①

MODEL ANSWER

AS-4006

B.Tech. (First Year) (Course-A) Examination
2013
ENGINEERING PHYSICS-I
Maximum Marks : 60

Section - A

1. Choose the correct answer : 10 x 2 = 20

(i) (c) (ii) (b) (iii) (a) (iv) (a) (V) (C)
(Vi) (d) (Vii) (b) (viii) (a) (ix) (b)
(X) (a)

Section - B 5 X 8 = 40

UNIT - I

2. Explain briefly how the mass of an object varies with velocity? Derive the Einstein's mass-energy equivalence equation.

Ans. :-

If m be the mass of an object when it is moving with a velocity v then

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} \quad -(1).$$

Equation (1) is the relativistic formula for the variation of mass with velocity.

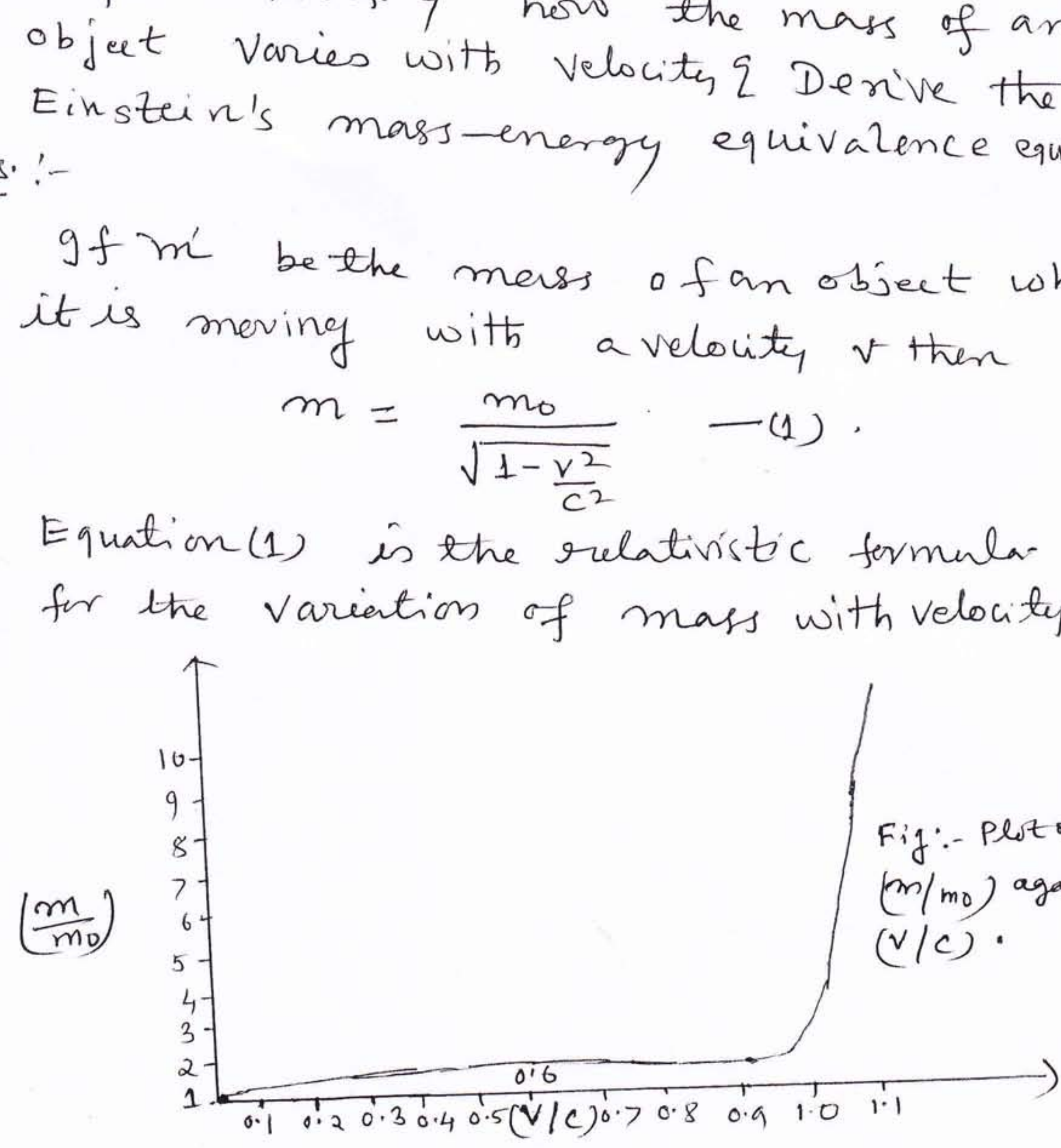


Fig:- Plot of (m/m0) against (v/c).

From eq.(1), it is clear that as the velocity of moving object increases, its mass also increases. When $v \to c$, i.e., when the velocity of moving object is equal to the velocity of light, then $m \to \infty$; i.e., the object travelling at speed of light would have infinite mass. This means that no material particle can move with a velocity equal to or greater than the speed of light. When $V << c$, the term $(V/c)^2$ in denominator of eq.(1) becomes negligible and hence $m = m_0$.

The force applied on a particle of mass 'm' moving with relativistic velocity ($v \simeq c$) is given by

$$\vec{F} = \frac{d(m\vec{v})}{dt} \quad \text{—(2)}$$

As mass varies with velocity, we have

$$\vec{F} = m\frac{d\vec{v}}{dt} + \vec{v}\frac{dm}{dt} \quad \text{—(3)}$$

When the particle of mass 'm' displaces through a distance 'dx' in time interval 'dt' under influence of the force $\vec{F}$, the increase in kinetic energy will be equal to the workdone by the force, i.e.,

$$dE_K = \vec{F}\cdot\vec{dx} = \left[m\frac{d\vec{v}}{dt} + \vec{v}\frac{dm}{dt}\right]\cdot\vec{dx}$$

$$dE_K = m\frac{d\vec{v}}{dt}\vec{dx} + \vec{v}\frac{dm}{dt}\cdot\vec{dx}$$

$$dE_K = m\frac{d\vec{x}}{dt}\vec{dv} + \vec{v}\frac{d\vec{x}}{dt}dm$$

$$dE_K = m\vec{v}\,\vec{dv} + v^2 dm \quad \left(\text{Because } \vec{v} = \frac{\vec{dx}}{dt}\right) \quad \text{—(4)}$$

According to the variation of mass with velocity

$$m = \frac{m_o}{\sqrt{1 - v^2/c^2}}$$

$$m^2 = \frac{m_o^2}{(1 - v^2/c^2)}$$

$$m^2c^2 - mv^2 = m_o^2c^2$$

$$m^2c^2 = m_o^2c^2 + m^2v^2 \quad \text{—(5)}$$

Differentiating eq.(5), we get.

$$c^2\cancel{2}\cancel{m}\,dm = m^{\cancel{2}}\cancel{2}v\,dV + v^2\cancel{2}\cancel{m}\,dm$$

[differentiation of $m_o^2c^2$ will be zero]

$$c^2\,dm = mv\,dV + v^2\,dm \quad \text{—(6)}$$

Comparing eq.(4) and (6), we get

$$dE_K = c^2\,dm \quad \text{—(7)}$$

From eq.(7), it is clear that change in KE is directly proportional to a change in mass 'dm'. The total change in KE can be obtained by integrating eq.(7) between the limits (m, mo), i.e.,

$$E_K = \int_0^{E_K} dE_K = c^2\int_{m_o}^{m} dm = c^2[m]_{m_o}^{m}$$

$$E_K = c^2(m - m_o) \quad \text{—(8)}.$$

Equation(8) shows that increase in KE of the particle. is due to the increase in mass.

$$E_K = c^2\left[\frac{m_o}{\sqrt{1-v^2/c^2}} - m_o\right] = m_oc^2\left[\frac{1}{\sqrt{1-\frac{v^2}{c^2}}} - 1\right]$$

If $v << c$, $v^2/c^2 << 1$ and hence, we have

$$\frac{1}{\sqrt{1-v^2/c^2}} = \left(1-\frac{v^2}{c^2}\right)^{-1/2} = \left(1+\frac{1}{2}\frac{v^2}{c^2}\right)$$

Therefore,

$$E_K = m_0\cancel{c^2}\left[\cancel{1} + \frac{1}{2}\frac{v^2}{\cancel{c^2}} - \cancel{1}\right] = \frac{1}{2} m_0 v^2 \quad — (9)$$

It is clear from eq.(9) that at $v << c$, the relativistic formula of K.E. reduces to the classical formula.

One can re-write eq.(8) as

$$mc^2 = E_k + m_0c^2 \quad — ⑩$$

If the total energy E of the particle is interpreted as mc^2, then eq.(10) indicates that the total energy is sum of rest energy and energy due to motion E_K.

$$E = E_0 + E_K$$

where, $E = mc^2$ & $E_0 = m_0c^2$.

When $E_K = 0$, the particle is motionless. However, it possesses rest energy, i.e.,

$$E = E_0 = m_0c^2,$$

where E_0 is called the rest energy.

—— × —— × —— × ——

2. Compute the 'm' and 'v' of an electron having total energy 1.5 MeV. Given $m_0 = 9.11 \times 10^{-31}$ kg and $c = 3 \times 10^8$ m/s.

