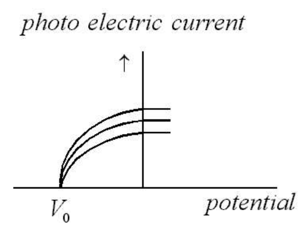
- The number of photons n emitted by a source of monochromatic radiation of frequency $\nu$ and power P in t seconds is $P = \left(\frac{n}{t}\right)h\nu$, where $\frac{n}{t}$ is the number of photons emitted per second.
- Energy of a photon in electron volt can be found by using the formula $E\ (in\ eV) \approx \frac{12400}{\lambda\ (in\ A^o)}$
- As the electrons are to be liberated from a metal the minimum energy w, required is obtained by substituting $K.E_{max}$=0 and the minimum frequency of radiation required to liberate it as $\nu = \nu_o$ called threshold frequency in $K.E_{max} = h\nu - w$

$0 = h\nu_o - w$, $\quad w = h\nu_o = \frac{hc}{\lambda_0}$ $\quad w\ (in\ eV) \approx \frac{12400}{\lambda\ (in\ A^o)}$

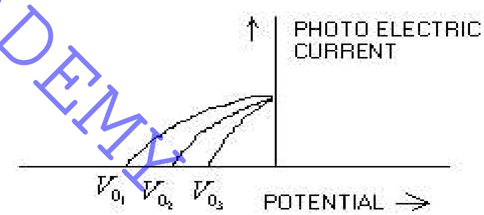
- Einstein's photoelectric equation in terms of $\lambda$ and $\lambda_0$: $K.E_{max} = h\nu - w = h\nu - h\nu_0 = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$
- For a given metal surface, if the light of frequency $\geq \nu_0$ is incident, the number of photoelectrons liberated per second or photoelectric current increases with the intensity of incident light.
- The photoelectric current does not depend upon the frequency of the incident light provided $\nu \geq \nu_0$.
- Work done to stop the electrons = $V_s e = K.E_{max}$ (by work-energy theorem)
$V_s e = h\nu - h\nu_0$ (by Einstein's photoelectric equation)
$V_s = \left(\frac{h}{e}\right)\nu - \left(\frac{h\nu_0}{e}\right)$
- A graph plotted between $V_s$ and $\nu$ is to be a straight line.
- Slope of the straight line = $\frac{h}{e}$
- Its X - intercept = $\nu_0$
- Its Y - intercept = $-\left(\frac{h\nu_0}{e}\right) = -\left(\frac{w}{e}\right)$.
- Graphs between $V_s$ and $\nu$ for two different metal blocks will be parallel as the slopes are same.




- The graph shows photoelectric current as a function of p.d. for light of different intensities $I_1$, $I_2$, $I_3$. We observe that $V_o$ remains the same when the frequency ($\upsilon$) of incident light is same for a given metal and it is independent of incident intensity. But photo electric current is directly proportional to intensity




- Different sources, having same intensity but of different wavelengths correspond to different values of stopping potentials $V_{0_1}, V_{0_2}, V_{0_3}$ for a given metal. It can be seen that $V_{0_1} > V_{0_2} > V_{0_3}$ if $\lambda_1 < \lambda_2 < \lambda_3$




## 18.de-Broglie Waves (or) Matter waves

☞ If m is the mass and V the velocity of the material particle, then p=mV

$$\lambda = \frac{h}{m\upsilon}$$

☞ If E is the kinetic energy of the material particle then

$$E = \frac{1}{2}m\upsilon^2 = \frac{p^2}{2m}, p = \sqrt{2mE} \quad \text{or}$$

Therefore ,the deBroglie wavelength is given by

$$\lambda = \frac{h}{\sqrt{2mE}}$$

- If a charged particle carrying charge q is accelerated through a potential difference of V volt,then Kinetic energy KE=qV In that case

  , $\lambda = \dfrac{h}{\sqrt{2mqV}}$

- When the material particles like neutrons are in thremal equilibrium at absolute temperature T, then they posseses Maxwellian distribution of velocities and so their average kinetic energy is given by

$$\lambda = \frac{h}{\sqrt{3mkT}}$$

- **de-Broglie wavelength associated with charged particles :-**

  (1) For electrons

  $(m_e = 9.1\times 10^{-31}\,kg)$ $\lambda = \dfrac{h}{\sqrt{2mqV}}$

  $= \dfrac{12.27}{\sqrt{V}}\overset{0}{A}$

- **de-Broglie wavelength associated with uncharged particles :**

  (1) For neutrons

  $(m_n = 1.67\times 10^{-27}\,kg)$ ,

  $$\lambda = \frac{h}{\sqrt{2mE}} = \frac{6.62\times 10^{-34}}{\sqrt{2\times 1.67\times 10^{-27}E}} = \frac{0.286}{\sqrt{E(eV)}}\overset{0}{A}$$

- For gas molecules $\lambda = \dfrac{h}{m\times C_{rms}}$ $\Rightarrow$ For gas molecules at Tk $E = \dfrac{3}{2}kT$

  $\therefore \lambda = \dfrac{h}{\sqrt{3mkT}}$

- **Davison and Germer Experiment :-**
- The wave nature of electrons was first experimentally verified by it .
- Here Nickel was taken as example. It was found that high intensity of electrons were identified at

  $\phi = 50^0$ & $V_0 = 54V$;

**19.Rutherford's $\alpha$ -ray scattering:-**

- Distance of closest approach between a bombarding particle and target scatterer of like charge occurs for a head -on-collision.The particle turns around and scatters backward at $180^0$.At that instant the entire kinetic energy (K) has been converted into coulomb potential energy.

  we solve this equation to determine $r_{min}$

  $$K = \frac{(Z_1e)(Z_2e)}{4\pi\varepsilon_0 r} \quad .....(7)$$

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

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

**Spectral series of Hydrogen Atom**

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n^2_1} - \frac{1}{n_2^2}\right):$$

**20.SIZE OF THE NUCLEUS:**

- Radius of the nucleus depends on number of nucleons. $R = R_0 A^{1/3}$ Value of $R_o$ = 1.1 x $10^{-15}$m

**21.DENSITY OF THE NUCLEUS:**

- Density of nucleus is independent of mass number of the atom.
- Density of the nucleus is 2.97 x $10^{17}$ $Kgm^{-3}$.

**EINSTEIN'S MASS ENERGY RELATION**

- When matter is completely annihilated, energy released is $E = mc^2$
- **MASS DEFECT:**

  $\Delta m = \left[\left[ZM_p + (A-Z)M_n\right] - M_{nucleus}\right]$ Z = Atomic number $M_p$ = Mass of proton $M_n$ = Mass of neutron A = Mass number $M_{nucleus}$ = Mass of nucleus.

- **BINDING ENERGY:** The energy required to bring the nucleons from infinity to form the nucleus is called binding energy. It is energy equivalent of mass defect BE= [$\Delta$ m]$C^2$

  NOTE: BE = mass defect x 931.5 MeV if mass is expressed in a.m.u.

  Binding Energy per nucleon : The ratio of the binding energy of a nucleus to its mass number is called binding energy per nucleon. It is also called binding fraction.

  $$B.E.\ per\ nucleon = \frac{Binding\ Energy}{Mass\ Number}$$

**22.RADIOACTIVITY**

- a) $\alpha$ particle is the nucleus of helium atom

  b) $\alpha$ particle is a combination of two protons and two neutrons.

  c) $\alpha$ particle carries 4 units of mass and 2 units of positive charge.

- Rate of disintegration is proportional to the number of radio active atoms present in the element,

$$\frac{dN}{dt} = -\lambda N$$

- The exponential equation for radio active decay phenomenon is $N = N_0 e^{-\lambda t}$

- For any radio active substance

a) $t_{1/2} = \frac{0.693}{\lambda}$ b )

$t_{1/2} = \frac{2.30 \times \log 2}{\lambda}$ c )

$t = \frac{t_{1/2}}{\log 2} \times \log \frac{N_0}{N}$

d) $t_{1/2} = 0.693 \times \tau$ (Where $\tau$ is Average life) e )

$t = 3.32 \times t_{1/2} \times \log \frac{N_0}{N}$

- The average life of the radio active substance is proved to be equal to the reciprocal value of decay constant.

a) $\tau = \frac{1}{\lambda}$ b) $\tau = \frac{t_{1/2}}{0.693}$ c )

$\tau = 1.44 \times t_{1/2}$

- The number of half lives in the decay time 't' is given by $n = \frac{t}{t_{1/2}}$

- The ratio $\left(\frac{N_0}{N}\right)$ is equal to $\left(\frac{W_0}{W}\right)$

- For any radio active substance
1) Activity = rate of disintegration 2) Activity = $\lambda N$ 3) $Activity = \frac{0.693 \times N}{t_{1/2}}$

- Units for activity
Curie, millicurie, micro curie, Rutherford, Becquerel
1 Ci = $3.7 \times 10^{10}\ d.p.s$ 1 mCi = $3.7 \times 10^{7}\ d.p.s$ 1 $\mu Ci = 3.7 \times 10^{4}\ d.p.s$
1 Rd = $10^6$ d.p.s 1 Bq = 1 d.p.s

- The Curie is defined as the activity of one gram of radium in which $3.7 \times 10^{10}$ atoms disintegrate per second.

**23. NUCLEAR FORCES**

- The Nuclear Forces are of Four Typess
1) Attractive Forces 2) Repulsive Forces
3) Coulomb Forces 4) Tensor Forces
- Short range: They will act upto nearly one fermi. Beyond that they become negligible.
- Charge independent : $F_{pp} = F_{pn} = F_{nn}$

**NEUTRON**

- Neutron is unstable outside the nucleus.

$${}_0n^1 \rightarrow {}_1H^1 + {}_{-1}e^0 + \bar{\nu}$$ (anti neutrino)

- Thermal neutrons have an average energy of nearly 0.025 eV. Fast moving neutrons have an average energy of 2 MeV.
- MODERATOR:
  - The function of a moderator is to slow down the fast moving neutrons to increase the rate of fission.
  - The commonly used moderators in the order of efficiency are
  (i) Heavy water , (ii) graphite,
  (iii) Berillium and Berillium Oxide
  - A good moderator should have
  (1) low atomic mass
  (2) poor absorption of neutrons
  (3) good scattering property.
  (4) The size of moderator atom should be nearly of same size as that of the size of a prompt neutron.
- CONTROL RODS:
  - The function of a control rod is to absorb (capture) the neutrons.
  - Cadmium, Boron and steel rods are used as control rods in a nuclear reactor.

26. POWER OF A NUCLEAR REACTOR

- The output power of a nuclear reactor is given by
P = nE
n = No. of fissions taking place in 1 sec.
E = Energy released per fission
- If "x" grams of a nuclear fuel of mass number 'A' undergo fission in a time of 't' sec. 'E' is energy released per fission, then the power output of the nuclear reactor is given by

$P = \frac{NEx}{At}$ where N - Avagadro number

- At temperatures of about $10^7$K, light nuclei combine to give heavier nuclei. Hence, fusion reactions are called thermo nuclear reactions.
- Nuclear fusion takes place in the sun and other stars.
- Energy produced in a single fission of ${}_{92}U^{235}$ is larger than that in a single fusion of Hydrogen into Helium.
- But fusion produces more energy than fission per nucleon.
- In fission, 0.09% of mass is converted into energy. In fusion 0.66% of mass is converted into energy.

- Hydrogen bomb is a fission – fusion bomb.

STELLAR AND SOLAR ENERGY:

- Stellar and solar energy is due to fusion.

**27. AVERAGE VALUE OF A.C. < I >**

- For one complete cycle < I > = 0 •For half cycle

$$< I > = \frac{2I_0}{\pi} = 0.636I_0$$

- **R.M.S. VALUE OF A.C. ($I_{rms}$)**

It is equal to that direct current which produces same heating in a resistance as is produced by the A.C. in same resistance during same time.

$$I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707I_0 = 70.7\% \text{ of } I_0$$

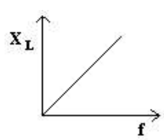
- **REACTANCE (X)**
  - **INDUCTIVE REACTANCE ($X_L$)**

•It is the part of impedance in which A.V. leads the A.C. by a phase angle of $\frac{\pi}{2}$.

