INSTITUTE OF INFORMATION TECHNOLOGY

JAHANGIRNAGAR UNIVERSITY

Number of Assignment : 02

Submission Date : 02/07/2021

Course Tittle : Physics

Course Code : ICT - 1107

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Class Roll – 2023 (Improvement)

Exam Roll – 192340

IIT - 48 Batch JU

Q: 1) state and explain the ~~Hyg~~ Huygens principle of secondary waves or secondary wavefronts with necessary diagrams.

Ans to the question no- 01

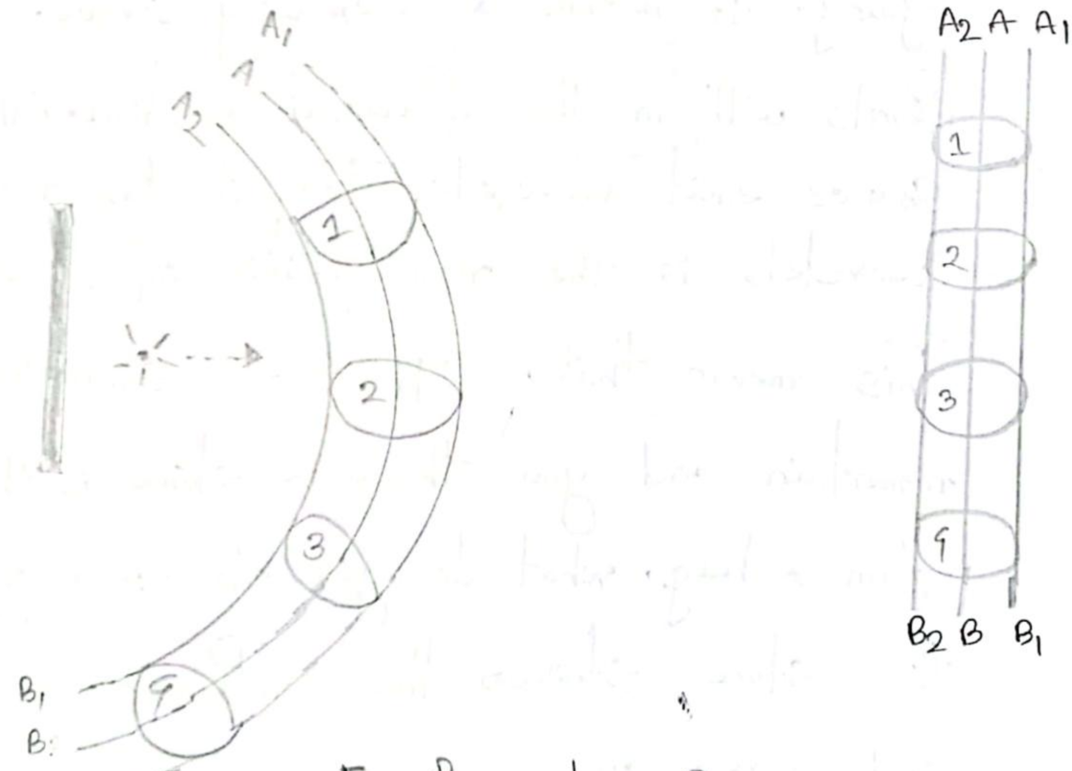


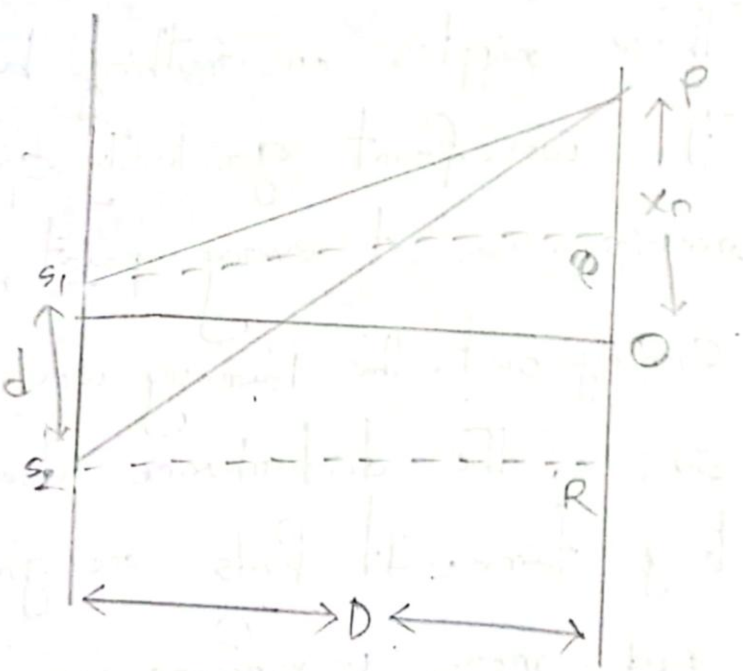
Fig: Propagation of wave

Every point on a wavefront is in itself the source of spherical wavelets which spread out in the forward direction at the speed of light. The sum of of these spherical wavelets ~~from~~ forms the wavefront. So, if we consider a point source it will emit its wavefront and nature of the wavefront will be spherical one. As per the Huygen's principle, the points on the wavefront are going to become a secondary source. So, the wavefronts will in the forward direction. All the second Source emit wavelets. Tangent drawn to all the wavelets is the new position of the wave from. This means that, suppose are standing on the mountain and you throw a stone in the water from a haig. what do you observe? you see that the stone strikes the surface of the water and waves are seen surrounding that point. Every point on the surface of water starts Oscillating. The waves spread in au the direction. Earlier the water way at rest. But the moment we throw the stone in the water within a few fractions of second the disturbance spreads in all direction. There are ripples from the concentric circle arround the disturbance and spread out.

These ripples are nothing but the wavefront. The wavefront gradually spread in all the directions. So, at every point, we have a wave coming out. The Primary wavefront is formed and so on. The disturbance does not last for a long time. It feads are gradually because more and more waveforms are formed.

Q: 2) Show that the distance between two Consecutive bright or dark fringes is Const. and is independent of the fringe number with necessary diagrams.