Ans:- $E_K = 1.5 \text{ MeV} = 1.5 \times 10^6 \times 1.6 \times 10^{-19}$ Joule

$$E_K = (m - m_0)c^2 = (m - 9.11 \times 10^{-31})(3 \times 10^8)^2$$

$$(m - 9.11 \times 10^{-31}) = \frac{1.5 \times 10^6 \times 1.6 \times 10^{-19}}{(3 \times 10^8)^2},$$

$$m = 3.58 \times 10^{-30} \text{ kg}$$

$$V = c\sqrt{\left(1 - \frac{m_0^2}{m^2}\right)} = 3 \times 10^8 \times \sqrt{1 - \left(\frac{9.11 \times 10^{-31}}{3.58 \times 10^{-30}}\right)^2}$$

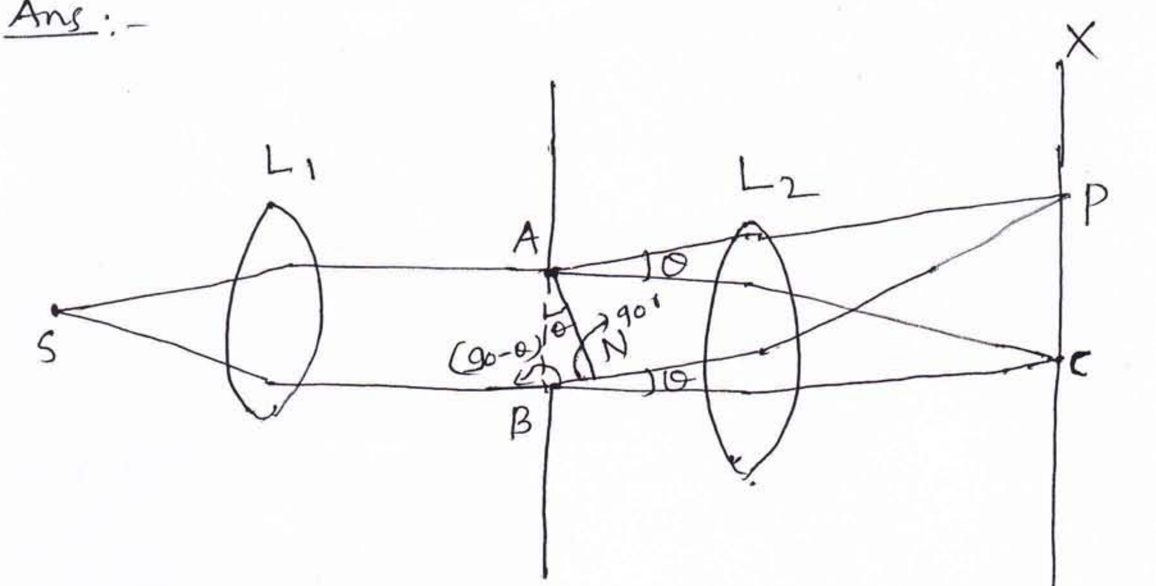
$$V = 2.9 \times 10^8 \text{ m/s}$$

—— × ——

UNIT – II

3. Derive an expression for the intensity distribution due to Fraunhofer diffraction at a single slit and show that intensity of the first subsidiary maximum is about 4.5% of that of the principal maximum.

Ans :-



Let S is point monochromatic source of light of wavelength 'λ' place at the focus of collimating lens L1. Light beam is incident normally from 'S' on a narrow slit AB of width 'e' and is diffracted from it. The diffracted beam is focused at the screen 'XY' by another converging lens L2. According to Huygen's wave theory, every point in 'AB' send out secondary wavelets in all directions. The undeviated rays from AB are focussed at 'c' on the screen by the lens L2, while the diffracted ray with angle θ are focussed at 'p' on the screen. The rays from the ends 'A' and 'B' reach at 'C' in the same phase and hence, intensity is maximum. In order to calculate intensity at point 'p', the normal 'AN' be drawn on 'BN'.

since the path beyond AN is same, the path difference between secondary wavelets from `A' and `B' in direction θ is `BN'

$$BN = AB\sin\theta = e\sin\theta.$$

$$[AB = e = \text{Width of the slit}]$$

or phase difference $= \frac{2\pi}{\lambda} e\sin\theta$ —(1)

Let AB is divided in to `n' equal parts and amplitude of the Wave ~~front~~ from each part is `a' (because ~~of~~ width of each part is same). The phase difference between any two consecutive waves from these parts would be,

$$\frac{1}{n}[\text{Total phase}] = \frac{1}{n}\left[\frac{2\pi}{\lambda} e\sin\theta\right] = \delta.$$ —②

According to theory of composition of n-vibrations each of amplitude `a' and common phase difference `δ' between successive vibrations, the resultant amplitude at `P' is given by

$$R = \frac{a\sin\left(\frac{n\delta}{2}\right)}{\sin(\delta/2)}$$

$$R = \frac{a\sin\left[\frac{n}{\cancel{2}}\cdot\frac{1}{n}\frac{\cancel{2}\pi}{\lambda}e\sin\theta\right]}{\sin\left[\frac{1}{n}\frac{\cancel{2}\pi e\sin\theta}{\cancel{2}\lambda}\right]}$$

Let us assume $\alpha = \frac{\pi e\sin\theta}{\lambda}$

$$R = \frac{a\sin\alpha}{(\alpha/n)}$$ —(3)

since for large value of n, α/n is very small, $\sin(\alpha/n)$ may be replaced by (α/n). Therefore, we get

$$R = \frac{a\sin\alpha}{\alpha/n} = \frac{na\sin\alpha}{\alpha}$$

where $n \to \infty$ and $a \to 0$, but product $na = A$ remains finite.

$$R = A\frac{\sin\alpha}{\alpha} \quad \text{—(4)}$$

The intensity at 'p' is proportional to the square of the amplitude. Taking constant of proportionality as unity, the resultant intensity at 'p' is given by

$$I = A^2\left(\frac{\sin\alpha}{\alpha}\right)^2 \quad \text{—(5)}$$

Principal Maxima :-

The expression for resultant amplitude 'R' can be written in ascending power of α as

$$R = \frac{A}{\alpha}\left[\alpha - \frac{\alpha^3}{3!} + \frac{\alpha^5}{5!} - \frac{\alpha^7}{7!} + \cdots\right]$$

$$R = A\left[1 - \frac{\alpha^2}{3!} + \frac{\alpha^4}{5!} - \frac{\alpha^6}{7!} + \cdots\right] \quad \text{—(6)}$$

From eq. (6), it is clear that 'R' will be maximum if the negative terms in eq. (6) vanish. This is possible only when $\alpha = 0$ or

$$\alpha = \frac{\pi e\sin\theta}{\lambda} = 0 \quad \text{or} \quad \theta = 0.$$

⑧

The resultant intensity at 'p' will be maximum for $\theta = 0$ and called the principal maxima. Hence intensity of principal maxima is A^2 because maximum value of R is A.

Minimum Intensity Position

It is clear from eq. (5) that intensity will be minimum when $\sin\alpha = 0$ but $\alpha \neq 0$. the values of α which satisfy this equation are

$$\alpha = \pm m\pi, \quad \text{where } m = 1, 2, 3, \ldots$$

or

$$\frac{e\pi \sin\theta}{\lambda} = \pm m\pi$$

$$\boxed{e \sin\theta = \pm m\lambda} \quad \text{— ⑦}$$

The value of $m = 1, 2, 3 \ldots$ gives the directions of first, second, third -- minima. The value of $m = 0$ is not admissible because for this value, $\theta = 0$ which corresponds to principal maximum.

Secondary Maxima

In addition to principal maxima, there are weak secondary maxima between equally spaced minima. The position can be obtained with the rule of finding maxima and minima of function in calculus. Differentiating the expression of 'I' given in eq. (5) with respect to 'α' and equaling to zero, we get

$$\frac{dI}{d\alpha} = \frac{d}{d\alpha}\left\{A^2\left(\frac{\sin\alpha}{\alpha}\right)^2\right\} = 0$$

$$A^2 \, 2\frac{\sin\alpha}{\alpha}\left\{\frac{\alpha\cos\alpha - \sin\alpha}{\alpha^2}\right\} = 0$$

obviously, either $\frac{\sin\alpha}{\alpha} = 0$ or

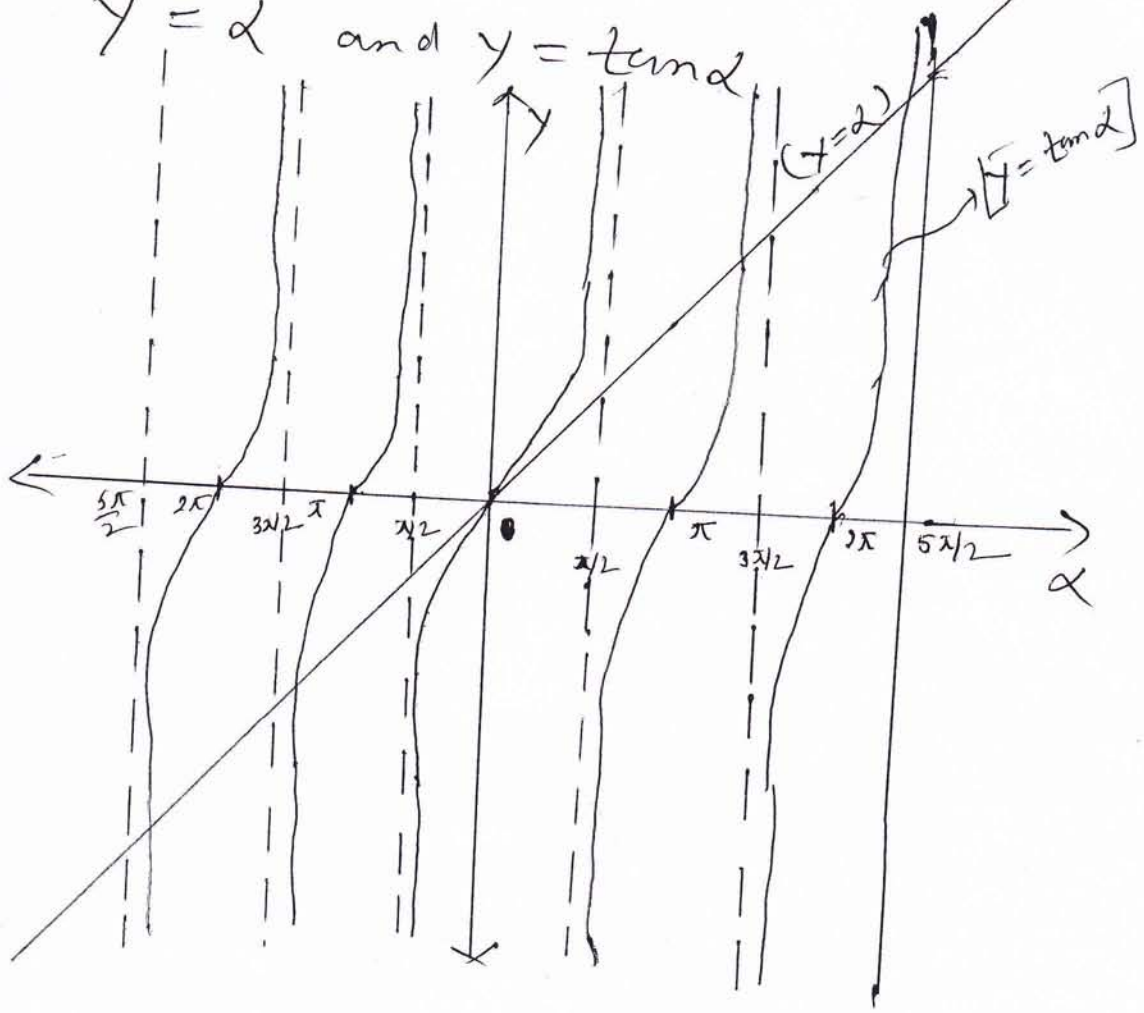
$\alpha \cos\alpha - \sin\alpha = 0 \Rightarrow \alpha = \tan\alpha.$ —⑧