•Its value is $X_L = \omega L = 2\pi fL$.

•It bypasses D.C. but offers finite impedance to the flow of A.C.

• $X_L$ - f curve.

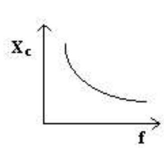



- **CAPACITIVE REACTANCE ($X_C$)**
- It is that part of impedance in which A.C. leads the A.V. by a phase angle of $\frac{\pi}{2}$.

•Its value is $X_c = \frac{1}{\omega C} = \frac{1}{2\pi fC}$.

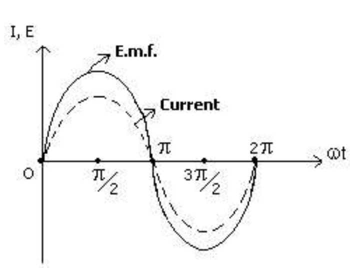
•It bypasses A.C. but blocks D.C.

•$X_C$ - f curve

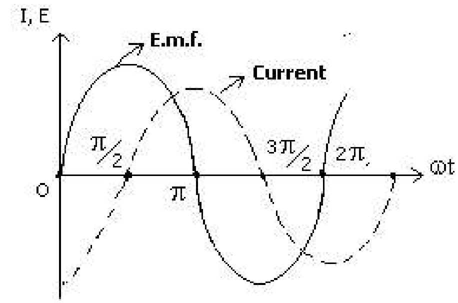



**8 PHASOR DIAGRAMS:**

**A.C THROUGH A RESISTOR**



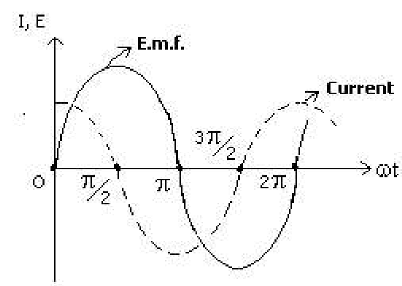

∴ Peak value of current $I_0 = \frac{E_0}{\omega L}$




• Inductive reactance in terms of RMS value is

$$X_L = \omega L = \frac{E_{rms}}{I_{rms}}$$

**A.C THROUGH A CAPACITOR**




• Capacitive Reactance : Capacitance not only causes the voltage to lag behind the current but it also limits the magnitude of current in the circuit

$$I_0 = \frac{E_0}{\left(\frac{1}{\omega C}\right)} \Rightarrow X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC} = \frac{E_0}{I_0} = \frac{E_{rms}}{I_{rms}}$$

**29.A.C THROUGH LCR SERIES CIRCUIT**

☞ the peak value of current, ,

$$I_0 = \frac{E_0}{\sqrt{R^2 + (X_L - X_C)^2}}$$

☞ where $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$ is capacitive reactance

& $X_L = \omega L = 2\pi fL$ is inductive reactance.

☞ The alternating current in the circuit may lead or lag or may be in phase with emf depending on the value of $\phi$

☞ If $X_L > X_C$ then $\phi$ is +ve. In this case the A.C. lags behind the emf by a phase angle

$$\phi = Tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

☞ If $X_L < X_C$ then $\phi$ is -ve. In this case the A.C leads the emf by a phase angle $\phi = \mathrm{Tan}^{-1}\left(\frac{X_L - X_C}{R}\right)$

☞ If $X_L = X_C$ then $\phi$ is 0. In this case the A.C and emf are in phase.

☞ $$I_0 = \frac{E_0}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$\Rightarrow Z = \sqrt{R^2 + (X_L - X_C)^2} = \frac{E_0}{I_0}$$

☞ Impedance, $Z = \sqrt{R^2 + (X_L - X_C)^2}$

$$= \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} = \sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$$

☞ Impedance interms of RMS values

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \frac{E_{rms}}{I_{rms}}$$

☞ If $X_L > X_C$, then the circuit will be inductive

☞ If $X_L < X_C$, then the circuit will be capacitive

☞ If $X_L = X_C$, then the circuit will be purely resistive.

☞ The LCR circuit can be inductive or capacitive or purely resistive depending on the value of frequency of alternating source of emf.

**30. RESONANCE :**

☞ Resonance in series LCR circuit :

☞ At certain frequency called resonant frequency $f_r, X_L = X_C$ (inductive reactance exactly cancels capacitive reactance ) and resonance will occur. This is called series Resonance.

☞ When series resonance occurs, the LCR series circuit is purely resistive in nature

☞ Expression for resonant frequency At resonance $X_L = X_C$

$$2\pi f_r L = \frac{1}{2\pi f_r C} \Rightarrow f_r = \frac{1}{2\pi\sqrt{LC}}$$

This frequency is also called natural frequency of circuit

☞ At resonance, impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$ becomes $Z = R$. i.e., impedance is minimum

☞ At resonance, current in the circuit $I_{rms} = \frac{E_{rms}}{\sqrt{R^2 + (X_L - X_C)^2}}$ become $I_{rms} = \frac{E_{rms}}{R}$ i.e., current is maximum.

☞ At resonance, phase angle $\phi = \mathrm{Tan}^{-1}\left(\frac{X_L - X_C}{R}\right)$ becomes $\phi = 0$ i.e., the alternating current and emf are in phase.

30. **Quality Factor (Q-factor) of Resonance Circuit**

$$Q = \frac{2\pi \times \text{energy stored in the circuit percycle}}{\text{energy dissipated per cycle}}$$

$$Q = \frac{\omega_0 L}{R} \quad Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

**31.Power consumed in a series LCR circuit**

$$P = E_{rms} I_{rms} \cos\phi$$

The quantity $\cos\phi$ is called the power factor.

Here P is called **True power (P)** and $I_{rms}E_{rms}$ is called appearent power or virtual power.

☞ In a pure resistive circuit true power = appearent power.

☞ In a pure inductive circuit P = $E_{rms}I_{rms}\cos\left(\frac{\pi}{2}\right) = 0$

Thus, no power loss takes place in a circuit having inductor only.

☞ In a pure capacitive circuit P = $E_{rms}I_{rms}\cos\left(\frac{\pi}{2}\right) = 0$

Thus, no power loss takes place in a circuit having capacitor only.

☞ For RC circuit, $\cos\phi = \frac{R}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$ ☞

For LR circuit, $\cos\phi = \frac{R}{\sqrt{R^2 + \omega^2 L^2}}$

For LCR circuit,

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

☞ **Wattless Current** is that component of the circuit current due to which the power consumed in the circuit is zero.

☞ **Wattful current** is that component of the circuit current due to which the power is consumed in the circuit

**32.AMPERE'S LAW**

- The line integral of the magnetic induction over a closed loop is equal to $\mu_0$ times the current (i) passing through the area bounded by the loop.

$$\oint B.dl = \mu_0 i$$

**33.BIOT - SAVART'S LAW AND APPLICATION**

- In vector form, $\overline{dB} = \frac{\mu_0}{4\pi} \frac{i\overline{dl} x \overline{r}}{r^3}$
- Magnetic Induction on the axis of a circular current carrying coil is : B = $\frac{\mu_0 n i r^2}{2\left(r^2 + x^2\right)^{\frac{3}{2}}}$

where n is the number of turns, 'r' is the radius of the coil and 'x' is the distance of the point from the centre of the coil.

The magnetic induction at the centre of circular current carrying arc, subtending angle $\theta$ at center is $B = \frac{\mu_0 i}{4\pi r}(\theta)$ where '$\theta$' is in radians

- 1) If $\theta = \pi$, that is for semi circle B = $\frac{\mu_0 n i}{4r}$

2) If $\theta = 2\pi$ that is for a circle B = $\frac{\mu_0 n i}{2r}$

- The magnetic moment of a circular coil of area 'A' carrying a current 'i' and having 'n' turns is, M = n i A
- Magnetic dipole moment of a revolving electron

(M) = $\frac{evr}{2}$

- An electron (Charge 'e') revolving around the nucleus in an orbit with a speed 'V' then the magnetic field induction at it's centre is

B = $\frac{\mu_0 V e}{4\pi r^2}$

☞ A long solenoid carrying a current acts like a bar magnet, B = $\mu_0 n i$ along the axis of the solenoid where, n is the number of turns per meter.

At the ends of long solenoid, $B = \frac{1}{2}\mu_0 n i$

**34.FIELD DUE TO A STRAIGHT CONDUCTOR•**

B = $\frac{\mu_0 i}{2\pi r}$

where 'i' is the current through the conductor and 'r' is the perpendicular distance of the point from the conductor.

- If the point P lies along the axis of the conductor then B = 0
- If the point P lies at a perpendicular distance r from one end of an infinitely long conductor then magnetic induction at P is.

B = $\frac{\mu_0 i}{4\pi r}$

Similarly for conductor of finite length perpendicular to one end, $B = \frac{\mu_0 i}{4\pi r}\sin\theta$

**FORCE EXPERIENCED BY A CURRENT CARRYING CONDUCTOR PLACED IN A MAGNETIC FIELD**

- If the length makes an angle $\theta$ with the field then,

F = BiL Sin$\theta$ or $\overline{F} = i\left(\overline{L} X \overline{B}\right)$

- Force experienced per unit length of each conductor is,f = $\frac{F}{l}$ = $\frac{\mu_0 i_1 i_2}{2\pi r}$
- If the currents in the parallel conductors are in the same direction then they attract each other. If the currents are in opposite direction then they repel each other.
- If two straight parallel current carrying conductors with currents $i_1, i_2 \left(i_2 > i_1\right)$ are separated by a distance 'd' then distance of null point from conductor $i_1$ is $x = \frac{d}{\left(\frac{i_2}{i_1}\right) \pm 1}$ $+ve$ for the currents in the same direction.

$-ve$ for the currents in the opposite direction.

**35.TORQUE ON A CURRENT CARRYING COIL IN A UNIFORM MAGNETIC FIELD**

- If the normal drawn to the plane of the coil makes an angle '$\varphi$' with the direction of the magnetic field then.

$\tau$ = n I AB sin φ    In vector form $\bar{\tau}$ = n I

$(\bar{A}x\bar{B})$ = $\bar{M}x\bar{B}$

- If the normal drawn to the plane of the coil makes an angle 'φ' with the direction of the magnetic field then.

  $\tau$ = n I AB sin φ

  In vector form $\bar{\tau}$ = n I $(\bar{A}x\bar{B})$ = $\bar{M}x\bar{B}$
- The horse - shoe type of magnet provides the radial field with the help of cylindrical poles and soft iron cylinder
- The current through the MCG, I = $\left(\frac{C}{nBA}\right)\theta$ = K$\theta$

  where 'K' is called as galvanometer constant and 'C' is the couple per unit twist of the suspension fibre.
- Current sensitivity of the galvanometer =

  θ/I = (nBA)/C

  The Current sensitivity can be increased by,

  a) increasing the number of turns

  b) increasing the area of the coil   c) increasing 'B'   d) decreasing 'C'
- Voltage sensitivity of the galvanometer,

  = θ/V = (nBA)/CG

  where G is the resistance of the galvanometer

36.**AMMETER**

- A galvanometer is converted into an ammeter by connecting a low resistance in parallel called shunt resistance.
- Shunt resistance,   S = $\frac{I_g G}{I - I_g}$

  where $I_g$ is the full scale deflection current of the galvanometer, I is the maximum current to be read on the ammeter.
- In electrical circuits, an ammeter is always connected in series.
- When increasing the range of an ammeter,

  S = $\left(\frac{G}{n-1}\right)$   where n = new range / old range
- Effective resistance of the circuit is, $\frac{GS}{G+S}$

**VOLTMETER**

- A galvanometer is converted into a Voltmeter by connecting a high resistance in series to it.
- The resistance 'R' that should be connected to galvanometer in order to convert it into a voltmeter is,

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

  where 'V' is the maximum Voltage to be read with the converted Voltmeter.
- To change the range, R= (n-1) G where, n = new range / old range
- Resistance of Voltmeter is (G + R)
- The internal resistance of a Voltmeter is high. An Ideal Voltmeter should have infinite resistance.