Ans to the question no-2



Let the point p, located on the screen at a distance X_n from the point O, represent the n^{th} bright fringe, S_1 Q and S_2R are Perpendiculars on the Screen from the point S_1 and S_2 respectively in the right angled triangle S_1PQ.

$$S_1P^2 = S_2Q^2 + PQ^2 = D^2 + \left(x_n - d/2\right)^2 \quad \text{—— (1)}$$

Similarly from the right angled triange S_2P

$$S_2P^2 = D^2 + \left(x_n + d/2\right)^2 \quad \text{—— (2)}$$

Subracting eqn (1) from (2)

$$S_2P^2 - S_1P^2 = \left[D^2 + \left(x_n + d/2\right)^2\right] - \left[D^2 + \left(x_n - d/2\right)^2\right]$$

$$= 2x_n d$$

or, $(S_2P - S_1P)(S_2P + S_1P) = 2x_n d$

or, $$S_2P - S_1P = \frac{2x_n d}{S_2P + S_1P} \quad \text{—— (3)}$$

Both x_n and d are small compared to D, which is usually several thousend times longer than x_n or d. one can therefore, Write approximately

$$S_2P = S_1P \cong D \text{ or } S_2P + S_1P = 2D$$

Eqn (3) can, therefore, be written as.

$$S_2P - S_1P = \frac{2x_n d}{2D}$$

$$= \frac{x_n d}{D} \quad \text{—— (4)}$$

Now $(S_2P - S_1P)$ is the path difference of the light waves at the point p and according to the condition of interference must be equal to nd, since p represents the n^{th} bright fringe

Thus $$S_2P - S_1P = \frac{X_n d}{D} = n\lambda$$

or $$X_n = n\lambda \frac{D}{d} \quad \text{—— (5)}$$

when, $n = 0, 1, 2$

$n=0$ corresponds to the central bright fringe

$n=1$ gives the listance of the first bright fringe $n=2$ of the second bright fringe and so on. substituting $n = n+1$ in eqn-(5)

$$X_{n+1} = (n+1)\lambda \frac{D}{d} \quad \text{—— (6)}$$

where X_{n+1} is the distance of the $(n+1)^{th}$ bright fringe from the central bright fringe

subtracting eqn (5) from (6), we get

$$X_{n+1} - X_n = [n+1-n]\lambda \frac{D}{d} = \frac{\lambda D}{d} \quad \text{—— (7)}$$

Now $(X_{n+1} - X_n)$ is the distance of separation between the n^{th} and $(n+1)$ bright fringe.

Substitutating $n = 1, 2, 3, 4, \dots \dots$

it can be seen that

$$x_4 - x_3 = x_3 - x_2 = x_2 - x_1 = x_{n+1} - x_n = \frac{dD}{d}$$

= Constant and independent of the fringe number.

Thus the distance between any two consecutive bright fringes is same or all bright fringe are equally spaced.

Q: 3) How Newton's rings are formed? Describe The experimental features of Newton's Newton's rings. Describe the method of calculation of unknown wavelength of monochromatic referactive index of a liquid using the newton's rings experiment.

Ans to the question no: 3

Newton's rings is a noteworthy illustration of the interfrence of light waves reflected from the opposit Surfaces of a thin film of Variable thickness. when a plano- Convex lens of large radius of curvature is placed on a glass plate so that it convex surface faces the plate, a thin air flim of Progressively increasing thickness in all directions from the point of contact between the lens and glass plate is very easily formed. The air flim thus possesses a radial symmetry about the point of Contact. when it is illuminated normally, Prefarably with monocromatic light, an interfrence pattern consisting of a series of alternate dark and bright circular ring, Connective with the

the point of contact is observed, The fringers are the loci of points of equal optical film thickness and gradually become narrower as their radii increase until the eye or the magnifying intrument can no longer separate them the circular ring can also be formed by bringing in contact two spherical surfaces of different radi of curvature the rings are localized in the air film. Since the phenomenon was first examined in By Newton, The rings are termed Newton's ring (Fig 9·1) They are frequently used in the labratory for experimental determination of the wave-lenth of light

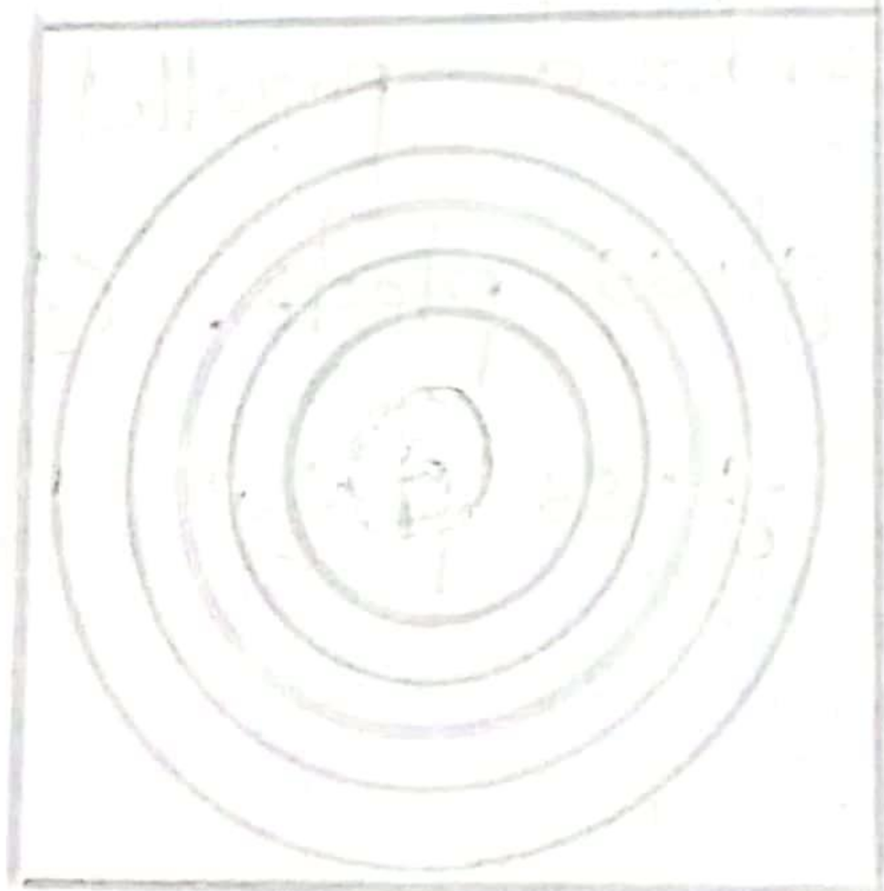


Fig : 3.1

Experimental features:

S is an extended source of monochromatic light at the focus of a lens L_1 (Figure 3.2). The light is, rendered parallel by the lens and then falls on a glass plate. G fixed at 45° to the virtual. The glass plate Partially reflects the light normaly on