$\left(\frac{\sin\alpha}{\alpha}\right) = 0$ gives the values of α (except for $\alpha = 0$) for which the intensity is zero on screen. Hence the position of secondary maxima is given by

$$\boxed{\alpha = \tan\alpha} \quad \text{—⑨}$$

The values of α satisfying eq. (9) are obtained graphically by plotting the curves

$Y = \alpha$ and $y = \tan\alpha$



The equation $y = \alpha$ gives a straight line passing throught the origin and making an g angle 45° with x-axis. The equation $y = \tan\alpha$ gives a discontinuous curve. The point of intersection of these two curves gives the value of 'α' satisfying equation $\boxed{\alpha = \tan\alpha}$. The points of intersections are

$$\alpha = 0, \pm\frac{3\pi}{2}, \pm\frac{5\pi}{2} \text{ -- etc.}$$

The first value $\alpha = 0$ gives the position of principal maxima while the value of $\alpha = \pm\frac{3}{2}\pi, \pm\frac{5}{2}\pi, \pm\frac{7\pi}{2}$ .. gives the position of first secondary maxima, Second secondary maxima, third secondary maxima and so on, respectively. After substituting values of α in eq. ⑤, we get intensities at various maxima as

$$I_0 = A^2 \text{ (Principal maxima)} \quad \text{—(10)}$$

$$I_1 = A^2\left[\frac{\sin(3\pi/2)}{3\pi/2}\right]^2 = A^2/22 \quad \text{—(11)}$$

I_1 = intensity first subsidary (Secondary) maxima.

$$I_2 = A^2\left[\frac{\sin(5\pi/2)}{5\pi/2}\right] = \frac{A^2}{62} \quad \text{—(12)}$$

I_2 = intensity of second subsidary (Secondary) maxima.

From eq. (11), we have $I_1 = (I_0)0.045$, which says that the intensity of first subsidiary maximum is about 4.5% of that of principal maximum.

3(a). In Newton's ring experiment, the diameter of the 15th ring was found to be 0.590 cm and that of the 5th ring was 0.336 cm. If the radius of the plano-convex lens is 100 cm, calculate the wavelength of light used.

Ans.:-

$$D_{15} = 0.590\,cm = 0.590 \times 10^{-2}\,m$$

$$D_5 = 0.336\,cm = 0.336 \times 10^{-2}\,m$$

$$p = (15-5) = 10, \quad R = 100\,cm = 1.0\,m$$

$$\lambda = \frac{D_{n+p}^2 - D_n^2}{4pR} = \frac{(0.590 \times 10^{-2})^2 - (0.336 \times 10^{-2})^2}{4 \times 10 \times 1.0}$$

$$\lambda = 5880 \times 10^{-10}\,m$$

$$\boxed{\lambda = 5880\,\text{Å}}$$

3(b). Newton's rings are observed in reflected light of wavelength 5900 Å. The diameter of the 10th dark ring is 0.5 cm. Find the radius of curvature of the lens and thickness of the air film.

Ans:-

$$\lambda = 5900 \times 10^{-10}\,m, \quad n = 10$$

$$D_n = 0.5\,cm = 5 \times 10^{-3}\,m$$

(i) The diameter of the dark ring is given by $D_n^2 = 4n\lambda R \Rightarrow R = \frac{D_n^2}{4n\lambda}$

$$R = \frac{(5 \times 10^{-3})^2}{4 \times 10 \times 5900 \times 10^{-10}} = 1.059\,M$$

(ii) The thickness of the air film is given by

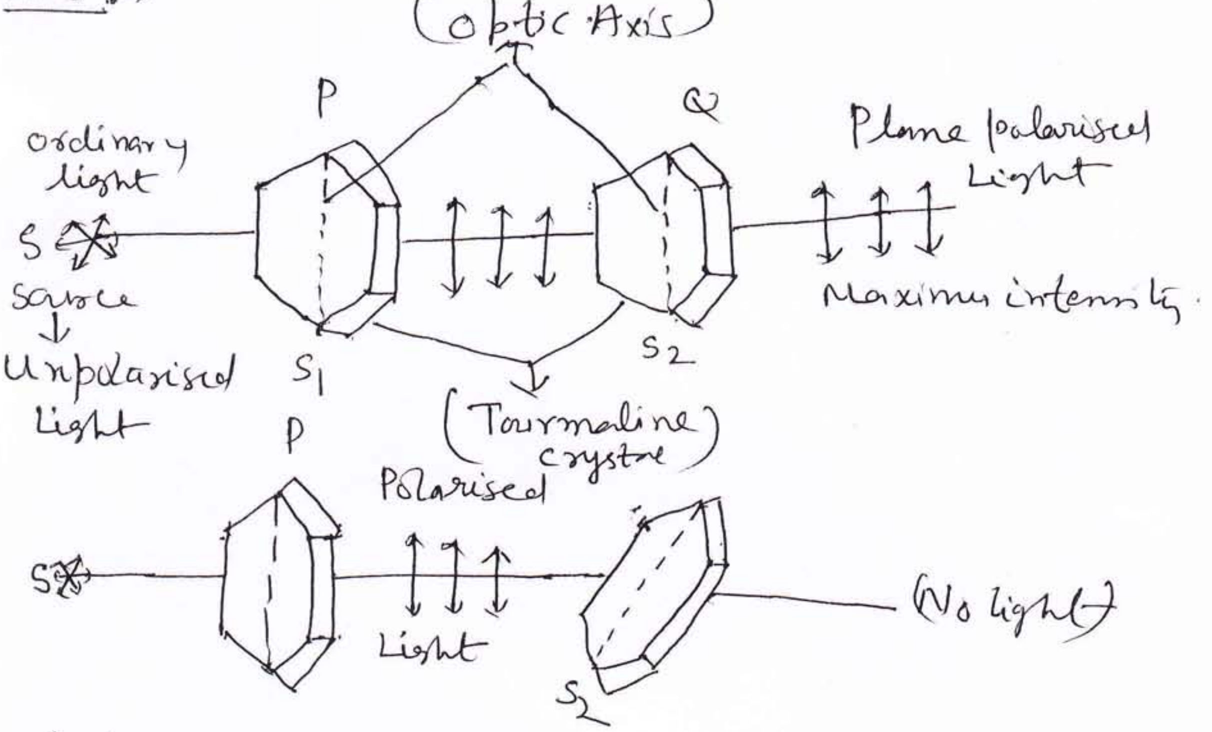
$$2t = n\lambda \Rightarrow t = n\lambda/2$$

$$t = \frac{10 \times 5900 \times 10^{-10}}{2} = 2.95 \times 10^{-6}\,m$$

UNIT-III

4. What is a polarised light? How will you produce and detect plane, ellipically and circularly polarised light? Describe the Laurent's half-shade palarimeter and explain how will you use it to determine the specific rotation of Sugar solution?.

Ans:-



A beam of ordinary light coming out of source 'S' is allowed to pass through a pair of tourmaline crystals. 'P' and 'Q' are two tourmaline crystals. When the optic axis of the crystals 'P' and 'Q' are parallel, the light passes out of 'Q'. However, when the crystal 'Q' is rotated, the intensity of light decreases and becomes zero when the optic axis of 'Q' is perpendicular to the optic axis of crystal 'P'. It is also clear from the above figure that the light after passing through the first crystal 'P' is not symmetrical about the direction of propagation, and its vibrations are confined only to a single line in a plane perpendicular to the direction of propagation.

Thus, the light which has acquired the property of one-sideness is called polarised light.

Production of plane, circularly and ellipfically Polarised light

(i) Plane Polarised Light:

When an ordinary monochromatic beam of light is passed through a Nicol prism, it splits into O-ray and E-ray. The O-ray is totally internally reflected at the Canada Balasm layer, while the extra-ordinary ray passes through Nicol prism. This emergent ray is plane palarised light

(ii) circularly Polarised light

When the ordinary light is passed through a Nicol prism, the emergent light is plane polarised. This plane palarised light is allowed to fall on a quarter wave plate such that angle between the optic axis and vibration of plane polarised light 45°. The light emerging from quarter wave plate is circularly polarised.

(iii) Elliptically polarised Light

When the ordinary light is passed through a Nicol prism, the emerging light from the Nicol prism is plane polarised. This plane palarised light is then allowed to fall on a quarter wave plate such that the angle between the optic axis and the vibration of plane polarised light is θ, where θ may ~~be~~ have value other than 0°, 45° and 90°.

The Light emerging out of the quarter wave ~~plat~~ plate is elliptically polarised light. For $\theta = 0^\circ$ and 90° the emergent light remains plane polarised.

Detection of Plane, circularly, and Elliplically Polarised Light

To detect or analyse the plane, cicularly or elliplically polarised light, the light under test is ~~plan~~ passed through another rotating Nicol Prism and variation in intensity of the emerging light is noted. There are following possibilities:

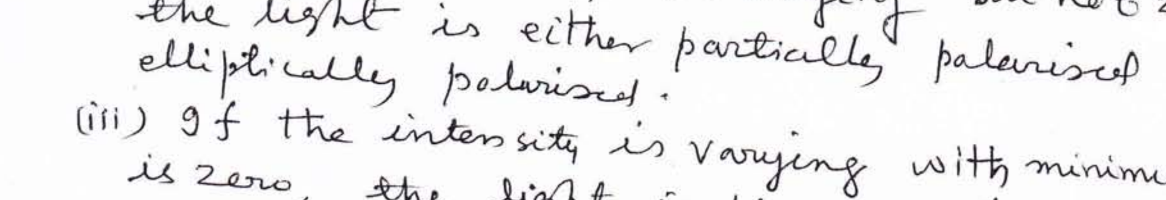
(i) If there is no change in the intensity the light is either unpolarised or circularly polarised.

(ii) If the intensity is varying but not zero the light is either partially polarised or elliplically polarised.