37. The total magnetic flux *linked* with the coil is the flux linked with each turn multiplied by the number of turns. Thus, $\phi$ = BAncos $\theta$

- The unit of magnetic flux is weber (Wb). Magnetic flux is a scalar.
- LENZ'S LAW: The induced emf and induced current are always in such a direction as to oppose the change that produces them. This is nothing but a consequence of the law of conservation of energy.
- From Faraday's law $e = \frac{-d\phi}{dt}$
- The total magnetic flux through a coil is directly proportional to the current that passes through it. i.e, $\phi$ = Li where L is a constant of proportionality known as the coefficient of self induction or simply self inductance.
- $e = -L\left(\frac{di}{dt}\right)$

***38.Energy density in magnetic field :***

$U = \frac{1}{2}Li^2$   where V is the volume enclosed by the solenoid   ∴ Energy density

$= \frac{U}{V} = \frac{B^2}{2\mu_0}$

- MUTUAL INDUCTANCE: The total flux linked to the secondary is directly proportional to the current in the primary. $\phi_s$ = M $i_p$, where "M" is a constant of proportionality known as the coefficient of mutual induction

$$\frac{d\phi_s}{dt} = -M\frac{d}{dt}(i_p)$$

$$\therefore e_s = -M\frac{di_p}{dt}$$

☞ ***Self and mutual inductance of a solenoid***

Solenoid is an assembly of large number of turus wound over a cylinderical core. If l is the length, A-the cross-sectional area and N-the total number of turns in a solenoid, then $L = \frac{\mu_0 N^2 A}{l}$

☞ In case of a pair of coils (shown in the figure) of total turns $N_P$ and $N_s$ respectively, the coefficient of mutual inductance M is given by

$M = \mu_0 n_p N_s A$ where $n_p = \frac{N_p}{l}$ is the number of turns per metre length in primary coil.

☞ ***Coefficient of magnetic coupling***

Two coils are said to be magnetically coupled if full or part of the magnetic flux produced by one coil links into the another coil. If $L_1$ *and* $L_2$ are the self inductances of the coils and M is their mutual inductance, then the coefficient of coupling 'k' is given by $M = \sqrt{L_1 L_2}$

**39.TRANSFORMER**

- A transformer works on the principle of mutual induction.
- The primary is connected to an alternating source of emf, by mutual induction, an emf is induced in the secondary.
- VOLTAGE RATIO: If $V_1$ and $V_2$ are the primary and secondary voltage in a transformer, $N_1$ and $N_2$ are the number of turns in the primary and secondary coils of the transformer, then $\frac{V_1}{V_2} = \frac{N_1}{N_2}$.
- CURRENT RATIO: If the primary and secondary currents are $I_1$ and $I_2$ respectively, then for ideal transformer $\frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{N_2}{N_1}$
- IDEAL TRANSFORMER: In an ideal transformer the input power is equal to the output power. $V_1 I_1 = V_2 I_2$
  The efficiency of an ideal transformer is 100%.
- LOSSES IN A TRANSFORMER: The losses in a transformer are divided in to two types. They are *copper losses* and *iron losses*.
- The loss of energy that occurs in the copper coils of the transformer (i.e. primary and secondary coils) is called 'copper losses'. These are nothing but joule heating losses where electrical energy is converted in to heat energy.
  The loss of energy that occurs in the iron core of the transformer (i.e. hysteresis loss and eddy current loss) is called 'iron losses'.
- MINIMIZING THE LOSSES IN A TRANSFORMER: The core of a transformer is laminated and each lamination is coated with a paint of insulation to reduce the 'eddy current' losses.
  By choosing a material with narrow 'hysteresis loop' for the core, the hysteresis losses are minimized.

40. When two magnets are placed at an angle θ with each other and with like pole together, the resultant magnetic moment is $\sqrt{M_1^2 + M_2^2 + 2M_1M_2\cos\theta}$

- When two magnets are placed at an angle θ with each other and with unlike pole together, the resultant magnetic moment is $\sqrt{M_1^2 + M_2^2 - 2M_1M_2\cos\theta}$
- A bar magnet of moment M is bent is an arc so that angle at the center of the arc is θ, then the new magnetic moment is $\frac{2M\sin(\theta/2)}{(\theta)}$ (θ is in radians)
- A bar magnet of moment M is bent into a semi circular arc. Then the new magnetic moment is $\frac{2M}{\pi}$.

41. If two poles $m_1$, $m_2$ ($m_2 > m_1$) are separated by a distance d, then distance of neutral point from smaller pole is

$x = \frac{d}{\sqrt{\frac{m_2}{m_1}} \pm 1}$, where $m_2 > m_1$ + used for like poles
- for unlike poles

- For like poles neutral point is in between the poles and for unlike poles neutral point is outside.
- The mutual forces of attraction (or) repulsion acting on the two poles separated by a certain distance forms an action reaction pair and the ratio of the magnitudes of these two forces is 1 : 1.
- The relation between B and H is $B_0 = \mu_0 H$ in vacuum and B = μ H in a material medium Where μ is the absolute permeability of the medium

**42.COUPLE ACTING ON THE BAR MAGNET (OR)TORQUE ON A MAGNETIC DIPOLE**

- C = m 2l B sinθ ( or) C = M B sinθ
  Where θ is the angle between magnetic moment and magnetic field. In vector notation $\vec{C} = \vec{M} \times \vec{B}$

**Work done in rotating a magnetic dipole in a magnetic field**

- The work done in deflecting a magnet from angular position $\theta_1$ to an angular position $\theta_2$ with the field is given by $W = \Delta U$ (change in PE) (or) $W = MB\left(\cos\theta_1 - \cos\theta_2\right)$
- When a bar magnet is held at an angle $\theta$ with the magnetic field, the potential energy possessed by the magnet is U = - M B cos $\theta$
- When the bar magnet is parallel to the applied field, then $\theta = 0^0$ and potential energy is - MB.
- When the bar magnet is perpendicular to the applied field, then $\theta = 90^0$ and potential energy is zero
- When the bar magnet is anti-parallel to the applied field, then $\theta = 180^0$ and potential energy is maximum i.e. U = +MB
- Two magnets of magnetic moments $M_1$ and $M_2$ are joined in the form of a cross and this arrangement is pivoted so that it is free to rotate in a horizontal plane under the influence of earth's magnetic field If $\theta$ is the angle made by the magnetic meridian with $M_1$ then

$$\tan\theta = \frac{M_2}{M_1}$$

43.**FIELD OF A BAR MAGNET**

- The magnetic induction at a point on the axial line is B = $\left(\frac{\mu_0}{4\pi}\right)\frac{2Md}{\left(d^2-l^2\right)^2}\left(S \longrightarrow N\right)$ For a short bar magnet

i.e. $l <<<< d$ then B = $\left(\frac{\mu_0}{4\pi}\right)\frac{2M}{d^3}$

- The direction of magnetic induction on the axial line is along $\overrightarrow{SN}$ from south to north.
- The magnetic induction at a point on the equatorial line at a distance d from the centre is $B = \frac{\mu_0}{4\pi}\frac{M}{(d^2+l^2)^{3/2}}$ for a short bar magnet $l <<<< d$ then B = $\left(\frac{\mu_0}{4\pi}\right)\frac{M}{d^3}$
- The direction of magnetic induction on the equatorial line is along from north to south pole
- The deflecting couple acting on the magnet is $I\alpha$
- Restoring torque developed by earth's magnetic induction is $MB_H$ sin$\theta$.
- $I\alpha = \overline{M}B_H \sin\theta$ ($\theta$ is the angular displacement)
- Time period T = $2\pi\sqrt{\frac{\theta}{\alpha}}$
- A freely suspended bar magnet experiences a torque and executes angular S.H.M. Time period of oscillation is T = $2\pi\sqrt{\frac{I}{MB_H}}$

where $I$ moment of inertia, M magnetic moment and $B_H$ Horizontal component of earth magnetic

**44.Magnetic Susceptibility:** It isthe ratio of intensity of magnetization to the intensity of magnetizing field. $x_m = \frac{I}{H}$

- $x_m$ represents the ease with which a material can be magnetised.
- Soft iron has greater susceptibility than steel.
- Relation between magnetic perme ability and magnetic susceptibility.

$$B = \left(I + H\right)\mu_0$$

$$\mu = \left(\chi_m + 1\right)\mu_0 \qquad \mu_r = \chi_m + 1$$

☞ **Curie's Law:** It states that intensity of magnetization is directly proportional to the magnetic induction (B) and inversely proportional to the absolute temperature

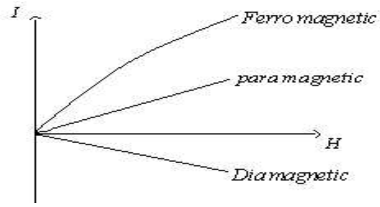
$I = \frac{CB}{T}$ Where C- Curie constant

☞ **Curie-Weiss Law:** Susceptibility $\chi_m \alpha \frac{1}{T-\theta}$

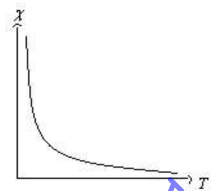
Where $\theta$ is called Curie temperature

☞ **Properties of soft iron and steel:** For soft iron, the susceptibility, permeability and retentivity are greater while coercivity and hysteresis loss per cycle are smaller than those of steel.

- I-H, curve for different materials




• Curve for magnetic susceptibility and temperature for a paramagnetic and ferromagneric material. $\chi \alpha \frac{1}{T}$




**45.If a point charge 'q' is moving in a circle of radius 'r' with speed 'v' and constant frequency 'f' then** $i = \frac{q}{T} = q\,f = \frac{qv}{2\pi r}$

- Let n be the no. of free electrons per unit volume under the application of electric field to the conductor of cross section A. If $V_d$ be the drift velocity then

Current $i = \frac{Ne}{t}$ where, $n = \frac{N}{vol}$

$i = nA\left(\frac{\ell}{t}\right)e$ N = n (volume) = $n(A\ell)$

$i = nAV_d e$ N: Total free electrons

$V_d = \frac{i}{nAe}$ e: Charge of electron $V_d = \frac{\ell}{t}$

$\Rightarrow$ Resistance $(R) = \frac{m}{ne^2 t}\frac{\ell}{A}$, $\Rightarrow$ resistivity

$\rho = \frac{m}{ne^2 t}$.

**Mobility ( $\mu$ )**

- Average drift velocity per unit electric field strength is mobility of electron $\mu = \frac{V_d}{E}$

S.I. unit : $m^2 s^{-1} volt^{-1}$.

- The specific resistance does not change with the shape of the resistor. It depends only on the material of the conductor at constant temperature.
- When both the wires are made of different materials.

$$\frac{R_1}{R_2} = \left(\frac{S_1}{S_2}\right)\left(\frac{l_1}{l_2}\right)\left(\frac{A_2}{A_1}\right) = \left(\frac{S_1}{S_2}\right)\left(\frac{l_1}{l_2}\right)\left(\frac{r_2^2}{r_1^2}\right)$$

where $S_1$ and $S_2$ are specific resistances of both the wires.

- If two wires made of same material have lengths $l_1, l_2$ and masses $m_1$ and $m_2$ respectively, then

$$\frac{R_1}{R_2} = \left(\frac{l_1^2}{l_2^2}\right)\left(\frac{m_2}{m_1}\right)$$

- If two wires made of same material have equal masses (or) when a wire is stretched from length $l_1$ to $l_2$, then

$$\frac{R_1}{R_2} = \left(\frac{l_1^2}{l_2^2}\right) = \left(\frac{A_2^2}{A_1^2}\right) = \left(\frac{r_2^4}{r_1^4}\right)$$

**46.VARIATION OF RESISTIVITY AND RESISTANCE WITH TEMPERATURE :**

- Variation of resistance of a conductor with temperature is given by $R_2 = R_1\left[1 + \alpha\left(t_2 - t_1\right)\right]$ where $\alpha$ is called temperature co-efficient of resistance. Where $R_1$ is the resistance of the conductor at a reference temperature $t_1$ (usually $0^0C$ or $20^0C$ ) and $R_2$ is the resistance at temperature $t_2$. Unit for $\alpha$ is /ºC. (per degree Centigrade) or /K (per Kelvin).