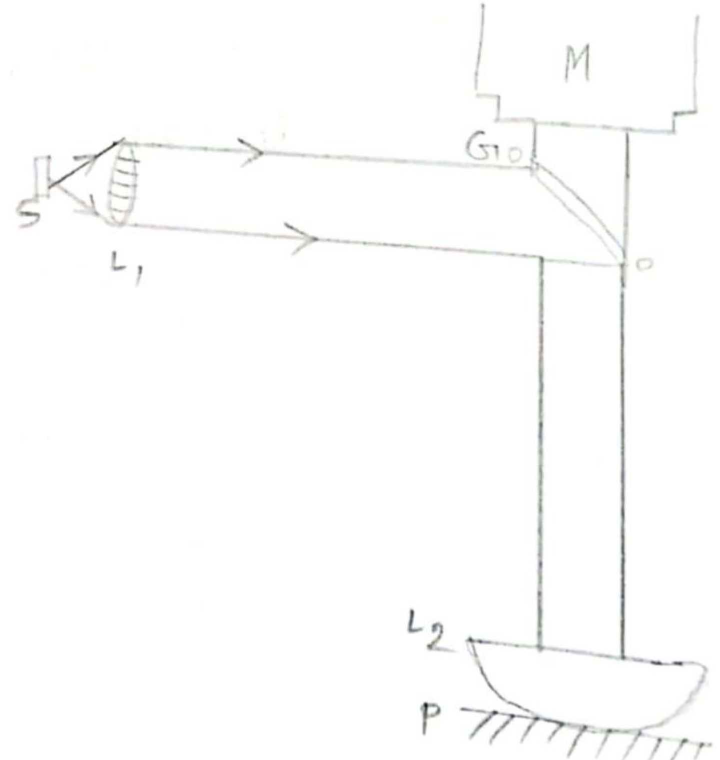


Fig: 3.2

plano convex lens L_2. placed on optically flat glass plate P. The lights reflected from the upper and lower surfaces of the air film formed between the convex lens L_2 and the glass plate Persue nearly the same path as that of the incident light and finally received by the eye or in a travelling microscope M. Interference takes place and alternate dark and bright circular fringes are Produced. The diameters of dark and bright rings can now be measured by gradually moving the microscope M from one side of the ring system to the diametrically opposite side, fixing one of the cross-wires exactly at the centre of width of the successive rings, care being taken to avoid the back-lash in the microscope screw.

Calculation of wavelength: In the labratory the diametres of the Newton's rings are measured with a travelling microscope usually a little away from the centre, a bright or dark ring is chosen which is clearly visible and its diametre measured Let it be the n^{th} order ring. For an air film, Since $\mu = 1$, we have

$$D_n^2 = 2(2n-1)\lambda R \; \ldots\ldots \text{ bright ring} \quad —(1)$$

$$D_n^2 = 4n\lambda R \; \ldots\ldots \text{ dark ring} \quad —(2)$$

The diameter of the n^{th} dark ring is $D_n = 2\sqrt{n\lambda R}$

The wavelenth of the monochromatic light employed to illuminate the film can be computed from either of the above equations.

In actual Practice, another ring, P rings from this rang onwards, is selected. The diameter of this $(n+p)^{th}$ ring is also measured.

$$D_{n+p}^2 = 2\left[2(n+p)-1\right]\lambda R$$

$$\Rightarrow D_{n+p}^2 = 2(2n+2p-1)\lambda R \; \ldots\ldots \text{ bright} \quad —(3)$$

and $D_{n+p}^2 = 4(n+p)\lambda R \ldots$ dark — (4)

(3) − (1) or (4) − (2) $\Rightarrow$

$$D_{n+p}^2 - D_n^2 = 4p\lambda R$$

$$\Rightarrow \lambda = \frac{D_{n+p}^2 - D_n^2}{4pR} \quad —(5)$$

Equation (5) for both dark and bright rings. In Newton's rings experiment (5) is invariably employed to compute λ.

Calculation of refractive index of a liquid with Newton's rings: The diameters of two particular rings, say the n^{th} and $(n+p)^{th}$, obtained in Newton's rings with an air film, are measured. Then a drop of liquid whose refractive index is to be measured is carefully introduce into the air film. The liquid is drawn in at the centre by the capillary action forming a liquid film between the lens and the plate when the film is illuminated with the same monochroramatic light, another set of Newton's rings in obtained the diameters of the same two rings [n^{th} and $(n+p)^{th}$] are then measured. The difference in diameters of the two rings for the two films are for air film $\left(D^2_{n+p} - D^2_n\right)_{air} = 4p\lambda R$

for Liquid film $\left(D^2_{n+p} - D^2_m\right)_{\cancel{air}\ liquid} = \frac{4p\lambda R}{\mu}$

when μ is the refractive index of the Liquid

Then,

$$\mu = \frac{\left(D^2_{n+p} - D^2_n\right)_{air}}{\left(D^2_{n+p} - D^2_n\right)_{Liquid}}$$

Since $\mu > 1$, the rings contract in the ration $\sqrt{1/\mu}$ when the air-film is replaced by the Liquid film.

Q:9)) Distinguish between Fraunhoffer and Fres- class of differactions. Describe The Fraunhoffer diffraction pattern produce by a Single slit illuminated by monochromatic light draw the intensity distribution curve for the diffraction pattern (please ~~in~~ include all the necessary and clear diagrams).

Ans to the question no- 9

Distinguish between Fraunhoffer and Fresnel class of diffraction.

Fraunhoffer Diffraction	Fresnel Diffraction
1. If the source of light and screen is at infinite distance from the obstacle then the diffraction is called Fraunhoffer diffraction	1. If the source of light and screen is at a finite distance from the obstacle, Then the diffraction called Freshnel diffraction

2. The Corresponding rays are parrallel.

2. The Corresponding rays are not Parallel.

3. The wavefronts falling on the obstacle are planes

3. The wavefronts falling on the obstacle are not plane.

The Fraunhoffer diffraction pattern Produced by a single slit illuminated by monochromatic light:

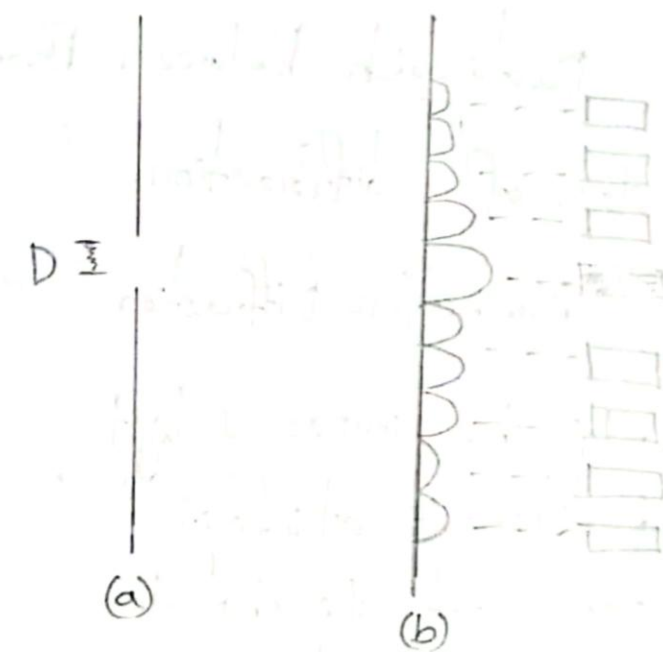


Fig (1) single slit diffraction pattern

Light passing through a single slit formsa. Diffraction pattern somewhat different from those formed by double slits or diffraction gratings Fingure (1) shows a single slit diffraction pattern Note that the central maximum is large than those on either side, and that the intensity decreases rapidity on either side. In contrast a diffraction grating produces evenly spaced lines that dim slowly on either side of center. The analysis of single slit diffraction is illustrated in figure 2. Here we consider light coming from different part of the some slit. According to Huygen's Principal every part of the wavefront in the slit emits wavelets. These are like rays that start out in phase and head in all direction. Assuming the screen is very far a way compared with the size of the slit, rays hading two tow. and a common destination are nearly paralle when they travel straight ahead, as in Fig 2a, they remain in phase and a central maximum is obtained. However when rays travel at an angle θ relative to the original direction of the beam. each travels a different distance to a a common location, and they can arrive in or out of phase In Figure 2b, The ray from the bottom travels a distance of one wavelength farther than the ray from the top.