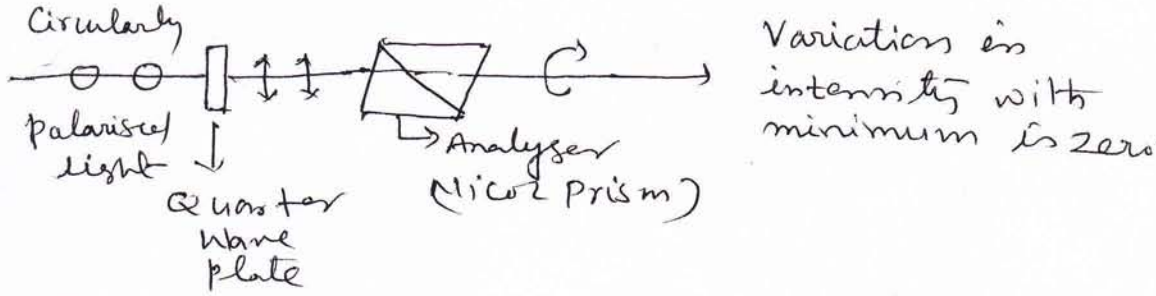
(iii) If the intensity is varying with minimum is zero, the light is plane polarised.

To differentiate between unpolarised and circularly polarised lights, the light under test is first passed normally through a quarter wave-plate and then viewed through another rotating Nicol prism. There are following possibilities:

(i) If there is no variation in intensity, the light under test is unpolarised.



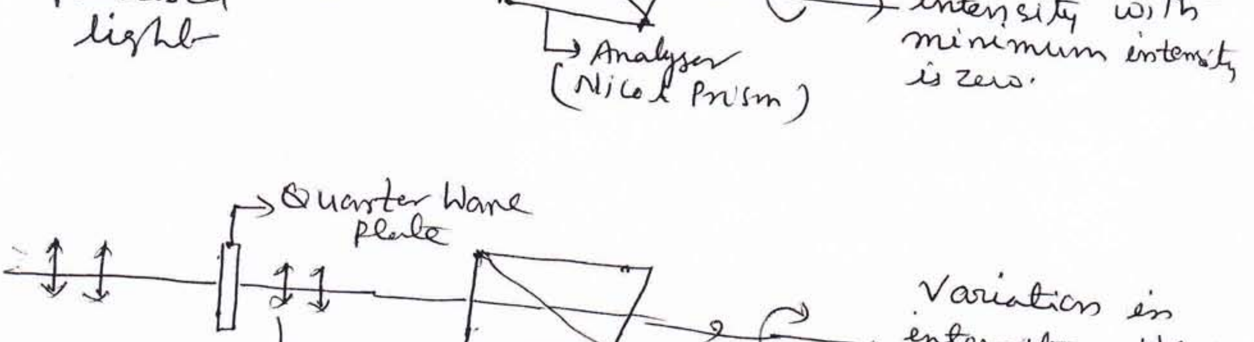
(ii) If there is variation in intensity with minimum is zero, the light under test is circularly polarised.

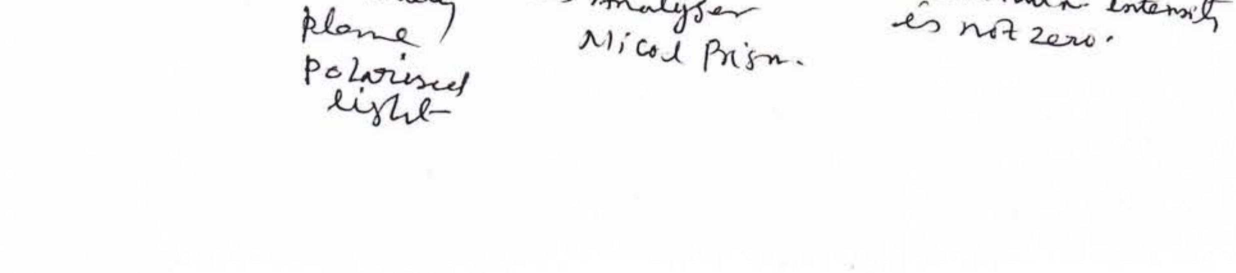


To differentiate between partially and elliplically polarised light, the light under test is passed normally through a quarter wave plate and then viewed through another rotating Nicol prism. There are following possibilities.

(i) If there is variation in intensity with minimum intensity is zero, the light is elliplically polarised.

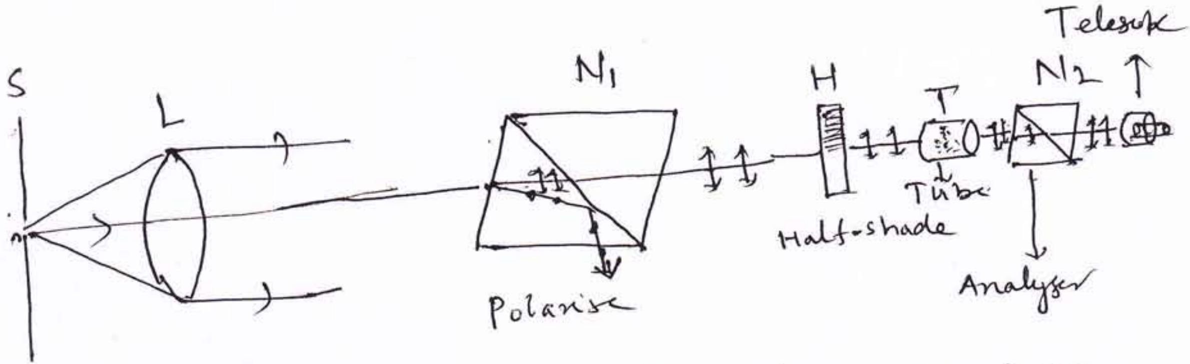
(ii) If there is variation in intensity with minimum is not zero, the light under test is partially plane polarised.





Laurent's Half-shade Polarimeter

It is an optical device, which is used for measuring the optical rotation of optically active substance..



It consists of two nicols N1 and N2, that are capable of rotation about a common axis and mounted in a brass-tube, placed at some distace apart. A glass tube 'T' of large diameter is provided which is filled with the solution of an optically active substance. Monochromatic light of wavelength λ is rendered ~~by~~ parallel by lens 'L'. It falls on the polariser N1, which converts the unpolarised light into plane polarised light. This plane polarised light now enters the half-shade device 'H' and then through the solution, whose specific rotation is to be determined. The transmitted light from 'H' passes through the analyser N2. The light emerging from N2 is viewed through a telescope G.

Determination of Specific Rotation of Sugar Solution :-

The following procedure is adopted to measure the specific rotation of sugar solution using polarimeter:

(1) The tube is first filled with water and analyser is adjusted to obtain the condition of equal brightness in the field of view of two halves and reading is noted.

(2) The water is replaced by sugar solution of known concentration. The analyser is rotated to obtain the condition of equal brightness in the field of view of two halves and the reading is noted.

(3) The differense of two reading gives the angle of rotation (θ) for that concentration.

(4) The experiment is repeated with solution of different concentration and the corresponding θ is determined.

(5) A graph is plotted between 'θ' and 'c', which is straight-line as shown in Figure-

(6) The slope of curve gives the ratio (θ/c).

(7) The specific rotation is calculated with the help of the expression

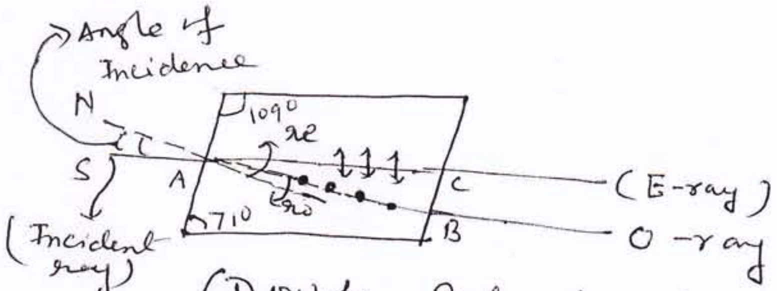
$$\boxed{\alpha = \frac{10\theta}{l\,c}}$$

, where 'l' is the length of tube in cm.

——— × ———

4. What is the phenomena of double refraction? Write the characteristic of ordinary and extra-ordinary rays and describe the construction and action of Nicol prism.

Ans :- When unpolarised light is passed through a uniaxial calcite crystal, it splits into two refracted rays. One of the refracted ray obeys the laws of refraction and is called the ordinary rays (O-ray). However, other refracted ray does not obey the laws of refraction and is called the extra-ordinary ray (E-ray). Hence, if an object is viewed through such a crystal, two images of the object are seen, one due to O-ray and the other due to E-ray. This phenomena is known as double refraction. Both the rays, i.e., O-ray and E-ray are plane polarised. The vibration of the ~~ord~~ ordinary ray are perpendicular to the principal section of the crystal. On the other hand, the vibrations of the extra-ordinary ray are in the plane of principal section.



(Double Refraction Phenomena)

A ray of light `SA' from point source is incident on the calcite crystal at an angle of incidence `i' as shown in the above figure'. It is refracted along two path `AB' and `AC' making ~~and ang~~ angles of refraction r_o and r_e, respectively. These rays emerge out along `CE' and `BO' parallel to eachother. Thus, two images `O' and `E' can be obtained on the screen.

For ordinary ray, the refractive index is given by

$$\mu_o = \frac{\sin i}{\sin r_o} = \text{Constant},$$

whereas for extra-ordinary ray (E-ray),

$$\mu_e = \frac{\sin i}{\sin r_o} \neq \text{constant}.$$

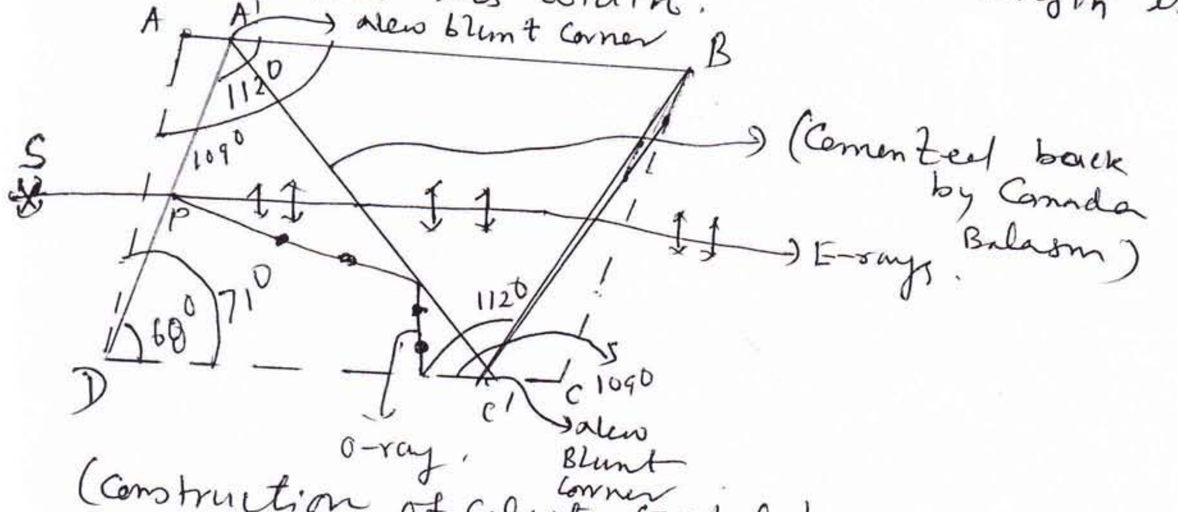
In calcite crystal, $r_e > r_o$ and hence $\mu_o > \mu_e$, which means that the velocity of light for o-ray inside the crystal is less than the velocity of E-ray, i.e., $V_o < V_e$. Such crystals are called uniaxial negative crystals. In quartz crystal, $r_e < r_o$ and therefore, $\mu_o < \mu_e$ which suggests that $V_o > V_e$. Such crystals are called as uniaxial positive crystals.