If '$R_1$' and '$R_2$' be the resistances at two temperatures '$t_1$' and '$t_2$' then $\alpha = \frac{R_2 - R_1}{R_1 t_2 - R_2 t_1}$

- **A conductor and a semi condutor are connected in series. If the resistance of combination is same at all temperatures then** $R_1\,\alpha_1 = R_2\alpha_2$ **where $R_1$, $R_2$ are resistances of conductor and semi conductor respectively.**
- A wire of resistance 'R' is cut into 'n' equal parts and all of them are connected in parallel, equivalent resistance becomes $\frac{R}{n^2}$.
- 12 wires each of resistance 'r' are connected to form a cube. Effective resistance across

a) Diagonally opposite corners $= \frac{5r}{6}$. b) face diagonal $= \frac{3r}{4}$. c) two adjacent corners $= \frac{7r}{12}$.

- If two wires of resistivities $S_1$ and $S_2$, lengths $l_1$ and $l_2$ are connected in series, the equivalent resistivity

$$S = \frac{S_1 l_1 + S_2 l_2}{l_1 + l_2}.$$ If

$$l_1 = l_2 \; then \; S = \frac{S_1 + S_2}{2}.$$ If

$l_1 = l_2$ then conductivity $\sigma = \frac{2\sigma_1\sigma_2}{\sigma_1 + \sigma_2}$.

- If two wires of resistivities $S_1$ and $S_2$, Areas of cross section $A_1$ and $A_2$ are connected in parallel, the equivalent resistivity

$$S = \frac{S_1 S_2 (A_1 + A_2)}{S_1 A_2 + S_2 A_1}.$$ If $A_1 = A_2$ then $S = \frac{2S_1S_2}{S_1 + S_2}$. and

conductivity $\sigma = \frac{\sigma_1 + \sigma_2}{2}$.

**47.INTERNAL RESISTANCE OF A CELL:**

- The power transferred to the load is maximum when external resistance becomes equal to the internal resistance by maximum power transfer theorem.
- When a cell of EMF 'E' and internal resistance 'r' is connected to an external resistance 'R' as shown, where i = current in the circuit. Now the cell discharges or delivers current i through R. Then,

V = potential difference across the external resistance

$V^1$ = Voltage across internal resistance (or) lost volts

Then,

• EMF of the cell, $E = V + V^1$ • From Ohm's law, $i = \frac{E}{(R+r)} = \frac{V+V'}{(R+r)}$

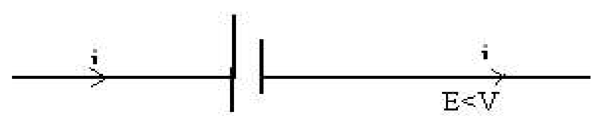
• $V = iR = \frac{ER}{(R+r)}$ • Fractional energy useful $= \frac{V}{E} = \frac{R}{R+r}$

• % of fractional useful energy $= \left(\frac{V}{E}\right)100 = \left(\frac{R}{R+r}\right)100$ • Fractional energy lost, $\frac{V'}{E} = \frac{r}{R+r}$

• % of lost energy, $\left(\frac{V'}{E}\right)100 = \left(\frac{r}{R+r}\right)100$ •

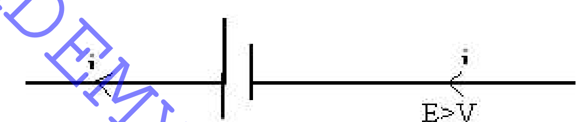
internal resistance, $r = \left[\frac{E-V}{V}\right]R$

• When the cell is charging, the EMF is less than the terminal voltage (E < V) and the direction of current inside the cell is from + ve terminal to the –ve terminal.




V = E + i r

• When the cell is discharging, the EMF is greater than the terminal voltage (E >V) and the direction of current inside the cell is from – ve terminal to the +ve terminal.




V = E – i r Hence E > V

• If external resistance (R) is equal to the internal resistance (r) then the source delivers maximum power and the terminal voltage across the cell

$$V = \frac{ER}{R+r} = \frac{E}{2}$$ Hence the % of energy lost and energy useful are each equal to 50%

- By mistake if 'm' cells out of 'n' cells are wrongly connected to the external resistance 'R' then total emf decreases by the emf of '2m' cells and

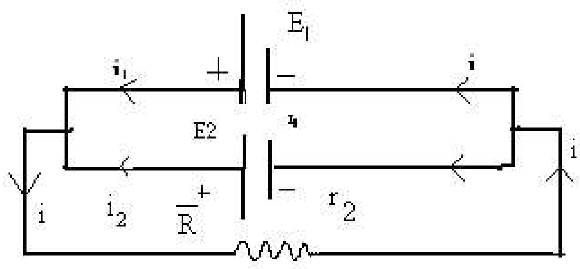
(a) total emf of the combination = (n – 2m) E

(b) total internal resistance = n r

(c) total resistance = R + n r (d) current through the circuit (i) = $\frac{(n-2m)E}{R+nr}$

**ELECTRIC CELLS IN PARALLEL:**

- If two cells of emf $E_1$ and $E_2$ having internal resistances $r_1$ and $r_2$ are connected in parallel to an external resistance 'R', then




the effective emf, E = $\frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$

the effective internal resistance, r = $\frac{r_1 r_2}{r_1 + r_2}$

**48.Electrical Energy :**

- The electric energy consumed in a circuit is defined as the total workdone in maintaing the current in an electric circuit for a given time.

Electrical Energy = Vit = Pt = $i^2Rt = \frac{V^2t}{R}$

S.I. unit of electric energy is joule

where 1 Joule=1watt $\times$ 1 sec = 1 volt $\times$ ampere $\times$ 1 sec

$1Kwh = 1000Wh = 3.6 \times 10^6 J$

**ELECTRICAL POWER:**

- The rate at which work is done in maintaining the current in electric circuit. Electrical power

$P = \frac{W}{t} = Vi = i^2R = \frac{V^2}{R}$ watt (or) joule/sec

**Bulbs connected in Sereies:**

- If Bulbs (or electrical appliances) are connected in series, the current through each resistance is same. Then power of the electrical appliance

$P \propto R$ & $V \propto R\left[\because P = i^2Rt\right]$

i.e. In series combination; the potential difference and power consumed will be more in larger resistance.

- When the appliances of power $P_1, P_2, P_3$.... are in series, the effective power consumed (P) is

$\frac{1}{P} = \frac{1}{P_1} + \frac{1}{P_2} + \frac{1}{P_3} + .........$ i.e. effective power is less than the power of individual appliance.

If 'n' appliances, each of equal resistance 'R' are connected in series with a voltage source 'V', the power dissipated 'Ps' will be $Ps = \frac{V^2}{nR}$.

**Bulbs connected in parallel:**

- If Bulbs (or electrical appliances) are connected in parallel, the potential difference across each resistance is same. Then $P \propto \frac{1}{R}$ and $I \propto \frac{1}{R}$.

  i.e. The current and power consumed will be more in smaller resistance.

- When the appliances of power $P_1, P_2, P_3$.... are in parallel, the effective power consumed(P) is

  $P = P_1 + P_2 + P_3 + .........$

  i.e. the effective power of various electrical applicance is more than the power of individual appliance.

- If 'n' appliances, each of resistance 'R' are connected in parallel with a voltage source 'V', the power dissipated 'Pp' will be

$$P_P = \frac{V^2}{(R/n)} = \frac{nV^2}{R}$$

$$\frac{P_P}{P_S} = n^2 \ (\text{or})\ P_P = n^2 P_S$$

- In parallel grouping of bulbs across a given sources of voltage, the bulb of greater wattage will give more brightness and will allow more current through it, but will have lesser resistance and same potential difference across it.

- For a given voltage V, if resistance is changed from 'R' to $\left(\frac{R}{n}\right)$, power consumed changes from 'P' to 'nP' $P' = \frac{V^2}{R'}$ where $R' = \frac{R}{n}$, then

  $P' = \frac{V^2}{(R/n)} = \frac{nV^2}{R} = np$.

- If $t_1, t_2$ are the time taken by two different coils for producing same heat with same supply, then

  If they are connected in series to produce same heat, time taken $t = t_1 + t_2$

  If they are connected in parallel to produce same heat, time taken is $t = \frac{t_1 t_2}{t_1 + t_2}$.

- Kirchhoff's first law obeys law of conservation of electric charge. Kirchhoff's second law obeys law of conservation of energy.

**49.WHEATSTONE BRIDGE:**

- When the Wheatstone bridge is balanced, then

$$\frac{P}{Q} = \frac{R}{S}$$

- Equivalent resistance of a balanced wheatstone network is $R_{eq} = \frac{(P+Q)(R+S)}{P+Q+R+S}$
- When galvanometer and cell are interchanged, the balance point is not effected.

**Meter bridge :**

- It works on the principle of Wheatstone Bridge. It is the simplified form of Wheatstone Bridge.
- It is used to find unknown resistance of a wire, specific resistance of the wire and also used to compare resistances.
- When the Meter bridge is balanced then

$$\frac{R}{X} = \frac{l_1}{l_2} = \frac{l_1}{100 - l_1}$$

Where $l_1$ *is* the balancing length from the left end.

**POTENTIOMETER:**

- Potential gradient or potential drop per unit length $= \frac{iR}{l}$ where '*l*' is the total length of potentiometer wire, 'R' is the total resistance of the wire and 'i' is the current through potentiometer wire due to primary circuit.
- If a resistance $R_s$ is connected in series with the potentiometer wire then $i = \frac{E}{r + R + R_S}$ and potential drop per unit length $= \left(\frac{E}{r + R + R_S}\right)\frac{R}{l}$
- The sensitivity of potentiometer can be increased by decreasing the potential gradient is by increasing the length of potentiometer wire or resistance in the primary circuit is to be increased and current is to be decreased.

**COMPARISON OF EMFS**

- If $l_1$ **&** $l_2$ *are* balancing lengths when two cells of emfs $E_1$ & $E_2$ are connected in the secondary circuit one after the other then, $\frac{E_1}{E_2} = \frac{l_1}{l_2}$

SUM AND DIFFERENCE METHOD :

- Let $l_1$ and $l_2$ are balancing lengths corresponding to two cells which are connected in secondary circuit first support each other and then oppose each other. Then

$$\frac{E_1 + E_2}{E_1 - E_2} = \frac{l_1}{l_2};\ \frac{E_1}{E_2} = \frac{l_1 + l_2}{l_1 - l_2}$$ **($E_1$ > $E_2$)**

- Internal resistance of a cell r = $\left(\frac{E - V}{V}\right)R = \left(\frac{l_1 - l_2}{l_2}\right)R$

Where $l_1$ = balancing length for the cell connected in the secondary circuit. $l_2$ = balancing length when a resistance R is connected in parallel to the cell.

E = emf of the cell V = Terminal voltage.

**50.COULOMB'S LAW AND FORCE DUE TO MULTIPLE CHARGES** :

- $$F = \frac{1}{4\pi \in_0 \in_r} \frac{q_1 q_2}{d^2}.$$

$$\overrightarrow{F_{12}} = \frac{1}{4\pi \in_0} \frac{q_1 q_2}{r_2^2} \hat{r}_{12} \text{ and } \overrightarrow{F_{21}} = -\overrightarrow{F_{12}}$$

- Two point sized identical spheres carrying charges $q_1$ and $q_2$ on them are seperated by a certain distance. The mutual force between them is F. These two are brought in contact and kept at the same seperation. Now, the force between them is $F^1$. Then $\frac{F^1}{F} = \frac{(q_1 + q_2)^2}{4q_1 q_2}$.

**NULL POINTS (OR) NEUTRAL POINTS:**

- Two charges $q_1$ and $q_2$ are seperated by a distance '$d$'. Then the point of zero intensity (null point) lies at a distance of

$$x = \frac{d}{\sqrt{\frac{q_2}{q_1}} \pm 1} \quad from \ q_1$$

+Ve sign for like charges -Ve sign for unlike charges.

- If a charged particle of charge Q is placed in an electric field of strength E, the force experienced by the charged particle = EQ.
- The acceleration of the charged particle in the

electric field, $a = \frac{EQ}{m}$.