Thus a ray from the center travels a distance $\lambda/2$ farther than the one on the left, arrives out of phase, and interfers destructively. A ray from slightly above the center and one from slightle above the bottom will also cancel one another. Infact each ray from the slit will have another to interfere destructively and a minimum in intensity will occur at this angle. There will be another minimum at the same angle to the right of the incident direction of the right.

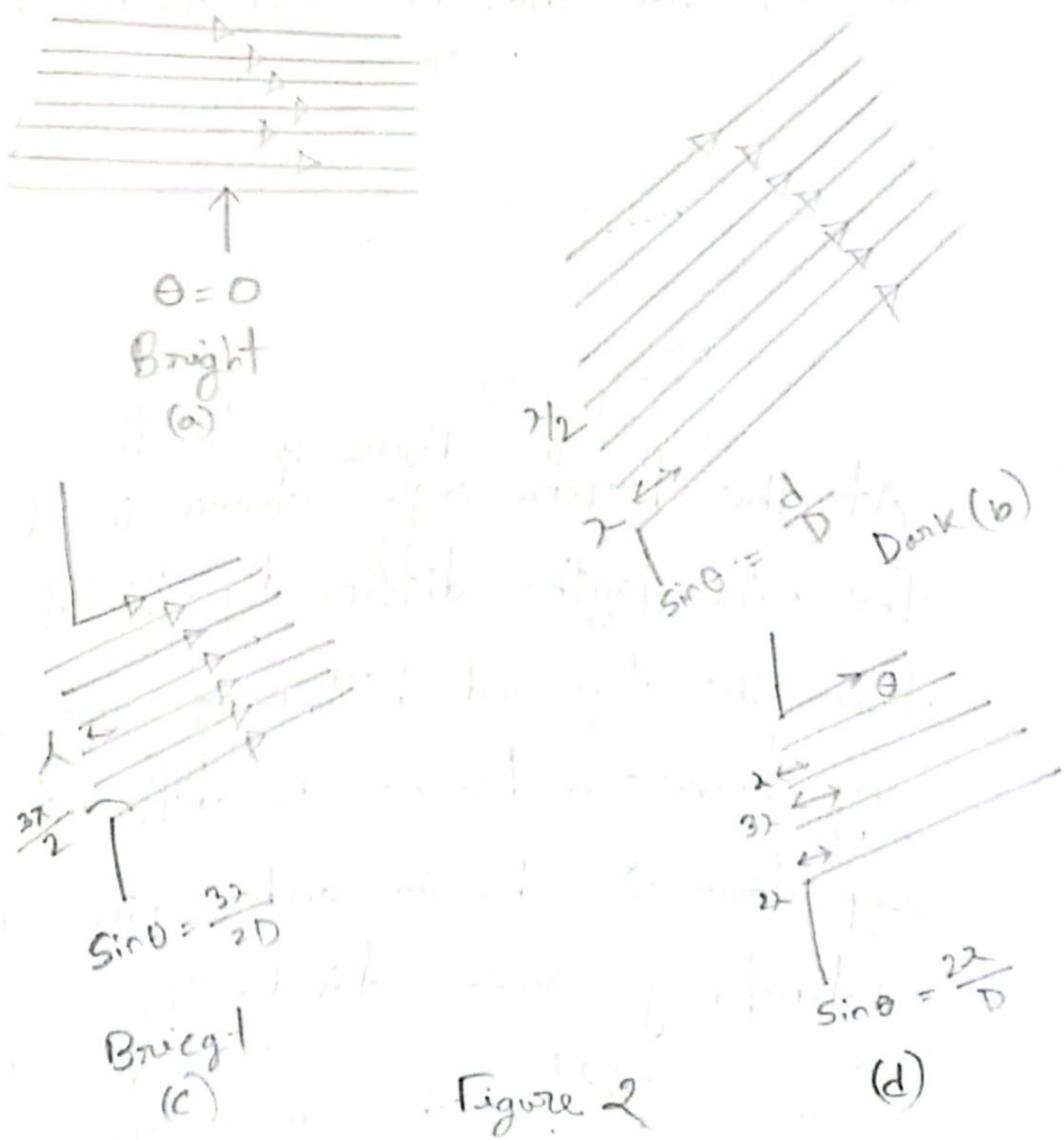


Figure 2

In Figure 2 we see that light passing through a single slit is diffracted in all directions and may interfere constructivly or destructively, depending on the angle. The difference in path length for rays from either side of the slit is seen to be $D\sin\theta$

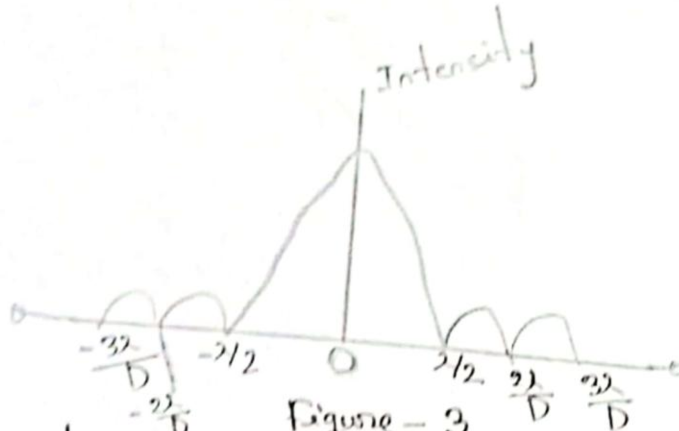


Figure - 3

At the larger angle shown in Figure 2c, the path lengths differ by $\frac{3\lambda}{2}$ for rays from the top and bottom of the slit one ray travels a distance λ different from the ray from the bottom and arrives in phase interfering constructively. Two rays each from slightly above those two will also add constructively, most rays from the slit will have another to interfere with constructively, and a maximum in intensity will occur at this angle. However, all rays do not interfere constructively for this situation, and so the maximum. Finally, in figure 2d, The angle show is large enough to produce a second minimum. As seen in the figure the difference in path length for rays from either side of the slit is $D \sin\theta$, and we see that a destructive minimum is obtained when this distance is an integral multiple of the wavelength.