Nicol Prism

Nicol Prism is an optical device made from a calcite crystal and used in many optical instruments for producing and analysing plane polarised light.

Construction of Nicol prism

Nicol Prism is calcite crystal with a principal section ABCD whose length is three times its width.



(Construction of Calcite crystal)

The end faces AD and BC of the crystal cut down in suchaway ~~that~~ they make angles of 68° and 112° in principal section instead of 71° and 109°. In this situation, the new blunt corners will be A' and C'. The crystal is then cut into two pieces from one blunt corner A' to another ~~but~~ blunt corner C' along a plane A'C' perpendicular to principal section ABCD. The two cut surfaces are polished optically flat and then cemented back together with a special cement called Canada Balasm. Canada Balasm is transparent liquid whose refractive index lies between the refractive indices of Calcite crystal for the O-ray and E-ray.

$$\mu_E < \mu_{CB} < \mu_O$$

Thus Canada Balasm is optically more denser than calcite for E-ray and less denser for O-ray.

Action

When unpolarised light SP (see Figure) parallel to DC' is incident on the face A'D, it splits into O-ray and E-ray whose vibrations are respectively perpendicular and parallel to the principal section of Nicol prism. The O-ray suffers total internal reflection at the Canada Balasm surface for nearly normal incidence because Canada Balasm is optically more denser than Calcite for E-ray and less denser for the O-rays. The E-ray is refracted through Canda Balasm and is transmitted.

(21)

Nicol Prism as Polariser and Analyser

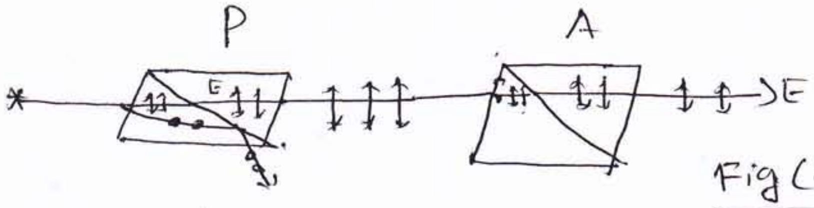


Fig (a)

Nicol prism can be used as polariser and Analyser. When an unpolarised light is incident on a Nicol prism 'P', the ray emerging from 'P' is plane polarised with vibrations in principal section of 'P' (E-ray). If this ray falls on a second prism 'A', whose principal section is parallel to that of 'P', its vibrations will be in the principal section of 'A'. Hence the ray will behave as E-ray in prism A and will be completely transmitted. The intensity of emergent light will be maximum.

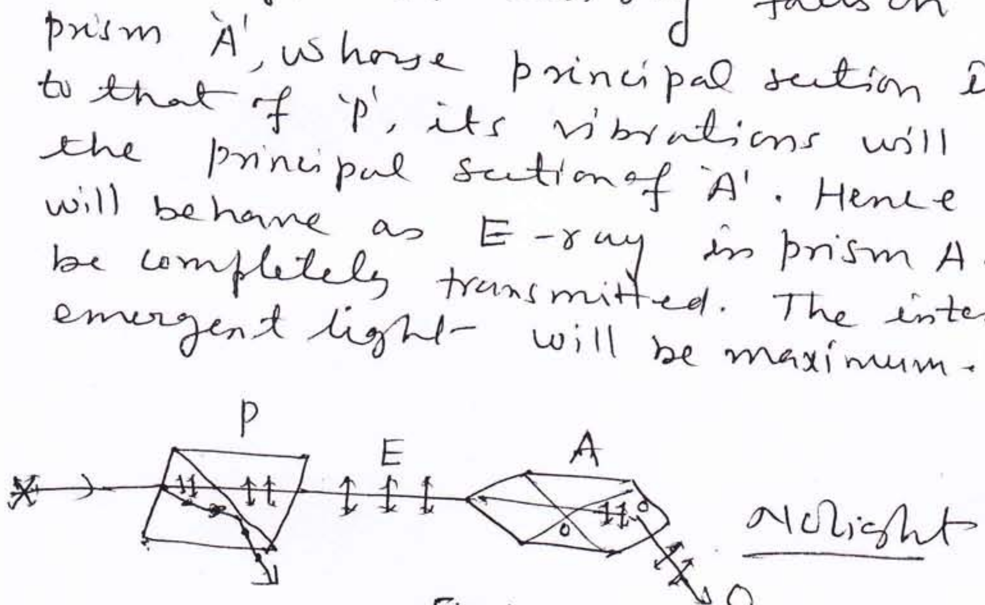


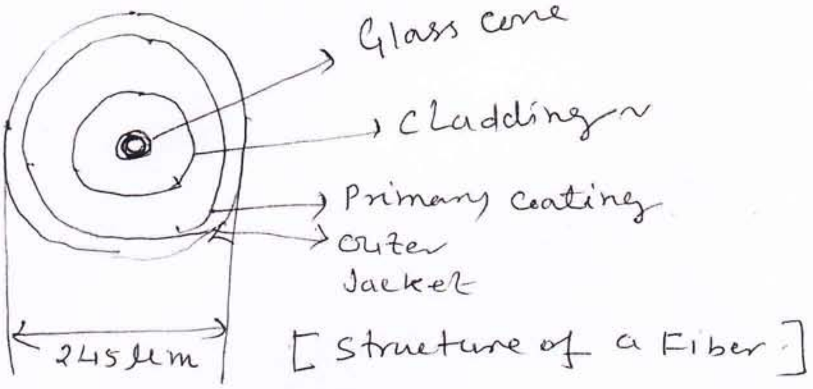
Fig. (b)

Now if the Nicol prism 'A' be rotated such that its principal section becomes perpendicular to that of 'P', the vibrations of plane polarised ray will behaves as O-ray inside 'A' and will lost by the total internal reflection at Canada Balsam surface. Therefore, no light will emerge from 'A'. Here, the Nicol prism 'P' is called as 'polariser' and the Nicol prism 'A' called as 'Analyser'.

Unit - IV

5. Explain in brief types, Working principle and application of optical Fiber with neat diagram.

Ans :- An optical fiber is a glass or plastic fiber designed to guide light along its length. Fiber are used instead of metal wires because signals ~~are~~ propagates along them with less loss and they are immune to electromagnetic interference. The optical fiber is simply a cylindrical waveguide system operating at optical frequencies.

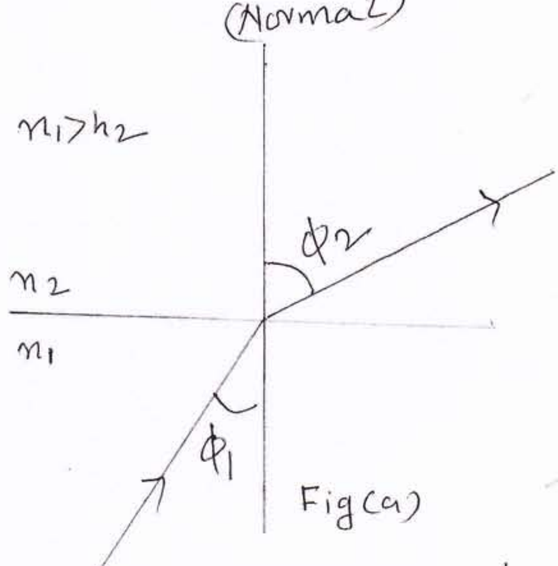


[Structure of a Fiber]

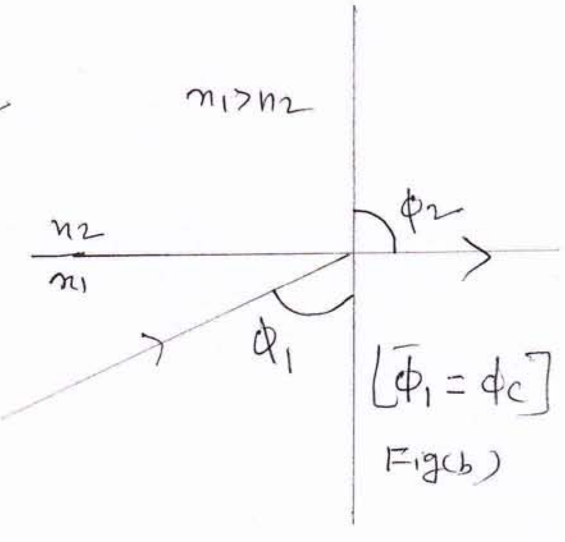
Physically a fiber optics is a very thin flexible medium having a cylindrical shape that consists of three sections, core, cladding, and protective jacket. The core is the inner most section having diameter approximately 5 μm - 100 μm is made up of glass or plastic. This core is surronded by cladding of slightly lower refractive index with a diameter ~ 125 μm, which is made up of glass and plastic. The outermost section is made of plastic or polymer or some other suitable material and used for the protection against moisture, crushing or any other environmental dangers.

Basic Principle of optical Fiber : The purpose of optical fibers is to carry light signal from one place to another place; The Fiber optics is based on the principle of refraction. Refraction ~~gevens~~ governs the behaviour of light as it passes from one trasparent medium to another and is described by Snell's law.

When light passes from denser to rarer medium, it bends away from the normal as shown below ~~below~~ in Fig(a).