- The velocity of the charged particle after time 't', is $\left.\begin{aligned} V &= at \\ &= \left(\frac{EQ}{m}\right)t \end{aligned}\right\}$ if the initial velocity is zero
- The distance travelled by the charged particle, is $\left.\begin{aligned} S &= \frac{1}{2}at^2 \\ &= \frac{1}{2}\left(\frac{EQ}{m}\right)t^2 \end{aligned}\right\}$ if the initial velocity is zero
- When a charged particle of mass m and charge Q remains suspended in an electric field then mg=EQ.
- When a charged particle of mass m and charge Q remains suspended in an electric field, the number of fundamental charges on the charged particle, $\begin{aligned} mg &= EQ \\ &= E(ne) \\ n &= \frac{mg}{Ee} \end{aligned}$.
- Intensity of electric field inside a charged hollow conducting sphere is zero.
- A hollow sphere of radius r is given a charge Q. Intensity of electric field at any point inside it is zero.
  Intensity of electric field on the surface of the sphere is $\frac{1}{4\pi \epsilon_0}\frac{Q}{r^2}$
  Intensity of electric field at any point outside the sphere is (at a distance 'x' from the centre) $\frac{1}{4\pi \epsilon_0}\frac{Q}{x^2}$
- The bob of a simple pendulum is given a +ve charge and it is made to oscillate in a vertically upward electric field, then the time period of oscillation is $2\pi\sqrt{\frac{l}{g - \frac{EQ}{m}}}$
- In the above case, if the bob is given a -ve charge then the time period is given by $2\pi\sqrt{\frac{l}{g + \frac{EQ}{m}}}$
- A sphere is given a charge of 'Q' and is suspended in a horizontal electric field. The angle made by the string with the vertical is, $\theta = \tan^{-1}\left(\frac{EQ}{mg}\right)$.
  The tension in the string is $\sqrt{(EQ)^2 + (mg)^2}$

51. Potential at a point due to a point charge $= \frac{1}{4\pi \epsilon_0}\frac{Q}{r}$

- Potential due to a group of charges is the algebric sum of their individual potentials.
  i.e. $V = V_1 + V_2 + V_3 + \ldots\ldots$
- Two charges +Q and -Q are separated by a distance d, the potential on the perpendicular bisector of the line joining the charges is zero.
- When a charged particle is accelerated from rest through a p.d. ' V ' , work done,
  $W = Vq = \frac{1}{2}mv^2 \ (or)\ v = \sqrt{\frac{2Vq}{m}}$
- The work done in moving a charge of q coulomb between two points separated by p.d. $V_2 - V_1$ is $q(V_2 - V_1)$.
- The work done in moving a charge from one point to another point on an equipotential surface is zero.
- A hollow sphere of radius R is given a charge Q the potential at a distance $x$ from the centre is $\frac{1}{4\pi \epsilon_0}.\frac{Q}{R}(x \le R)$. The potential at a distance when x>R is $\frac{1}{4\pi \epsilon_0}.\frac{Q}{x}$.
- A sphere is charged to a potential. The potential at any point inside the sphere is same as that of the surface.
- Inside a hollow conducting spherical shell, E=0, $V \neq 0$.
- Relation among E, V and d in a uniform electric field is $E = \frac{V}{d}$ (or) $E = -\frac{dv}{dx}$
  The component of electric field in any direction is equal to the negative of potential gradient in that direction.

**ZERO POTENTIAL POINT:**

- Two unlike charges $Q_1$ and $-Q_2$ are seperated by a distance 'd'. The net potential is zero at two points on the line joining them, one (x) in between them and the other (y) outside them

$$\frac{Q_1}{x}=\frac{Q_2}{d-x} \text{ and } \frac{Q_1}{y}=\frac{Q_2}{d+y}$$

**POTENTIAL ENERGY OF SYSTEM OF CHARGES:**

- Two charges $Q_1$ and $Q_2$ are separated by a distance 'd'. The P.E. of the system of charges is

$$U=\frac{1}{4\pi\epsilon_0}.\frac{Q_1Q_2}{d}$$

- Three charges $Q_1, Q_2, Q_3$ are placed at the three vertices of an equilateral triangle of side 'a'. The P.E. of the system of charges is

$$U=\frac{1}{4\pi\epsilon_0}\left[\frac{Q_1Q_2}{a}+\frac{Q_2Q_3}{a}+\frac{Q_3Q_1}{a}\right] \text{ or}$$

$$U=\frac{1}{4\pi\epsilon_0}\frac{\sum Q_1Q_2}{a}.$$

- The total flux passes through the given surface is given by $\phi_e=\vec{E}.\vec{S}$ $\therefore \phi_e = ES\cos\theta$

where $\theta$ is the angle made by the normal with the electric field.

52. **GAUSS LAW :** The total normal electric flux $\phi_e$ over a closed surface is $1/\epsilon_0$ times the total charge $Q$ enclosed within the surface.

$$\phi_e=\left(\frac{1}{\epsilon_0}\right)Q$$

- **ELECTRIC FIELD AT A POINT DUE TO A LINE CHARGE:**

A thin straight wire over which 'q' amount of charge be uniformly distributed. $\lambda$ be the linear charge density i.e, charge present per unit length of the wire.

$$E=\frac{q}{2\pi\epsilon_0 rl} \qquad E=\frac{\lambda}{2\pi\epsilon_0 r}$$

- **ELECTRIC FIELD INTENSITY AT A POINT DUE TO A THIN INFINITE CHARGED SHEET :**

'q' amount of charge be uniformly distributed over the sheet. Charge present per unit surface area of the sheet be $\sigma$. i.e surface charge density $\sigma$

$$E=\frac{q}{2A\epsilon_0} ;$$

$E=\frac{\sigma}{2\epsilon_0}$ $where\ \sigma=\frac{q}{A}$ • E is independent of the distance of the point from the charged sheet.

- **ELECTRIC FIELD INTENSITY AT A POINT DUE TO A THICK INFINITE CHARGED SHEET :**

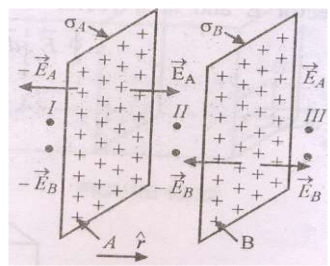
'q' amount of charge be uniformly distributed over the sheet. Charge present per unit surface area of the sheet be $\sigma$.

$$E=\frac{q}{A\epsilon_0}=\frac{\sigma}{\epsilon_0}$$

- Electric field at a point due to a thick charged sheet is twice that produced by the thin charged sheet of same charge density.
- **ELECTRIC INTENSITY DUE TO TWO THIN PARALLEL CHARGED SHEETS:**

Two charged sheets A and B having uniform charge densities $\sigma_A$ and $\sigma_B$ respectively.

- **In region I** : E $=\frac{1}{2\epsilon_0}(\sigma_A+\sigma_B)$. **In region II** :




$E_{II}=\frac{1}{2\epsilon_0}(\sigma_A-\sigma_B)$. **In region III** :

$$E_{III}=\frac{1}{2\epsilon_0}(\sigma_A+\sigma_B)$$

- **ELECTRIC FIELD DUE TO TWO OPPOSITELY CHARGED PARALLEL THIN SHEETS :**

$$E_I=-\frac{1}{2\epsilon_0}[\sigma+(-\sigma)]=0$$

$$E_{II}=\frac{1}{2\epsilon_0}[\sigma-(-\sigma)]=\frac{\sigma}{\epsilon_0}$$

$$E_{III}=\frac{1}{2\epsilon_0}(\sigma-\sigma)=0$$

- **ELECTRIC FIELD DUE TO A CHARGED SPHERICAL SHELL**

'q' amount of charge be uniformly distributed over a spherical shell of radius 'R'

$\sigma=$ Surface charge density, $\sigma=\frac{q}{4\pi R^2}$

- **When point 'P' lies outside the shell (r>R):**

$$E = \frac{1}{4\pi \in_0} \times \frac{q}{r^2}$$

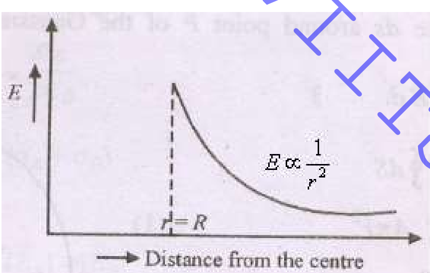
- This is the same expression as obtained for electric field at a point due to a point charge. Hence a charged spherical shell behaves as a point charge concentrated at the centre of it.

$$E = \frac{1}{4\pi \in_0} \frac{\sigma.4\pi R^2}{r^2} \left( \because \sigma = \frac{q}{4\pi R^2} \right)$$

$$E = \frac{\sigma.R^2}{\in_0 r^2}$$

- **When point 'P' lies on the shell (r =R) :** $E = \frac{\sigma}{\in_0}$

- **When Point 'P' lies inside the shell (r <R):** E = 0




- The electric intensity at any point due to a charged conducting solid sphere is same as that of a charged conducting sperical shell.

**ELECTRIC POTENTIAL (V) DUE TO A SPHERICAL CHARGED CONDUCTING SHELL (HOLLOW SPHERE)**

- When point $(P_3)$ lies outside the sphere $(r > R)$, the electric potential, $V = \frac{1}{4\pi\varepsilon_0} \frac{q}{r}$

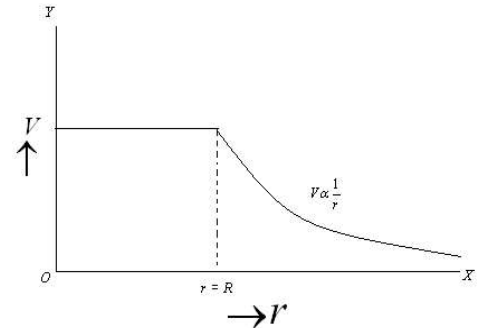
- When point $(P_2)$ lies on the surface $(r = R)$,

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

- When point $(P_1)$ lies inside the surface $(r < R)$,

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

- Note: The electric potential at any point inside the sphere is same and is equal to that on the surface.




**Note:** The electric potential at any point due to a charged conducting sphere is same as that of a charged conducting spherical shell.

**53.DIPOLE MOMENT $(\vec{p})$:**

It is defined as the simple product of magnitude of either charge and the distance of separation be tween the two charges. $\vec{p} = q(\overrightarrow{2a})$ Dipole moment $\vec{p}$ always points from -q to +q .

☞ **ELECTRIC FIELD DUE TO A DIPOLE AT A POINT LYING ON THE AXIL LINE (END ON POSITION):**

$$E_{axial} = \frac{1}{4\pi\varepsilon_0} \frac{2pr}{\left(r^2 - a^2\right)^2}$$

(from negative to positive cherge) In case of a short dipole (r>>a). $E_{axial} = \frac{1}{4\pi\varepsilon_0} \frac{2p}{r^3}$

☞ **ELECTRIC FILED DUE TO A DIPOLE AT A POINT LYING ON THE EQUATORIAL LINE (BROAD SIDE ON POSITION):**

$$E_{equitorial} = \frac{1}{4\pi\varepsilon_0} \frac{p}{\left(r^2 + a^2\right)^{3/2}}$$

{ from positive to negative charge} In case a short dipole (r>>a),

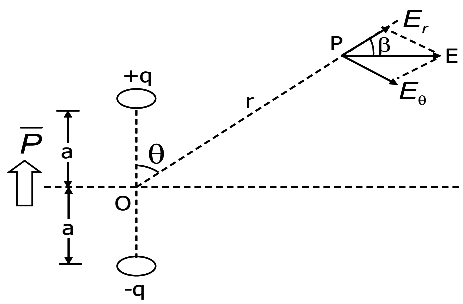
$$E_{equitorial} = \frac{1}{4\pi\varepsilon_0} \frac{p}{r^3}$$

☞ **ELECTRIC FILED DUE TO A SHORT DIPOLE AT ANY POINT P(r, $\theta$):**

$$E = \frac{1}{4\pi\varepsilon_0} \frac{p}{r^3} \sqrt{1 + 3\cos^2\theta}$$

$$\tan\beta = \frac{E_\theta}{E_r} = \frac{1}{2}\tan\theta$$

$$\Rightarrow \beta = \tan^{-1}\left[\frac{1}{2}(\tan\theta)\right]$$




**TORQUE ON A DIPOLE PLACED IN A UNIFROM ELECTRIC FILED:**

The torque due to the force on the positive charge about a point O is given by Fa sin $\theta$.The torque on the negative charge about O is also Fa sin $\theta$

$$\tau = 2Fa\sin\theta$$

$$\Rightarrow \tau = 2aqE\sin\theta \Rightarrow \tau = pE\sin\theta$$

$$\vec{\tau} = \vec{p}\times\vec{E}$$

**POTENTIAL ENERGY OF A DIPOLE PLACED IN A UNIFROM ELECTRIC FIELD:**

Work done by an external agent to rotate the dipole from an angle $\theta_0$ to $\theta$ with the filed is

$$W = PE(\cos\theta_0 - \cos\theta)$$

The potential energy stored of a dipole in uniform electric field is $U = -PE\cos\theta$

This is equivalent to the dot product of the vectors $\vec{p}$ and $\vec{E}$.

$$U = -\vec{p}.\vec{E} = (p_xE_x + p_yE_y + p_zE_z)$$

**ANGULAR SHM OF DIPOLE IN UNIFORM ELECTRIC FIELD:**

When a dipole is suspended in a uniform field, it will align itself parallel to the field.