Thus to obtain destructive inter-ference for a single slit, $D \sin\theta = m\lambda$ for $m = 1, -1, 2, -2, 3$ (destructive), we where D is the slit width) λ is the lights wavelength, θ is the angle relative to the orginal direction of the light and m is the order of the minimum figure

Figure 3 shows a graph of intensity for single slit interference, and it is apparent the maxima on either ~~sid~~ side of the central maximum are much less intense and not as wide. This is consistent with the illustration in Figure 1b.

The intensity distribution curves for the diffraction pattern.

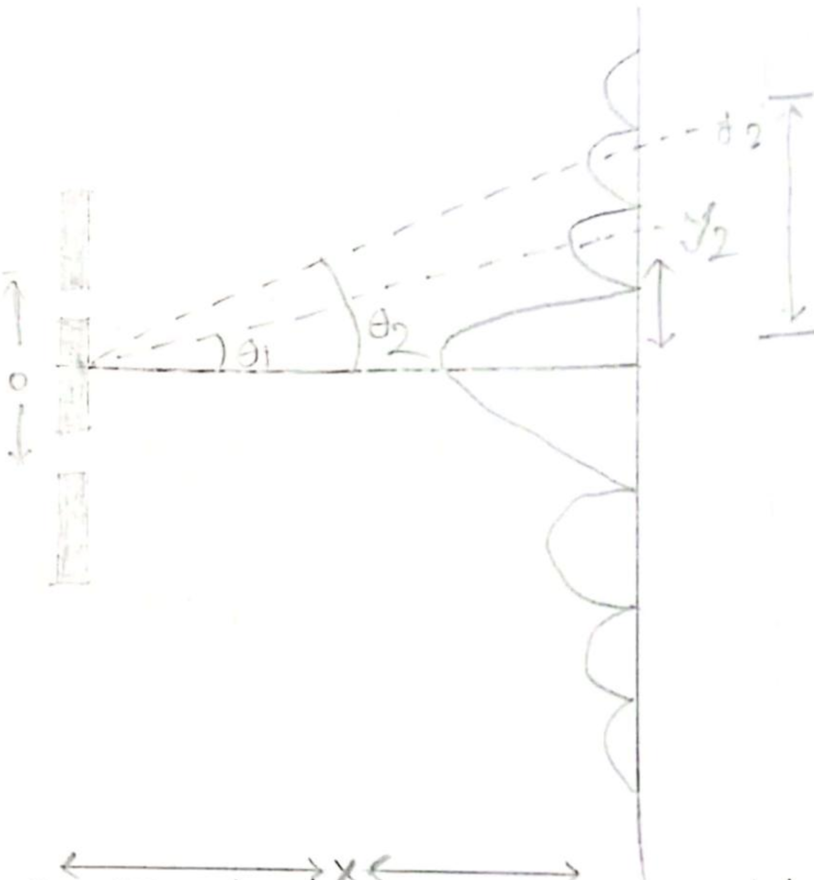


Fig: The intensity pattern for double slit diffractio

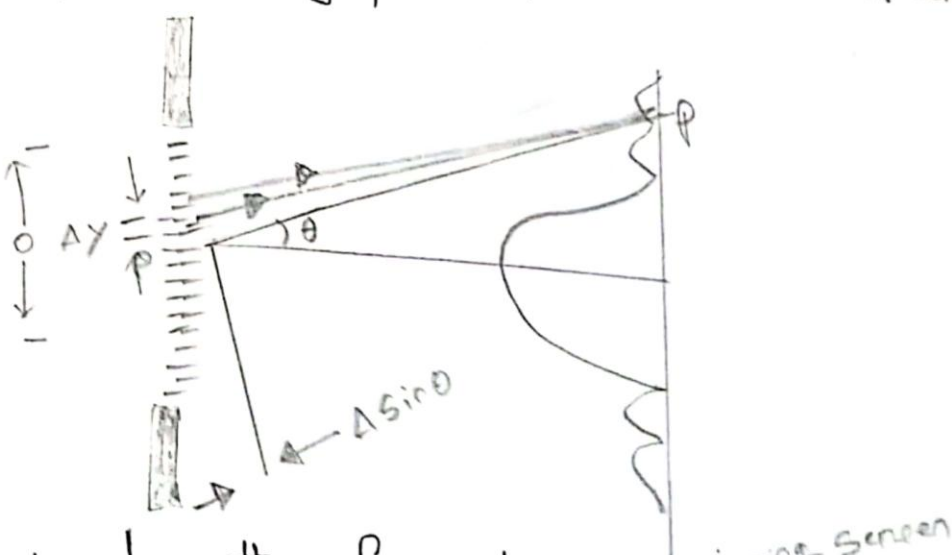


Fig: The intensity pattern for single slit diffraction

Q: 5) In the case of Fraunhoffer diffraction pattern show that the intensity of the first secondary maxima is roughly 4.9610 of that of the Principle maxima.

Ans to the question no — 05

On writing the exponsion of $\sin B$ in ascending power of B, the expression for the resultant amplitude R becomes

$$R = \frac{R_0}{\beta}\left(\beta - \frac{\beta^3}{3!} + \frac{\beta^5}{5!} - \frac{\beta^7}{7!} + \cdots\right)$$

$$= R_0\left(1 - \frac{\beta^2}{3!} + \frac{\beta^4}{5!} - \frac{\beta^6}{7!} + \cdots\right)$$

It is obvious that R will be maximum. If the negetive terms Varish. This is only posible when

$$\beta = \frac{\pi a \sin\theta}{\lambda} = 0; \quad \text{or} = \theta = 0$$

For $\beta = 0$ the quotient $\sin\frac{\beta}{\beta}$ becomes indeterminate but it should be remembered that $\sin\theta$ approches θ from small angles and is equal to it when θ vanishes. Hence for $\beta=0$, $R=R_0$; Thus the maximum value of R is R_0; it represents the amplitude when all the wavelets arrive in phase. The condition $\theta=0$ simply means that this maximum is formed by parts of secondary wavelets which travel normally to the slit. R_0^2 is then the value of the maximum intensity which is designated by I_0. The position of this maximum is, therefore directly opposite to the slit and is at the centre of the pattern. This maximum is known as the principle maximum and as explained below, it is bordered symmetrically by the dark and the bright bands.