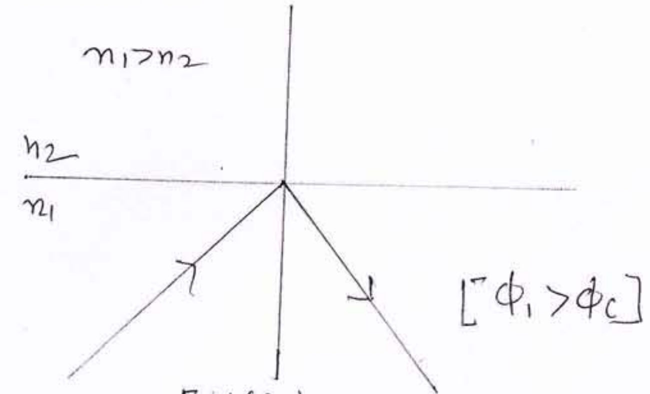


Fig(a)



$[\phi_1 = \phi_c]$

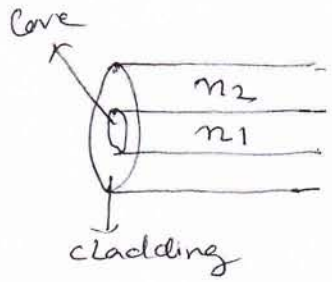
Fig(b)

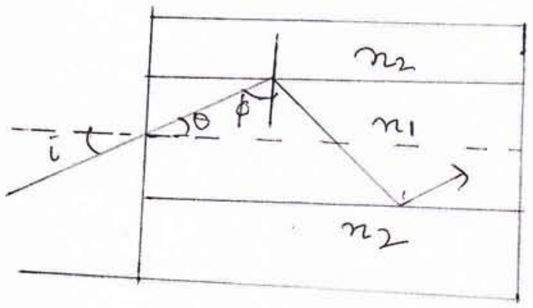


$[\phi_1 > \phi_c]$

Fig(c)

According to Snell's law → $n_1 \sin\phi_1 = n_2 \sin\phi_2$ where ϕ_1 and ϕ_2 represent the angles of incident and refraction, respectively. And n_1 and n_2 are the refractive indexes of core and cladding. If the angle of incidence ϕ_1 is increased, the refracted rays bends more and more away from the normal and at a particular angle of incidence, the refracted ray passes perpendicular to the normal. This particular angle of incidence is known as Critical angle (ϕ_c). When angle of incidece is further increased, there is total internal reflection (TIR) [Fig.(c)]. The value of critical angle of two media concerned is $\phi_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$. In optical fiber, the refractive index of n_1 of the core region is slightly more than refractive index of cladded material n_2.





For a ray entering the fiber, if the the angle of incidence ϕ (at core-cladding interface) is greater than the critical angle ϕ_c, then there is total internal reflection (TIR) at interface. Beacause of total internal reflection, the light beam can propagate through a long optical fiber even around gentle curve. Thus, the optical Fiber acts as a 'light guide' and is known as an optical 'waveguide'.

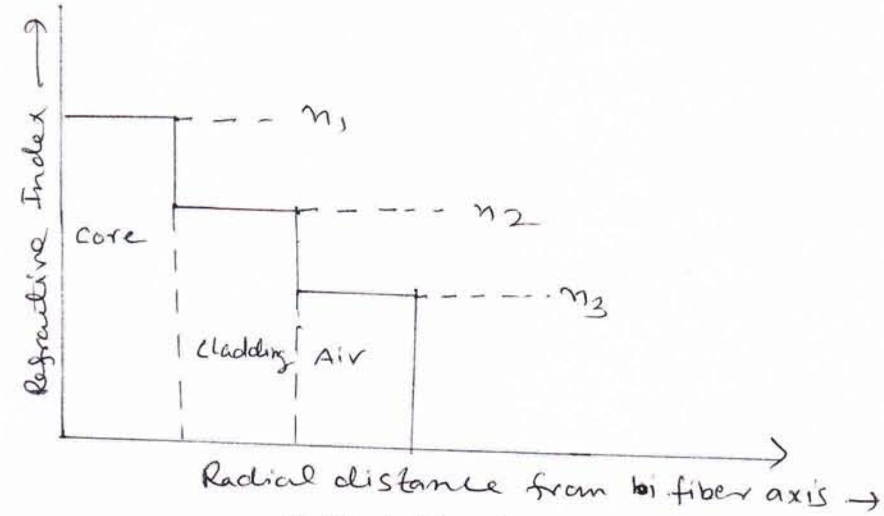
Types of Optical Fiber :- The optical Fiber can be classified mainly based on refractive index and mode of propagation.

(i) Refractive Index Profile: By ~~Condi~~ considering the refractive index of the core and cladding materials, the fiber can be classified as

(a) Step Index Fiber (SI)
(b) Graded Index Fiber (GI)
(c) W-Index Fiber

(a) Step Index Fiber (SI) :- In step index fiber core is of constant refractive index n_1 and cladding is of slightly lower refractive index n_2. Thus for this type of fiber, there is step change at core-cladding interface. The refractive index profile may be defined as

$$n(r) = n_1 \quad \text{for } r < a \text{ (core)}$$
$$n(r) = n_2 \quad \text{for } r > a \text{ (cladding)}$$



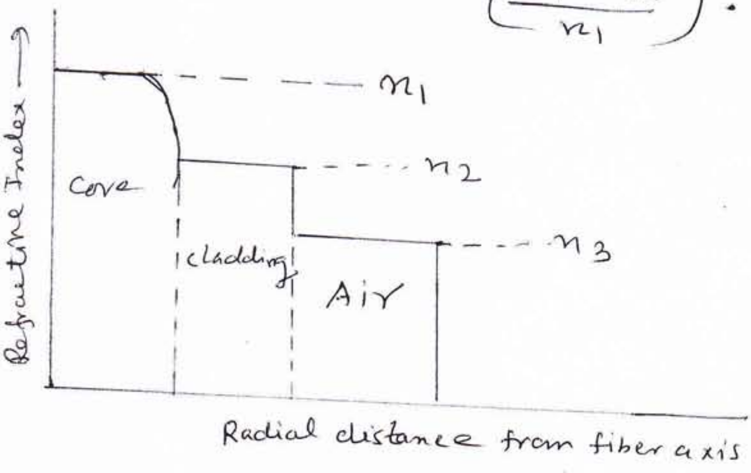
(Step Index Fiber)

(b) Graded Index Fiber :- Graded index fibers have decreasing core index $n(r)$ with radial distance from maximum value of n_1 at axis to a constant value n_2 beyond the core radius 'a'. The index variations may be given as

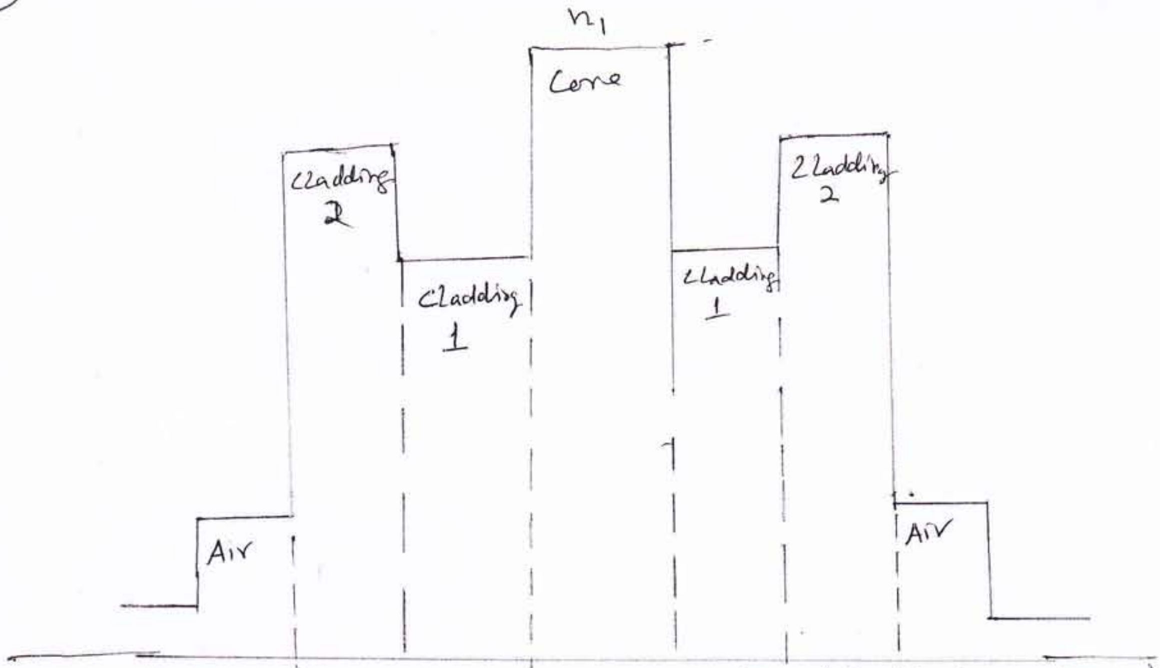
$$n(r) = n_1\left[1 - 2\Delta (r/a)^2\right]^{1/2} \quad \text{for } r<a \text{ (Core)}$$

$$n(r) = n_2\left[1 - 2\Delta\right]^{1/2} \quad \text{for } r>a \text{ (cladding)}$$

where $\Delta = \left(\frac{n_1 - n_2}{n_1}\right)$.



(c) W-Index Fiber :- In this fiber, the width of the cladding is made thick. The first cladding with refractive index n_2' is surrounded by a second thicker cladding layer with refractive index n_3 where $n_1 > n_2 > n_3$. This produced W-shaped refractive index profile.



(Refractive Index profile for W-Index Fiber)

(ii) Modal classification :- Two basic types of fibers are considered on the basis of mode of trasmission.

(a) Multimode (MM)
(b) Singlemode (SM).