Now if it is given a small angular displacement $\theta$ about its equilibrium position the (restoring) couple will be

Time period of oscillation is $T = 2\pi\sqrt{\frac{I}{pE}}$

**POTENTIAL DUE TO DIPOLE:**

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

On axial line $V = \frac{P}{4\pi\varepsilon_0 r^2}, (\theta = 0^0)$

On equatorial line $V = 0, (\theta = 90^0)$

54. **PARALLEL PLATE CAPACITOR:** If two plates each of area A are seperated by a distance 'd' then its capacity $C = \frac{\varepsilon_0 A}{d}$ (air as medium),

$C = \frac{k\varepsilon_0 A}{d}$ (dielectric medium)

When a dielectric medium is introduced between the plates of a parallel plate capacitor, its capacity increases to 'k' times the original capacity.

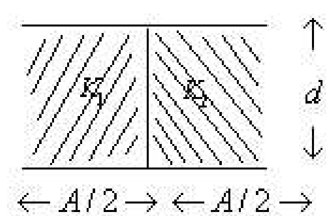
- When a dielectric slab of thickness 't' is introduced between the plates of a parallel plate capacitor,

$$new\ capacity = \frac{\varepsilon_0 A}{d - t\left(1 - \frac{1}{k}\right)} = \frac{\epsilon_0\ A}{(d-t) + \frac{t}{k}}$$

- When a metal slab of thickness 't' is introduced between the plates of a parallel plate capacitor,

$$new\ capacity = \frac{\varepsilon_0 A}{d - t}$$ . ( for metal k = $\infty$ )

- When a thin metal sheet $(t \approx 0)$ is introduced between the plates of a parallel plate capacitor, then capacity remains unchanged.
- A dielectric slab of thickness 't' is introduced between the plates, to restore the original capacity, if the distance between the plates is increased by x, then $x = t\left(1 - \frac{1}{k}\right)$.
- Two dielectric slabs of equal thickness are introduced between the plates of a capacitor as shown in figure, then new capacity $= \frac{C}{2}(K_1 + K_2)$.

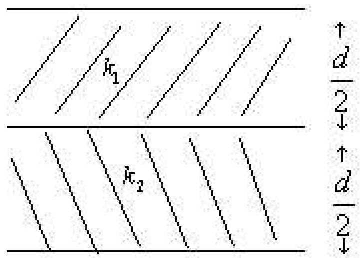



If the two dielectrics are of different face areas $A_1$ and $A_2$ but of same thickness, then capacity,

$$C = \frac{\epsilon_0}{d}(K_1A_1 + K_2A_2)$$

- If two dielectric slabs of constants $k_1$ and $k_2$ are introduced as shown in figure, new capacity

$$=\frac{2k_1k_2}{(k_1+k_2)}.C$$




- If number of dielectric slabs of same cross sectional area 'A' and of thicknesses $t_1, t_2, t_3, ........t_n$ and constants $k_1, k_2.......k_n$ are introduced between the plates, effective capacity

$$C=\frac{\varepsilon_0 A}{d-(t_1+t_2+....t_{3n})+\left(\frac{t_1}{k_1}+.....+\frac{t_n}{k_n}\right)}$$

- In the above case if the dielectric media are completely filled between the plates, effective capacity $C=\frac{\varepsilon_0 A}{\left(\frac{t_1}{k_1}+.....\frac{t_n}{k_n}\right)}$
- The capacity of a parallel plate capacitor is independent of the charge on it, potential difference between the plates and the nature of plate material.
- In a capacitor, the energy is stored in the electric field between the two plates.
- Capacity of a spherical conductor = $4\pi \in_0 r$, where r is the radius of the sphere.

☞ **Spherical condenser**

(a) $C=4\pi \in_0 \frac{R_1R_2}{R_1-R_2}$, if inner sphere is charged and outer sphere is earthed.

(b) $C=4\pi \in_0 \frac{R_1R_2}{R_1-R_2}+4\pi \in_0 R_1$,

If inner sphere is earthed and outer sphere is charged.

☞ **FORCE OF ATTRACTION BETWEEN THE PLATES OF A CAPACITOR:**

(a) Force $=\frac{1}{2}\varepsilon_0 E^2 A$ (b) $F=\frac{1}{2}\varepsilon_0 A\left(\frac{V^2}{d^2}\right)$

**55. ENERGY STORED IN A CONDENSER** :

- Energy stored in a charged condenser $U=\frac{1}{2}CV^2=\frac{1}{2}qV=\frac{q^2}{2C}$
- If a condenser is connected across a battery and $U$ is the energy stored in the condeser then the work done by the battery in charging the condenser is $2U$ ( W = qV = 2U )

For a parallel plate capacitor

$$U=\frac{1}{2}(Ad)\frac{\sigma^2}{\in_0}\left(as\ E=\frac{\sigma}{\in_0}\right)$$

Energy density $\frac{U}{V}=\frac{\sigma^2}{\in_0}=\frac{1}{2}\in_0 E^2$ ( here V is volume i.e. Ad)

**COMMON POTENTIAL AND LOSS OF ENERGY:**

If two charged bodies carrying charges $Q_1$ and $Q_2$ having like charges and having capacitances $C_1$ and $C_2$ are connected with each other, then their common potential after connection is given by.

$$V=\frac{Q_1+Q_2}{C_1+C_2}=\frac{C_1V_1+C_2V_2}{C_1+C_2}$$

where $V_1$ and $V_2$ are the initial potential of the charged bodies. The loss of energy is given by.

$$\Delta U=\frac{1}{2}\frac{C_1C_2}{(C_1+C_2)}(V_1-V_1)^2$$

- If the bodies with unlike polarities are connected together, then common potential

$V=\frac{C_1V_1-C_2V_2}{C_1+C_2}$. Loss of energy

$$\Delta U=\frac{1}{2}\left(\frac{C_1C_2}{C_1+C_2}\right)(V_1+V_2)^2$$

**EFFECT OF DIELECTRIC :**

- A parallel plate capacitor is fully charged to a potential V. **Without disconnecting the battery** if the gap between the plates is completely filled by a dielectric medium,capacity increases to k times the original capacity.
- P.D. between the plates remains same.
- Charge on the plates increases to k times the original charge.
- Energy stored in the capacitor increases to k times the original energy.
- **After disconnecting the battery** if the gap between the plates of the capacitor is filled by a dielectric medium,capacity increases to k times the original capacity.
- P.D. between the plates decreases to $\frac{1}{k}$ times the original potential.
- Charge on the plates remains same.

- Energy stored in the capacitor decreases to $\frac{1}{k}$ times the original energy.
- A capacitor is fully charged to a potential 'v'. After disconnecting the battery, the distance between the plates of capacitors is increased by means of insulating handles. Potential difference between the plates increases. ($V = \frac{Q}{C}$, Q remains same, and C decreases)
- A capacitor with a dielectric is fully charged. Without disconnecting the battery if the dielectric slab is removed, then some charge flows back to the battery.
- Corpuscular theory succeeded in explaining reflection and refraction but failed to explain interference, diffraction and polarization.
- Wave theory succeeded in explaining reflection, refraction, interference and diffraction phenomenon
- The velocity of these waves in vacuum is given by C= $\frac{1}{\sqrt{\mu_0 \in_0}}$ where

  $\mu_0$ = permeability of free space $\in_0$ = permittivity of free space
- The theory explained the phenomena including polarization connected with wave nature of light.

**56.REFLECTION**

- Deviation produced in Reflection is $\delta = 180^0 - (i + r)$ Since r = i

  $\Rightarrow \delta = 180^0 - 2i$
- Let $\theta$ be the angle between two plane mirrors and n be the number of images formed.

  (a) $n = \frac{360}{\theta}$ if $\frac{360}{\theta}$ is odd ( b )

  $n = \left(\frac{360}{\theta} - 1\right)$, if $\frac{360}{\theta}$ is even

  (c) Further if $\frac{360}{\theta}$ is odd, then (i )

  $n = \left(\frac{360}{\theta} - 1\right)$, if object lies symmetrically on the angle bisector of two mirrors (ii) n = $\frac{360}{\theta}$, if object lies unsymmetrically

  (d) Further if $\frac{360}{\theta}$ is a fraction then the number of images formed will be integral part o f the fraction e.g if $\frac{360}{\theta}$ is 4.8, then n = 4
- If the plane mirror is rotated in the plane of incidence by an angle $\phi$, then the reflected ray rotates by an angle 2$\phi$, the normal rotates by an angle $\phi$ while the incident ray remains fixed.
- . A person needs a plane mirror of minimum half of his height to see his full image
- A person standing in the middle of room can see complete wall behind him if the mirror in front of him is 1/3 rd of height of wall.

8. For a plane mirror, radius of curvature, $R = \infty$, focal length, $f = \infty$ and focal power, $P = 0$.

**57.SPHERICAL MIRRORS**

**Object image relationship for spherical mirror :**

**(a) For concave mirror**

1. Object lies at infinity

   Real, inverted very small image $(m << -1)$ is formed at F
2. Object lies between infinity and C

   Real, inverted diminished image $(m < -1)$ is formed between F and C
3. Object lies at C Real, inverted image $(m = -1)$ is formed at C
4. Object lies between F and C

   Real, inverted magnified image $(m > -1)$ is formed between C and infinity
5. Object lies at F Real, inverted, very large image $(m >> -1)$ is formed at inifinity
6. Object lies between F and P

Virtual, errect, enlarged image $(m > +1)$ is formed behind the mirror

**(b) For convex mirror**

1. Object lies at infinity Virtual, errect, very small image $(m << +1)$ is fomed at F
2. Object lies infront of mirror virtual, errect, diminished image $(m < +1)$ is formed between P and F

☞ Focal length of a mirror depends only on the radius of curvature of the mirror $\left(f=\frac{R}{2}\right)$. It does not depend either on the material of the mirror or on the wavelength of incident light.

**Spherical Mirror Formulae :**

(1) The spherical mirror formula is $\frac{1}{v}+\frac{1}{u}=\frac{1}{f}$

where u = object distance and v = image distance, both measured from the pole.

(2) $f=\frac{R}{2}$ (3) Linear magnification

$=\frac{\text{height or size of the image}}{\text{height or size of the object}}\ m=\frac{I}{o}=\frac{-v}{u}$

If 'm' is +ve image is virtual erect. If 'm' is -ve image is real, inverted.

☞ **Axial Magnification :**

$m_{ax}=\frac{dv}{du}=\frac{x_2}{x_1}=\frac{v^2}{u^2}=m^2$ where $x_2$= size of image along principal axis.

$x_2$= size of the object along principal axis.