In addition to the principal maximum at $\theta=0$, There are weak secondary maxima between the equally spaced minima the exact positions of these maxima can be obtained by differentiating the expression for intensit.

$$I = \frac{(I_0 \sin^2\beta)}{\beta^2}$$

with respect to β and equating it to zero. Therefore, for maxima and minima we have the condition,

$$\frac{dI}{d\beta} = 2I_0 \left[\frac{\sin\beta\cos\beta}{\beta^2} - \frac{\sin^2\beta}{\beta^3} \right] = 0$$

or, $\sin\beta \left[\beta - \tan\beta\right] = 0$

Hence either,

$$\sin\beta = 0 \quad \text{or} \quad \beta - \tan\beta = 0$$

Now $\sin\beta = 0$ gives the values of β (except zero) for which the intensity is zero. (Position of minimum intensity). The condition of maxima are therefore, given by the roots of the equation

$$\beta - \tan\beta = 0;$$

$$\beta = \tan\beta$$

The above equation is a transcendental equation. The values of β satisfying this equation are given by the points of intersection of the curves.

$y = \beta$ and $y = \tan\beta$, plotted on the same graph.

The curve $y = \beta$ is simply a straight line through the origin and inclined at 45° to the axis of β. To plot the curve $y = \tan\beta$, the following characteristic of the curve were derived mathematically.

(i) the curve cuts the axis of β at points where $y = \tan\beta = 0$, that is at points given by $\beta = 0, \pm\pi, \pm 2\pi \pm 3\pi$ etc.

(ii) At points where it cuts the axis of β the curve is inclined at 45° to the axis of β of those points.

(iii) Asymptotes of the curve are parallel straight line defined by $\beta = \pm\pi/2, \pm 3\pi/2, \pm 5\pi/2$ etc. The equation $y = \tan\beta$, therefore represents a family of curves having in the characteristic mentioned above. The curves are plotted in Fig (1) along with the curve $y = \beta$. As can be seen from the figure, the intersection occur at $\beta = 0, \pm 1.43\pi \left(\simeq \frac{3\pi}{2}\right), \pm 2.46\pi \left(\simeq \frac{5\pi}{2}\right), \pm 3.47\pi \left(\simeq \frac{7\pi}{2}\right), \pm 4.48\pi \left(= \frac{9\pi}{2}\right)$ etc. The value $\beta = 0$ of course, gives the position of Principle maximum. The other values namely $\beta = 1.43\pi$, 2.46π, 3.47π, 4.48π etc. give the respective position of the first, the second, the third, the fourth secondary maxima etc.

As can be seen, They are displaced somewhat towards the middle of two consective minima and this displacement increase with the order to the secondary maxima we can now form an idea regarding the relative intensities of the maxima. For simplicity of argument Let $R_0 = 1$. For the Principal maximum $\beta = 0$

and $I_0 = 1$

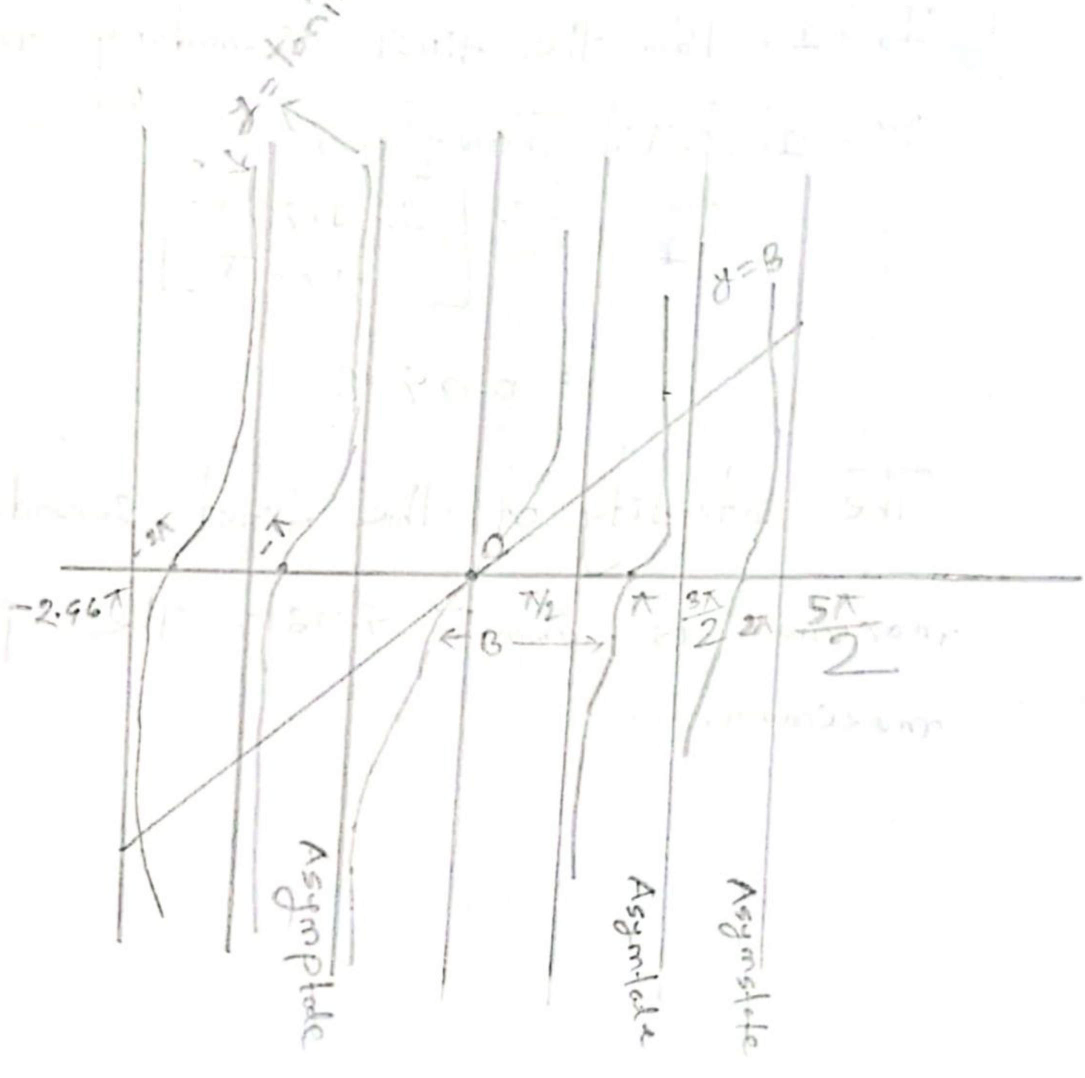

y = tan β
y = β
−2.96π
−2π
−π
π/2
π
3π/2
2π
5π/2
← β →
Asymptote
Asymptote
Asymptote

Fig - 1

For the Principal maximum $\beta = 0$ and $I_0 = 1$. For the first secondary maximum $\beta = 1.43\pi$. Therefore,

$$I_1 = R_0^2 \left[\frac{\sin 1.43\pi}{1.43\pi} \right]$$

$$= 0.0496$$

The intensity of the first secondary maximum is about 4.9610 the principal maximum.

Q:6)): state and explain Brewster's law. show that Polarizing angle of incidence, the reflected and reflected rays are mutually Perpen- diculor to each other.