Applications of optical Fibers

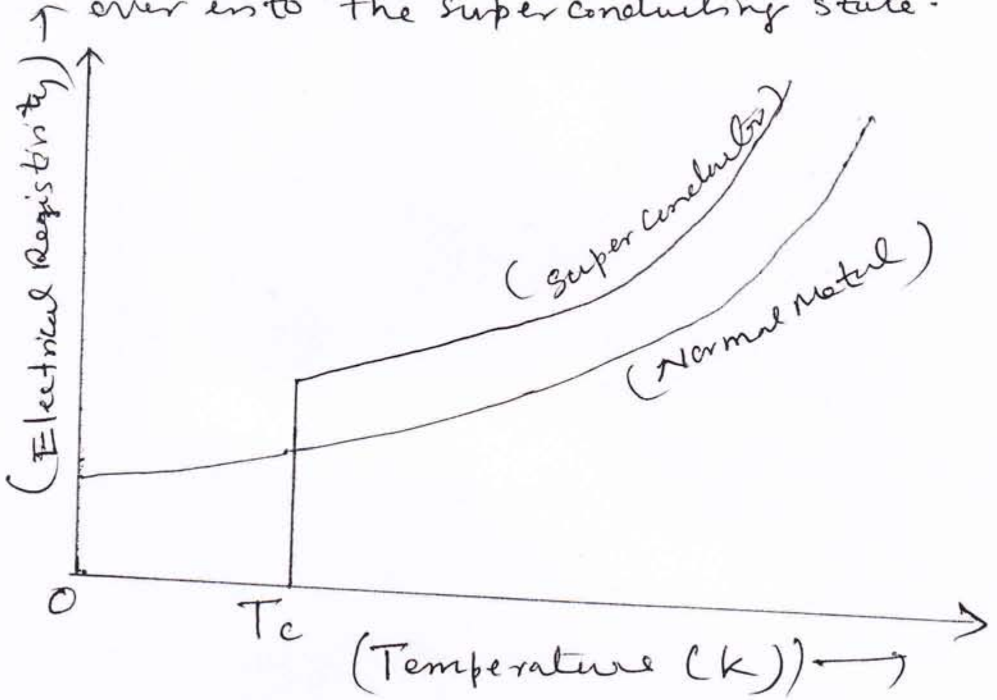
(a) Illumination and Image transmission
(b) Optical Fiber Communications.
(c) Fiber optic Sensor
(d) Endoscopes
(e) Military Applications.

Unit - IV

5. What is superconductivity phenomena? Explain in brief, characteristic, type and applications of superconductors.

Ans:-

Superconductivity :- The sudden disappearance of electrical resistance in materials below a certain temperature is known as superconductivity. The temperature at which normal material turns into a superconductor is called the critical temperature T_c. Every superconductor has its own critical temperature at which it passes over into the superconducting state.



The above plot of electrical resistivity of a normal conducting metal and a superconducting metal as function of temperature in the vicinity of 0°K. A sudden fall in resistance indicates the transition to the superconducting state.

Characteristics of Superconductors.

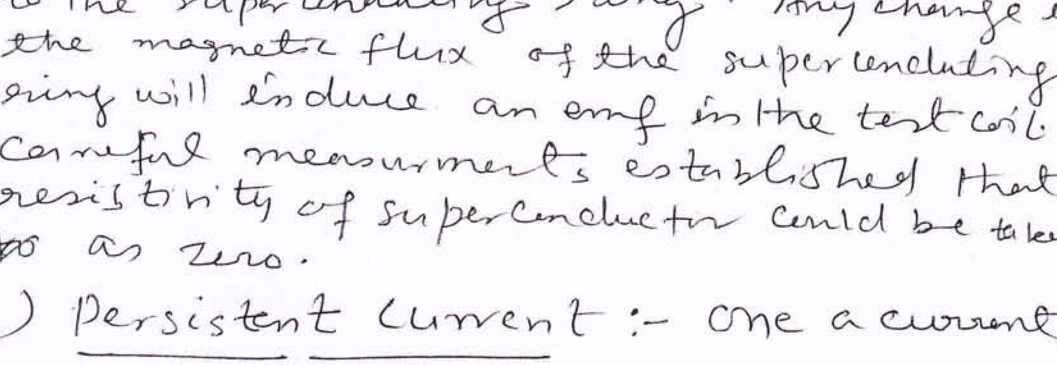
(1) Zero Electrical Resistance :- A superconductor is characterized by zero electrical resistivity. It is not fundamentally possible to test experimentally whether resistance is zero. A method devised by Onnes consists of measuring the decrease of the current in a closed ring of superconducting wire. The superconducting ring

is kept in a magnetic field and it is cooled to below the critical temperature so that it goes in to the superconducting state. When the external magnetic field is switched off, a current is induced in the ring. If the ring had a finite resistance, R, the current circulating in the ring would decrease according to the equation:

$$I(t) = I(0)\, e^{-Rt/L}$$

where 'L' is the inductance of ring. The decay current is monitored by a change in the magnetic flux through a test coil held close to the superconducting ring. Any change in the magnetic flux of the superconducting ring will induce an emf in the test coil. Careful measurments established that resistivity of superconductor could be taken ~~to~~ as zero.

(2) **Persistent Current** :- One a current is started in a closed loop of superconducting material, it will continue to keep flowing around the loop as long as the loop is held below the critical temperature. Such a steady current, which flows without diminishing in strength, is called a persistent current.



The persistent current does not need external power to maintain it because there do not exist I^2R losses. Calculation shows that once the current flow is initiated, it persists for more than 10^5 years. Superconducting coils with persistent current flowing through them produce magnetic fields and can therefore act as magnets. Such a superconducting magnet does not require power supply to maintain its magnetic field.

(3) Critical Temperature :- When temperature of superconducting material is increased, the material transforms into a normal material above the critical temperature T_c. The transition is ~~x~~ transition is reversible. When the material is cooled below T_c, it again goes into superconducting state.

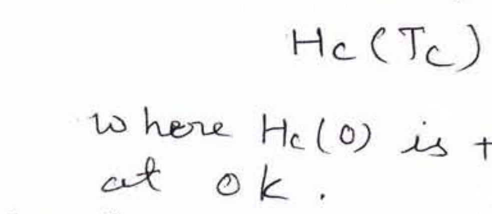
(4) Critical Magnetic field :- Superconducting state depends on the strength of the magnetic field in which the material is placed. superconductivity vanishes if sufficiently strong magnetic field is applied. The minimum magnetic field, which is necessary to regain the normal resistivity, is called the critical magnetic field H_c. When the applied magnetic field exceeds the critical value H_c, the superconducting state is destroyed and material goes into normal state. The temperature dependence of critical magnetic field can be given as

$$H_c(T_c) = H_c(0)\left[1-\left(\frac{T}{T_c}\right)^2\right]$$

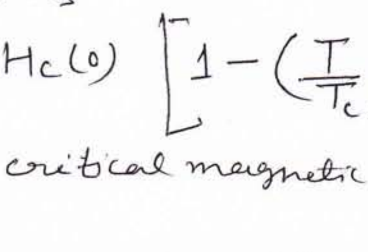
where $H_c(0)$ is the critical magnetic field at 0k.

(5) Perfect Diamagnetism - Meissner Effect :-

In 1933, Meissner & Ochsenfield found that when superconductors are ~~cottect~~ cooled below their critical temperature T_c in presence of a magnetic field, the magnetic flux is expelled from interior of the specimen and the superconductor becomes a perfect diamagnetic. This phenomena is known as Meissner effect.



(a) Normal ($T > T_c$, $H > H_c$)



(b) Superconder ($T < T_c$, $H < H_c$)

This effect is reversible. When the temperature is raised from below T_c, the magnetic flux lines suddenly penetrates the specimen at $T=T_c$ and material returns to the normal state. The magnetic induction inside the specimen is given by

$$B = \mu_0 (H+M) = \mu_0 H(1+\chi)$$

where H is the applied magnetic field and M is the magnetization produced within the specimen. At $T<T_c$, $B=0$ and therefore $\mu(H+M)=0$. Thus we have

$$M = -H.$$

The susceptibility of the material is

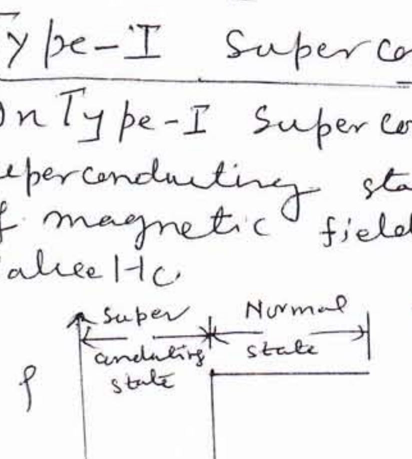
$$\chi = \frac{M}{H} = -1.$$

The specimen is therefore diamagnetic and state in which magnetization cancels the external magnetic field completely is referred to as perfect diagmagnetism.

Types of Superconductors : Superconductors are divided into two categories depending on the way in which the trasition from superconducting to normal state proceeds when the externally applied magnetic field exceeds H_c.

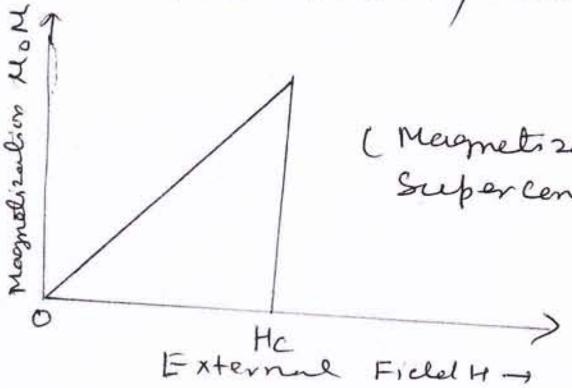
(1) Type-I Superconducter :

In Type-I Superconducters, the transition from superconducting state to normal state in presence of magnetic field occurs sharply at critical value H_c.



The resistivity ρ jump from zero to a high value at H_c.

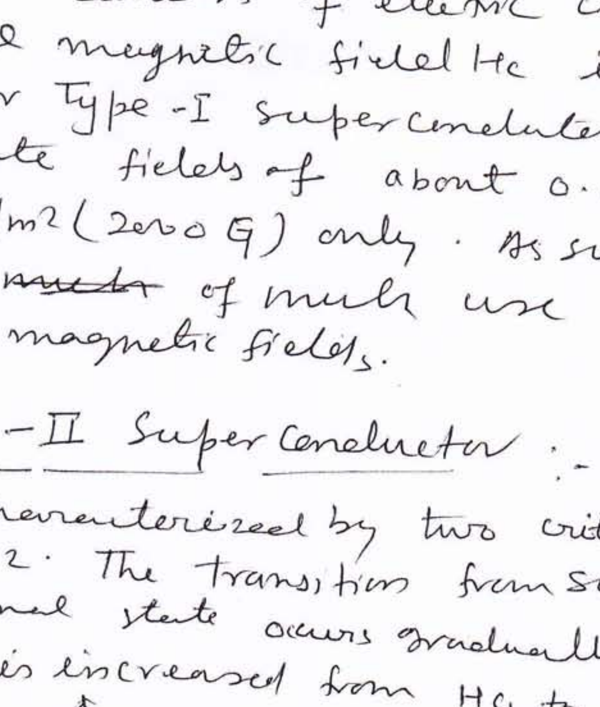
Type-I Supercondutors are perfectly diamagnetic below H_c and completely expel the magnetic field from the enterior of superconduting specimen. Upto the critical magnetic field H_c, the magnetization of the material grows in proportion to the external field and then abruptly drop to zero at transition to the normally conducting state..