☞ **Newton`s Formula :**

In case of spherical mirros if object distance $(x_1)$ and image distance $(x_2)$ are measured from focus instead of pole $u=(f+x_1)$ and Which on simplification gives $x_1x_2=f^2$

58. THE refractive index of any medium with reference to vacuum is called its absolute refractive index.

$\mu_{absolute}=\frac{\text{velocity of light in vacuum}}{\text{velocity of light in the medium}}$ $\mu$ =

$\frac{C_o}{C_m}=\frac{\lambda_o}{\lambda m}$

● When a ray of light passes from medium 1 to medium 2, the ratio of refractive index of medium 2 to that of medium 1 is called relative refractive index of medium 2 with respect to medium 1.

$${}_1\mu_2=\frac{\mu_2}{\mu_1}=\frac{C_1}{C_2}=\frac{\lambda_1}{\lambda_2}=\frac{\sin i}{\sin r}$$

● If a ray of light travels from a medium "a" to medium "b" then into another medium "c" and finally again into medium "a" then ${}_a\mu_b\times{}_b\mu_c={}_a\mu_c$

☞ **optical path :** If light travels a distance $x$ in a medium of refractive index $\mu$ the equivalent path in vacuum it would travel in the same time is $\mu x$.

It is called optical path $(d=\mu x)$

● If 'c' is the velocity of light in vacuum, then the time taken by light to travel a distance '$x$' in a medium of refractive index $\mu$ is given by $t=\frac{\mu x}{c}$

● When looking from a rarer medium (air) into a denser medium object appear to be nearer due to refraction $\mu$

$=\frac{\text{real depth}}{\text{apparent depth}}$

● The shift produced by a denser medium of thickness "t" is "x" x=t(1-$\frac{1}{\mu}$), It is independent of a height from which it is viewed

● When a point object is seen through a glass slab of thickness "t", it appears as if it is moved towards glass slab by a distance,

$x$ = t(1-$\frac{1}{\mu}$)

● If a glass slab is kept in the path of convergingrays, the point of convergence moves away from the slab by distance

$x$ = t(1-$\frac{1}{\mu}$)

● If the denser medium contains multiple layers of thickness $t_1$, $t_2$,$t_3$ … and $\mu_1$, $\mu_2$ and $\mu_3$ ... are refractive indices of different layers.

apparent depth = $\frac{t_1}{\mu_1}+\frac{t_2}{\mu_2}+$............

● When looking from a denser medium into a rarer medium objects appear to be farther away.

$$\mu=\frac{\textbf{apparent depth}}{\textbf{real depth}}$$

When an object in rarer medium is seen from denser medium it appears to be farther and shift is $x$=t($\mu$-1)

● Whenever a light ray passes through a glass slab the incident and emergent rays will be parallel to each other. But the emergent ray is displaced laterally

The lateral displacement=x=$\frac{t}{\cos r}\sin(i-r)$. The length of the path travelled by light insidethe glass slab = $\frac{t}{\cos r}$ = t sec r

- A ray of light travels from rarer medium and strikes a denser medium. If reflected and refracted rays are perpendicular to each other then the refractive index of denser medium is $\mu = \tan i$

☞ If a ray of light travels from denser to rarer medium then $\mu = \cot i$

- Critical Angle(C): when a ray of light enters a rarer medium from a denser medium, the angle of incidence for which the angle of refraction becomes $90^0$ is called critical angle (c).

$$\mu = \frac{1}{\sin c}$$

- If $C_1$ and $C_2$ are the velocities of light in two media of refractive indices $\mu_1$ and $\mu_2$ ($\mu_2 > \mu_1$) then the critical angle for the pair of the media is given by Sin c = $\frac{\mu_1}{\mu_2} = \frac{C_2}{C_1} = \frac{\lambda_2}{\lambda_1}$
- For a fish or diver under water the outside world appears to be within a cone of vertex angle 2C ($\approx 98^0$)
- If "h" is the depth of the fish from the surface of the water of refractive index $\mu$, the radius of the circle on the surface of the water through which it can see the outer world is

$$R = h\tan C = \frac{h}{\sqrt{\mu^2 - 1}}$$

## 59.LENS MAKER'S FORMULA :

- The focal length "f" of a lens in air or vacuum depends on
- refractive index $\mu$ of its material
- radii of curvature $R_1$,$R_2$ of its surface.

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

- When a lens is immersed in a liquid

$$\frac{1}{f^1} = \left(\frac{\mu_g}{\mu_l} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where $\mu_g$ = refractive index of lens $\mu_l$ = refractive index of liquid.

f = focal length of lens in air $f^1$ = focal length of the lens in liquid

The new focal length $f^1$ is given by

$$\frac{f^1}{f} = \frac{(\mu_g - 1)}{\left(\frac{\mu_g}{\mu_l} - 1\right)}$$

☞ Now three cases arise :

(a) If $\mu_g > \mu_l$ then $f^1$ and $f$ are of same sign and $f^1 > f$.

That is the nature of lens remains unchanged, but its focal length increases and hence power of lens decreases. In other words the convergent lens becomes less convergent and divergent lens becomes less divergent.

(b) If $\mu_g = \mu_l$, then $f^1 \to \infty$ and the lens behaves as a simple glass plate.

(c) If $\mu_g < \mu_l$ then $f^1$ and $f$ have opposite signs and the nature of lens changes i.e. a convergent lens becomes divergent and vice versa.

☞ For equi convex lens $\frac{1}{f} = (\mu - 1)\left(\frac{2}{R}\right)$ For plano convex lens $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R}\right)$

For equi concave lens $\frac{1}{f} = -(\mu - 1)\left(\frac{2}{R}\right)$ For plano concave lens $\frac{1}{f} = -(\mu - 1)\left(\frac{1}{R}\right)$

For concavo convex lens

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

($\because$ $R_1$ and $R_2$ are positive)

For convexo concave lens

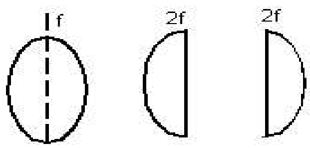
$$\frac{1}{f} = -(\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

($\because$ $R_1$ and $R_2$ are negative)

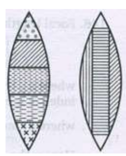
☞ When a convex lens of focal length "f" made of glass ($\mu$ = 1.5) is in air / vacuum, its focal length is equal to R.

- When a convex lens of focal length "f" made of glass ($\mu$ = 1.5) is immersed in water, $\left(\mu = \frac{4}{3}\right)$, its focal length becomes 4f.

- A lens immersed in a liquid whose refractive index is equal to that of the lens then the lens will have infinite focal length and its focal power becomes zero.
- An air bubble in water behaves as a diverging lens. A liquid drop in air behaves as a converging lens
- If a convex lens of focal length f is broken into two equal parts along principal axis the focal length of each part becomes "f".
- If an equiconvex lens of focal lengths 'f' is split into two plano convex lenses perpendicular to principal axis then the focal length of each becomes 2f.




☞ If the lens is filled horizontally with number of media n then the number of images will be n



☞ If the lens is filled vertically with number of media n then the number of images will be 1

**LENS EQUATION:**

☞ $\frac{1}{f}=\frac{1}{v}-\frac{1}{u}$ (appropriate sign conventions are to be applied)

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

**'m' is +ve image is virtual erect.**

If 'm' is -ve image is real, inverted.

- For real image produced by convex lens (a) u = f $\left[1+\frac{1}{m}\right]$ (b) v = f(1+m)
- The reciprocal value of focal length of a lens expressed in metres is called its "focal power"(p)

P = $\frac{1}{f}$ Where f is in metre P = $\frac{100}{f}$ where f is in centimetre

- The unit of focal power is Dioptre(D). If focal length of a lens is 1 metre then its power is said to be one diopter.
- The focal power is positive for converging lens and negative for diverging lens

**THIN LENSES IN CONTACT**:

If number of thin lenses of focal lengths $f_1$, $f_2$, $f_3$... are in contact with each other, the equivalent focal length "f" is given by $\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}+\frac{1}{f_3}+...$

The equivalent focal power is $P=P_1+P_2+P_3+..$

- **Lenses Separated by a Distance:** When two lenses of focal lengths $f_1$ and $f_2$ are kept apart by a distance d , the effective focal length f is given by $\frac{1}{f}=\frac{1}{f_1}+\frac{1}{f_2}-\frac{d}{f_1f_2}$

The combined focal power 'P' of the system is

$P=P_1+P_2-dP_1P_2$

If a convex lens and a concave lens of equal focal lengths are combined, the focal length of combination is equal to infinity and its focal poweri s zero.

- Two convex lenses of focal lengths $f_1$ and $f_2$ are separated by a distance d such that a parallel beam incident on one lens emerges parallel from the other lens, then $d=f_1+f_2$
- In the above case if the second lens is concave then $d=f_1-f_2$

**Lens displacement method :**

- The positions of the object and the real image on the principal axis of a convex lens can be interchanged. The interchangeable points are called conjugate foci.
- The focal length of convex lens in conjugate foci method is f = $\frac{L^2-d^2}{4L}$ where L = distance between the object and the sreeen.
- If $I_1$ and $I_2$ are the sizes of images formed in conjugate foci or lens displacement method, the size of object used is given by OJ= $\sqrt{I_1I_2}$
- If $m_1$ and $m_2$ are the magnifications of magnified and diminished images in two positions of conjugate foci method, then
- $m_1 \times m_2 = 1$ ● $\frac{m_1}{m_2}=\left(\frac{L+d}{L-d}\right)^2$ ● f = $\frac{d}{m_1-m_2}$F $L\geq 4f$
- **Linear Magnification :**

$$\frac{\text{height or size of the image}}{\text{height or size of the object}}$$

$$m=\frac{I}{o}=\frac{v}{u}=\frac{v-f}{f}=\frac{f}{u-f}$$

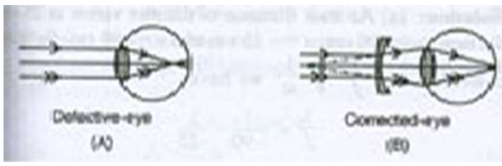
- **Areal Magnification :**

$$m_{ar} = \frac{A_1}{A_0} = \frac{v^2}{u^2} = m^2$$ where $A_1$= Area of Image; $A_0$= Area of Object

**6O.DEFECTS OF VISION**

**Myopia** [or Short-sightedness or Near-sightedness]

A short - sighted eye can see only nearer objects. In it distant objects are not clearly visible, i.e., far point is at a distance lesser than infinity and hence image of distant object is formed before the retina [Fig. (A)].




This defect is remedied by using spectacles having divergent lens.

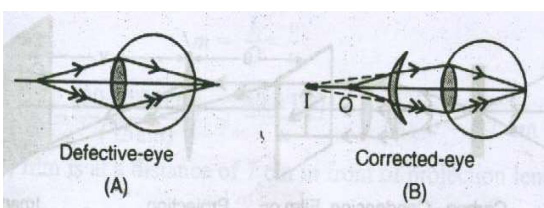
$$\frac{1}{-F.P.} - \frac{1}{-(\text{distance of object})} = \frac{1}{f} = P$$

And if the object is at $\infty$, $P = \frac{1}{f} = \frac{1}{-F.P.}$

Note : This is due to elongation of eye ball

☞ **Hyperopia or Hypermetropia** [or Longsighted-ness or far sightedness]

The far sighted eye can see only farther objects. In it near objects are not clearly visible, i.e., near point is at a distance greater than 25 cm and hence image of near object is formed behind the retina [Fig.(A)]




This defect is remedied by using spectacles having convergent lens.

$$\frac{1}{-N.P.} - \frac{1}{-(\text{distance of object})} = \frac{1}{f} = P$$

If object is placed at $D = 25cm = 0.25m$,

$$P = \frac{1}{f} = \left[\frac{1}{0.25} - \frac{1}{N.P.}\right]$$ Note : This is due to contraction of eye ball.

**61.SIMPLE MICROSCOPE:**

**(A) Image is at infinty (far point are normal adjustment)**

if $v = \infty$, $u = f$ (from lens formula)s

$$M.P. = \frac{D}{u} = \frac{D}{f}$$

Note: Here parallel beam of light enters the eye i.e.,eye is least strained.