Ans to the question no- 6

Brewter's law states that when unpolarized Ligth given wavelength is incident upon the surface of a transparent subtance it will experience maximum polarization when it is incident to the Surface at an angle (angle polarization or polarizing angle, also known as Brewster's angle) having a tangent equal to the refractive index of the surface. If μ_1 and μ_2 are the absolute refractive indies of the Surrounding medium and the reflecting matarial respectively and φ the polarizing. angle the Brewster's law can be expressed as

$$\tan\varphi = \frac{\mu_2}{\mu_1}$$

$$\text{or } \tan\varphi = \mu_2$$

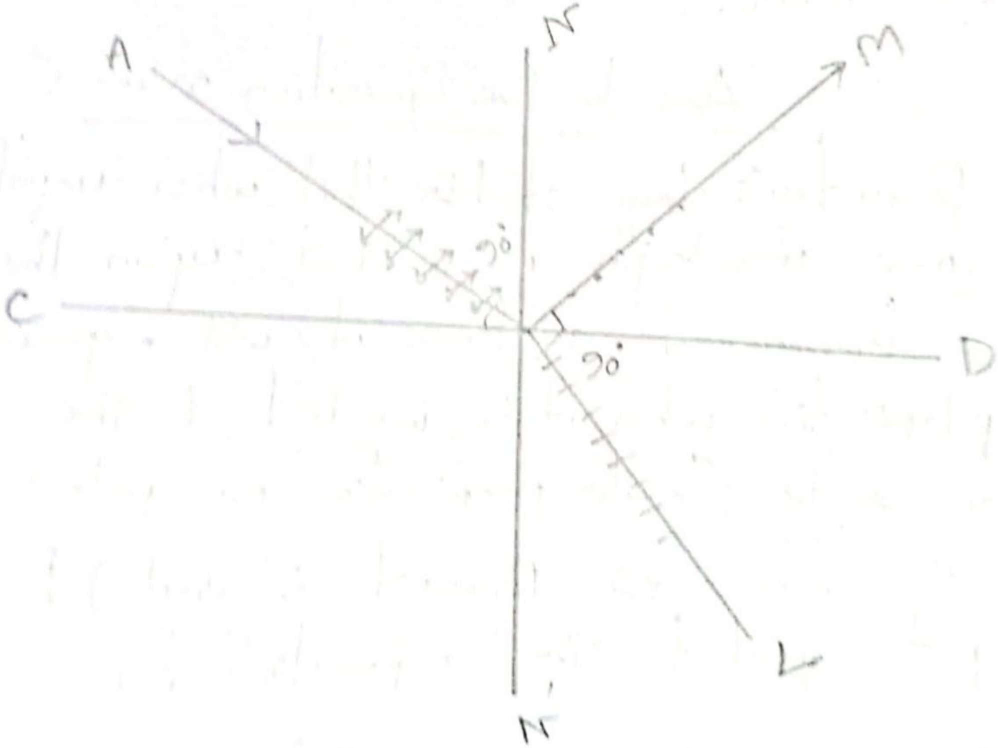


Fig: 6.1

where, μ_2 is the refractive index of the reflecting material with respect to its surrounding medium

Brewster's law immdiatly leads to an important deduction which is that at the polarizing angle of incidence, the reflected and refracted rays are 90° apart, they are Perpedicular to each other. Refferring to (fig 6.1), Snell's law gives

$$\frac{\sin\varphi}{\sin r} = {}_1\mu_2 \quad \text{--- (1)}$$

$$\tan\varphi = \frac{\sin\varphi}{\cos\varphi} = {}_1\mu_2 \quad \text{[according to Brewster's law]} \quad \text{--- (2)}$$

(i) and (2) $\Rightarrow$

$$\cos\varphi = \sin r$$

$$\Rightarrow \sin(90-\varphi) = \sin r$$

$$\Rightarrow 90-\varphi = r$$

$$\Rightarrow r+\varphi = 90$$

Now, $\angle MBN = \angle NBA = \varphi$

and $\angle MBL = \angle MBD + \angle DBL = 90°$

this Proves that Polarizing angle of incidence, the reflected and refaracted rays are mutually Perpendiculer to each other

Q:7) what do you mean by polarization (showed) of Light Distinguish between the ordinary and polarized light state and explain Malus's Law.

Ans to the question no - 7

Polarization of Light: Unpolarised light is polarized in all directions. The electric fields are Oriented in all directions. The light that we see (with our eyes) is unpolarised. The polarization of an electromegnetic wave (made up of electric and megnatic fields) is defined as the direction along which the electric field vector (E) points. In polarized light, the electric field is oriented in a single direction.