(Magnetization curve for Type-I Superconductor)

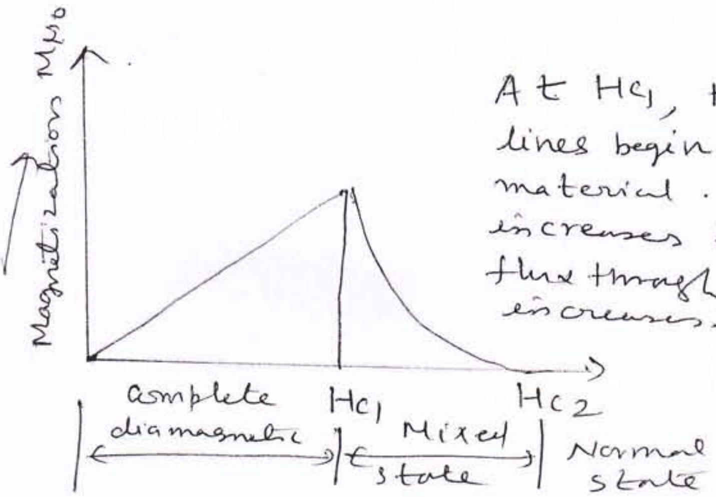
The magnetic field can penetrate only the surface layer and current can only flow in this layer. Consequently, Type-I superconductors are poor carriers of electric current. The critical magnetic field H_c is relatively low for Type-I superconductors. They would generate fields of about 0.01 Wb/m2 (100 G) to 0.2 Wb/m2 (2000 G) only. As such, they are not ~~much~~ of much use for production of high magnetic fields.

(2) **Type-II Superconductor** :- Type-II superconductors are characterized by two critical fields H_{c1} and H_{c2}. The transition from superconducting state to normal state occurs gradually as the magnetic field is increased from H_{c1} to H_{c2}.



32

The magnetization of material grows in proportion to the external field upto H_{c1} (Lower critical field). The external magnetic field expelled from the interior of the material till then. /



At H_{c1}, the magnetic field lines begin penetrating the material. As magnetic field increases further, the magnetic flux through the material increases.

At upper H_{c2}, the magnitization vanishes completly and external field has completely penetrated and destroyed the superconductivity. In the region between H_{c1} and H_{c2}, the material is in a magnetically mixed state but electrically superconductor. ~~At~~ H_{c2} can be as high as 20-50 Wb/m2 and the retention of superconductivity in such high magnetic field makes Type-II material very useful in application of creating very high magnetic field.

Applications of Superconductors

(1) The most obvious application of superconductors in power trasmission.
(2) superconducting coils can be used in trasformers and electrical machines.
(3) The superconductor are useful in many area of research and diagnostic equipments in medicine as the high magnetic fields are required there.
(4) Type-II saaperconductor can be used as very fast electronic switches.

Unit - V

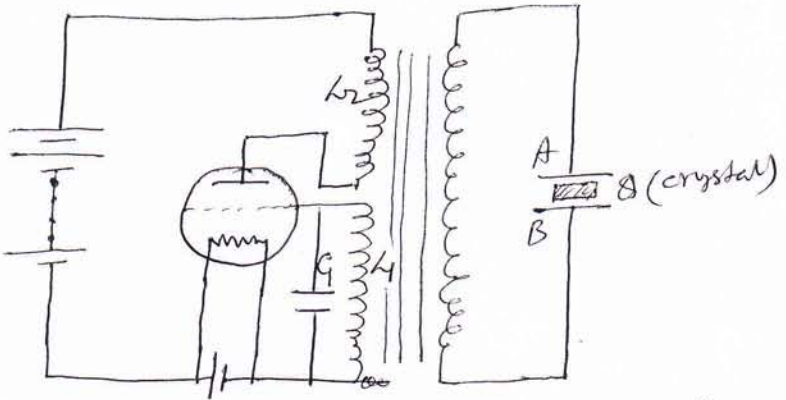
6. What are the ultrasonic waves? Explain in brief different methods for its production and write its important applications.

Waves of frequencies beyond the upper audible limit (> 20 kHz) is called ultrasonic waves. Human ear cannot sense ultrasonic sounds but dogs can. Dolphins generate ultrasonic waves and use the reflections of the waves to find their way.

Methods of production: 1. Mechanical method
2. Piezoelectric generator
3. Magnetostriction generator,

Mechanical method: Oldest method - produce upto 100 kHz with the help of Galton's whistle. - Rarely used due to limited frequency range.

Piezoelectric generator:

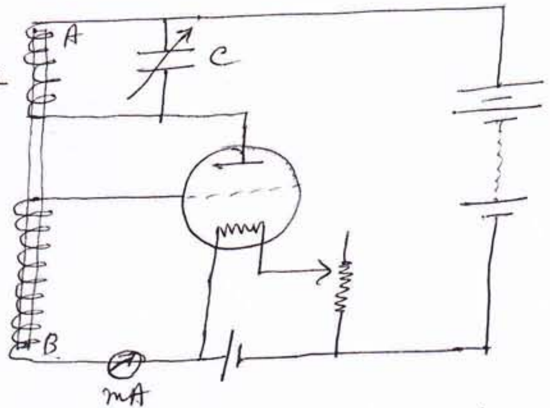


Oscillator circuit to produce emf.

When mechanical pressures are applied to the opposite faces of certain crystal (Quartz, Tourmaline) slices, then equal and opposite electric charges are developed on the other faces resulting a potential differences. The magnitude of the potential difference is proportional to the applied pressure. However, when pressure is replaced by tension, the sign of the charges is reversed. This phenomene is called piezoelectric effect.

(34) When natural frequency of the oscillator circuit coincides with the crystal frequency, resonance occurs and ~~cry~~ crystal is set into mechanical vibration due to piezoelectric effect. ~~tho~~ With a quartz crystal, ultrasonics of frequencies ~~of~~ 5,40,000 Hz can be produced.

Magnetostriction generator:



A bar of ferromagnetic material like iron/nickel changes its length when it is placed in a strong magnetic field applied parallel to its length. This changes in length is independent of the polarity of applied magnetic field. The ~~log~~ longitudinal expansion and contraction in rod produces ultrasonic sound waves in the medium surrounding the rod. If the length of the rod is such that the frequency of its vibration is equal to the frequency of the applied current, resonance occurs and thereby the amplitude of vibration is increased. Since the rod vibrates longitudinally, the frequency of the fundamental mode of vibration can be used as

$$n = \frac{1}{2l}\sqrt{\frac{Y}{\rho}}$$

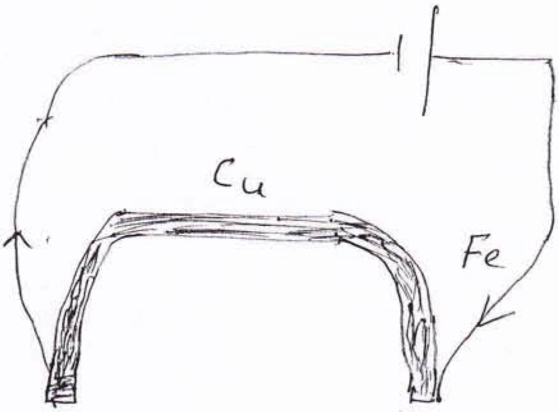
where Y is the Young's modulus of the material and ρ its density. With this method, ultrasonics of frequencies - 3,00,000 Hz can be produced.

Important Applications ;

1. Metal soldering
2. Alloy formation
3. Detection of flaws in metals
4. Sound signalling
5. Velocity in liquid & gases.
6. Velocity of ultrasonics by accustic grating
7. Depth of sea, position of submerged rocks
8. Elastic symmetry of crystals
9. Biological effects & many industrial applications.

6. Write short notes on the following:
(a) Peltier effect
(b) Thermoelectric Power.

Ans. :(a) Peltier Effect :-

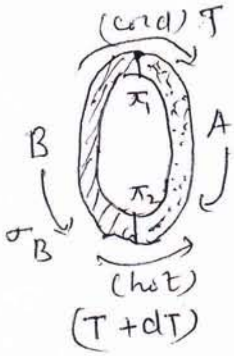


(Peltier Effect)

In 1834, Peltier discovered that when electric current is passed in a circuit consisting of two dissimilar metals, heat is evolved at one junction and is absorbed at the other junction. This is known as Peltier effect. It is the inverse of the Seebeck effect. The Peltier effect is a junction phenomenon. There is heat absorption or generation at the junction depending on the direction of current flow. Heat generated by current flowing in one direction was absorbed if the current was reversed. It is observed, as shown in the above diagram, that the right-hand junction is heated, showing that electrical energy is being transformed into heat energy. Meanwhile, heat energy is transformed into electrical energy at left junction, thereby causing it to ~~feel~~ be cooled. When the current is reversed, heat is absorbed at the right junction and produced at the left one.

(b) Thermoelectric Power :- The rate of change of e.m.f. with temperature is called thermoelectric power and is defined by 'P'. Thus,

$$P = \frac{de}{dT}.$$



Let us consider a thermocouple made of two dissimilar metals 'A' and 'B' with their junctions at temperatures (T+dT) and 'T'. The Peltier Coefficient at (T+dT) is $(\pi+d\pi)$ and at temperature 'T', it is 'π'. Let σ_A and σ_B be the Thomson coefficient of the metals 'A' and 'B' respectively. Current flows in the thermocouple circuit due to seebeck effect. Heat is absorbed at the hot junction and is evolved at the cold junction due to Peltier effect. And as temperature gradient exists along 'A' and 'B', heat is evolved in A and is absorbed in 'B' due to the Thomson effect.

If a unit charge passes through the circuit, the energy is absorbed due to peltier effect at the hot junction = $(\pi+d\pi)$.

Energy evolved due to Peltier effect at the Cold junction = $-\pi$

Energy absorbed in metal 'B' due to Thomson effect = $\sigma_B\, dT$

Energy evolved in metal 'A' due to Thomson effect = $-\sigma_A\, dT$

The total gain of energy is

$$de = (\pi+d\pi)-\pi+\sigma_B dT-\sigma_A dT$$

$$de = d\pi-(\sigma_A-\sigma_B)\,dT$$

Thermoelectric Power $'P' = \frac{de}{dT} = \frac{d\pi}{dt} + (\sigma_B-\sigma_A)$

$$\boxed{P = \frac{de}{dT} = \frac{d\pi}{dt} + (\sigma_B-\sigma_A)}$$