**(B) Image is at D (Near point)** In this situation v = -D, so that, $\frac{1}{-D} - \frac{1}{-u} = \frac{1}{f}$ or

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

so, $M.P. = 1 + \frac{D}{f}$

☞ Note: Here final image is closest to eye i.e., eye is under maximum stain.If eye is at a distance x from the lens then $MP = 1 + \frac{D-x}{f}$

**COMPOUND MICROSCOPE**

**(A) Final image is at infinity (far point or normal adjustment)**

$u_e = f_e \Rightarrow M.P. = -\frac{v_0}{u_0}\left[\frac{D}{f_e}\right]$ where ☞ $L = v_0 + f_e$

Note: A microscope is usually considered to operate in this mode unless stated otherwise.

**(B) Final image is at D (near point)**

For eye-piece $v_e = -D$ ☞

$\Rightarrow \frac{D}{u_e} = 1 + \frac{D}{f_e}$ ☞ $\therefore MP = \frac{v_0}{u_0}\left(1 + \frac{D}{f_e}\right)$

☞ length of microscope $L = v_0 + u_e$ ☞

$$L = v_0 + \frac{f_e D}{f_e + D}$$

**TELESCOPE**

**(A) Final image is at infinity (far point or normal adjustment)**

Here, $v = \infty \Rightarrow u_e = f_e$

so, $M.P. = -\left(\frac{f_0}{f_e}\right)$ $with, L = f_0 + f_e$

Note : Usually, a telescope operates in this mode unless stated otherwise.

**(B) Final image is at D (near point)**

Here $v_e = -D \Rightarrow \frac{1}{-D} - \frac{1}{-u_e} = \frac{1}{f_e}$ so,

$$M.P. = -\frac{f_0}{f_e}\left[1 + \frac{f_e}{D}\right]$$ ☞ Here $L = f_0 + u_e$ or

$$L = f_0 + \frac{f_e D}{f_e + D}$$

**TERRESTRIAL TELESCOPE**

**Magnifying power :**

**(a) Final image is at near point**

$$M = \frac{f_0}{f_e}\left(1 + \frac{f_e}{D}\right)$$ length of the telescope

$$L = f_0 + 4f + u_e$$

**(b) If the final image is at infinity ( normal adjustment)** then $M = \frac{f_0}{f_e}$ and

$L = f_0 + 4f + f_e$ **F RESOLVING LIMIT AND RESOLVING POWER**

**(a) Resolving Limit :**

Smallest anglular seperations $(d\theta)$ between two distant objects, whose images are seperated in the telescope is called resolving limit.

**(b) Resolving Power (R.P) :**

It is the reciprocal of resolving limit

$$R.P = \frac{1}{d\theta}$$

**For a Telescope :** Resolving limit,

$$d\theta = \frac{1.22 \times \lambda}{a}$$

$$\therefore R.P \,\alpha\, \frac{1}{\lambda}$$

Where $\lambda =$ wavelength of light used to illuminate the object. $a =$ apperture of the objective.

62. **PRISM**

A $\longrightarrow$ Angle of the prism or refracting angle ,

D $\longrightarrow$ angle of deviation

$i_1, i_2 \longrightarrow$ are the angle fo incidence and angle of emergence

$r_1, r_2 \longrightarrow$ are the angles of refraction (i) Angle of prism A = $r_1 + r_2$

(ii) Angle of deviation, D = $i_1 + i_2$-A (iii) Refractive index of the prism,

$$\mu = \frac{\sin i_1}{\sin r_1} = \frac{\sin i_2}{\sin r_2}$$

**I. When the prism is in the minimum deviation position :**

a) The light ray is symmetrically about the prism.

b) $i_1 = i_2 = i$ and $r_1 = r_2 = r$ c) Angle of minimum deviation, $D_m = 2i - A$

d) Angle of incidence, $i = \frac{A + D_m}{2}$ e) Angle of refraction, r = A/ 2

f) Refractive index of prism,

$$\mu = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin\frac{A}{2}}$$

g) In minimum deviation position the refracted ray inside the prism is parallel to the base.

case (i) : $A < 2C$, refraction takes place on both sides

case (ii) : $A = 2C$, light ray grazes the two surfaces

case (iii) : $A > 2C$, TIR takes place ( no emergent ray)

☞ $i - \delta$ **Curve :** For given prism of $\mu$ and A with monochromatic light of $\lambda$, $\delta$ varies with i as

☞ **Deviation in a small angled prism :**

a) As $\mu_v > \mu_R$. Therefore the deviation for violet colour is more than the deviation for red colour $(d_v > d_r)$

b) In case of thin prism, the angle of minimum deviation , $d_m = (\mu - 1)A$

**DISPERSION OF LIGHT:**

- The difference in the deviations of any two colours is called angular dispersion. $\delta = d_v - d_R$
- For a thin prism $\delta = A(\mu_V - \mu_R)$. It depends on
  i) angle of the prism
  ii) the difference of the refractive indices.

- The ratio of angular dispersion for two extreme colours to their mean deviation is called dispersive power of prism ($\omega$)

Dispersive power = $(\omega) = \dfrac{\text{Angular dispersion}}{\text{mean deviation}}$

Dispersive power does not depend upon the angle of prism. It only depends upon material.

- The dispersive power of the material of a prism for red and violet colours is given by $\omega = \dfrac{d_v - d_R}{d}$

where $d = \dfrac{d_V + d_R}{2}$ since angular dispersion $d_v$ - $d_R$ = $A(\mu_V - \mu_R)$ $\omega = \dfrac{\mu_v - \mu_R}{\mu - 1}$

where $\mu = \dfrac{\mu_V + \mu_R}{2}$

- Dispersive power has no units and dimensions
- **CONDITION FOR DISPERSION WITHOUT DEVIATION : (DIRECT VISION PRISM)**

If $A_1$ and $A_2$ are the angles of prism then the

i) $d_1 + d_2 = 0$ ii) $\delta_1 + \delta_2 \neq 0$

iii) $A_1(\mu_1 - 1) + A_2(\mu_2 - 1) = 0$

$$\frac{A_1}{A_2} = \frac{-(\mu_2 - 1)}{(\mu_1 - 1)}$$

- **CONDITION FOR DEVIATION WITHOUT DISPERSION : (ACHROMATIC PRISM)**

If $A_1$ and $A_2$ are the angles of the prism then the for mean ray (yellow ray) is

i) $\delta_1 + \delta_2 = 0$ ; $\omega_1 . d_1 + \omega_2 . d_2 = 0$ ii) $A_1(\mu_{V1} - \mu_{R1}) + A_2(\mu_{V2} - \mu_{R2}) = 0$ iii) $d_1 + d_2 \neq 0$

$$\frac{A_1}{A_2} = \frac{-(\mu_{V_2} - \mu_{R_2})}{(\mu_{V_1} - \mu_{R_1})}$$

**63.PHASE DIFFERENCE**:

- For constructive interference, the phase difference must be $2n\pi$ (where n is an integer)
- For destructive interference, the phase difference must be $(2n+1)\pi$ [ where n is any integer]

phase difference = $\dfrac{2\pi}{\lambda}$ (path difference).

- **YOUNG'S DOUBLE SLIT EXPERIMENT:**

- When two such light waves superpose with each other, the resultant amplitude of two waves is = $2a \cos \dfrac{\delta}{2}$

The resultant intensity of two waves is $I = R^2 = 4a^2 \cos^2 \dfrac{\delta}{2}$

- When phase difference $\delta$ = 0, $2\pi$, $4\pi$, $6\pi$, …$2n\pi$ and path difference x= 0, $\lambda$, $2\lambda$, $3\lambda$ …$n\lambda$ the resultant intensity $I = 4a^2$ which is maximum produces bright point. It is the condition for constructive interference.
- When phase difference $\delta$ = $\pi$, $3\pi$, $5\pi$, …. $(2n+1)\pi$ and path difference

$x = \dfrac{\lambda}{2}, \dfrac{3\lambda}{2}, \dfrac{5\lambda}{2} ... (2n+1)\dfrac{\lambda}{2}$

are observed between the waves the resultant intensity I = 0 which is minimum produces dark point. It is the condition for destructive interference.

- **INTERFERENCE DUE TO UNEQUAL AMPLITUDES:**

a) path difference (x) :

$x = r_2 - r_1 = d\sin\theta \approx d\tan\theta \approx \dfrac{dy}{D}$

where d=distance between two slits
D=distance between slits and screen y = distance of observed point 'p' from 'O'

b) The position of $n^{th}$ bright fringe from O is

$y_{bright} = n\left(\dfrac{\lambda D}{d}\right)$ where n=0,1,2,3

c) The position of $n^{th}$ dark fringe from O is

$y_{dark} = (2n-1)\dfrac{\lambda D}{2d}$ where n = 1,2,3,4

d) Fringe width ( $\beta$ ) :

The separation between two consecutive bright (or dark) fringes is called the fringe width $(\beta)$ given by

$$\beta = y_{n+1} - y_n = \frac{\lambda D}{d}$$

Angular fringe width is $\Delta\phi = \dfrac{\beta}{D} = \dfrac{\lambda}{d}$

e) In water (liquid) of refractive index $\mu$ the wavelength decreases from $\lambda$ to $\lambda^1$ then $\lambda' = \dfrac{\lambda}{\mu}$.

Therefore, if interference experiment is performed in water the fringe width decreases from $\beta$ to $\beta'$,

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

$\Rightarrow \beta' = \frac{\beta}{\mu}$

f ). Displacement of Fringes.

If a thin transparent plate is introduced in the path of one of the interfering waves, it is observed that the entire fringe system (or pattern) is shifted through a distance given by

$$x_0 = \frac{D}{d}(\mu - 1)t = \frac{\beta}{\lambda}(\mu - 1)t$$

where $\mu$= refractive index of the plate for the light used and t = thickness of the plate.

The shift takes place towards the wave in the path of which the plate is introduced. The introduction of the plate has no effect on the fringe width. The shift occurs because the original path difference is changed by ($\mu$ -1)t.



**64 Diffraction due to single slit**: The diffraction pattern due to a single slit consists of a central bright band having alternate dark and weak bright bands of decreasing intensity on both sides.

The condition for nth secondary minimum is that path difference $= a\sin\theta_n = n\lambda,$

where $n = 1, 2, 3...$ and the condition for nth secondary maximum is that path

difference $= a\sin\theta_n = (2n+1)\frac{\lambda}{2}$;

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

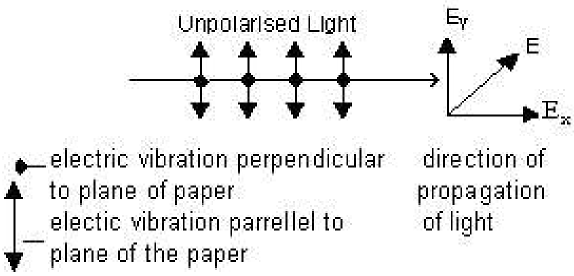
Width of central maximum is $2x = \frac{2D\lambda}{a} = \frac{2f\lambda}{a}$

Here, $a$ is width of slit and D is distance of screen from the slit ; $f$ is focal length of lens for diffracted light. For small angles $\sin\theta_n = \theta_n$

Distance of $n^{th}$ dark fringe from centre, $x_{dark} = \frac{n\lambda D}{a}$ Distance of $n^{th}$ bright fringe from centre, $x_{bright} = \frac{(2n+1)\lambda D}{2a}$

65.**POLARISATION:**

- The electric vector is resolved into two components vibrations $E_x$ and $E_y$ such that the component $E_y$ vibrates perpendicular to the plane of paper.




- From Brewster's law $\mu$ = Tan i.
  - If i= $\theta_p$ , the reflected light is completely polarised and the refracted light is partially polarised.
  - If i= $\theta_p$ , both the reflected and refracted light rays are perpendicular to each other.
  - If i< $\theta_p$ or i> $\theta_p$ , both reflected and refracted rays get partially polarised.
  - For glass $\theta_p$ = $\tan^{-1}(1.5) \approx 57^0$

For water $\theta_p$ = $\tan^{-1}(1.33) \approx 53^0$

Law of Malus: If light passes through two successive polarizers, the emerging light has intensity $I = I_1 \cos\theta$.

Where $I_1$ is the intensity that falls on the 2nd polariser and $\theta$ is the angle between the polarizing directions of two polarizers and $I_1 = \frac{I_0}{2}$ ($I_0$ =intensity of unpolarized light)