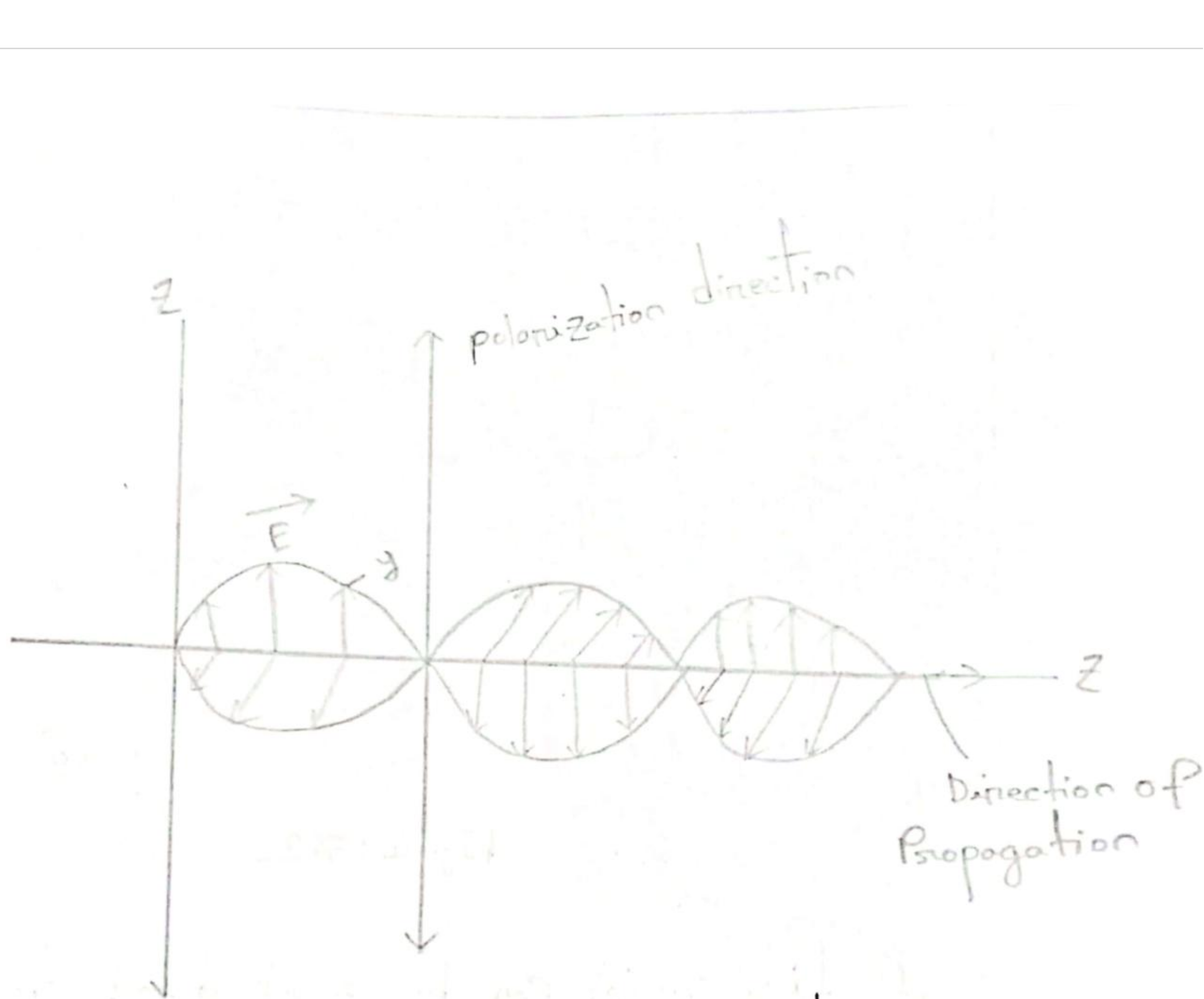


Fig – Polarization along z- direction

Distinguish between the oridinary and polarized light

The natural unpolarized light may be looked upon as a mixture of waves in all possible transeverse direction this is reffenred to as Perfect Symmetry As light waves are transverse in nature, each vibration

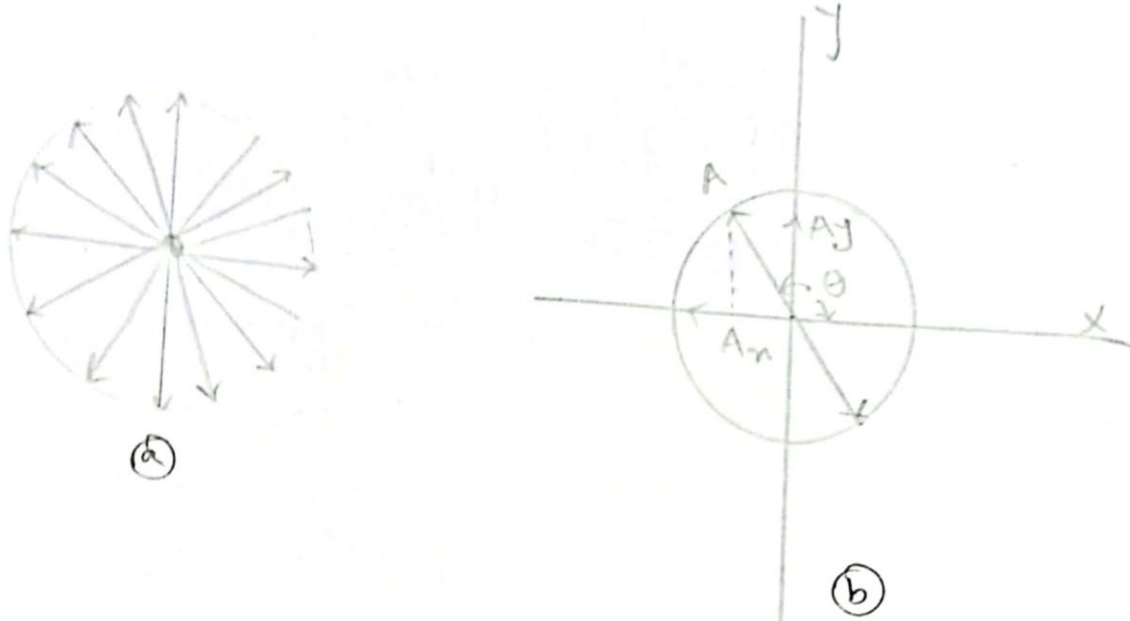


Figure : 7.2

of fig 7.2(a) Can be resolved into two component vibrations along two places at right angles to each other and also Perpendiculare to the direction of Pro-Pagation of Light of Light [Fig 7.2(b)].

Although these two Components may not be equal to each other, the Similarly resolved Components not be equal to be equal. Thus a beam of ordinary unpolarized light may be regarded as being made up of two kinds of vibration only. half the vibration vibrating in a vertical plane, say, along the plane of the paper referred to as parallel vibrations and polarized light is of three kinds.

<u>Malu's law</u>: Malus law states that the intensity of a plane polarized light that passes through an analyser varies as the square of the cosine of the angle between the plane of the polarizer and the transmission axes of the analyser. Mathmatically.

$$I \propto \cos^2\theta$$

Suppose the angle between the transmission axes of the analyser. If E_0 is the amplitude of the electric vector transmitted by the polarizer, then intensity I_0 of the light incident on the analyser is

$$I \propto E_0^2$$

The electric field vector E_0 can be resolved into two rectangular compents, $E_0 \cos\theta$ and $E_0 \sin\theta$. The analyser will transmit

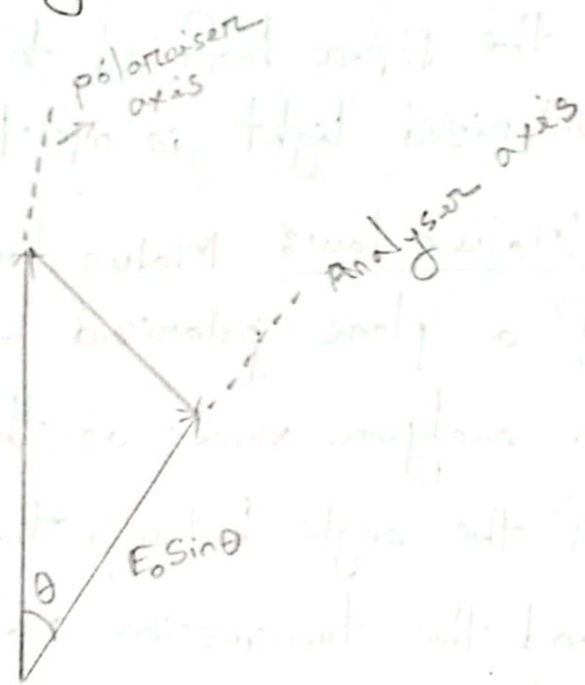


Fig: 7.3

only the component $(E_0 \cos\theta)$ which is parallel to its transmission axis $E_0 \sin\theta$ will be absorbed by the analyser. The intensity I of light transmitted by the analyser is,

$$I \propto (E_0 \cos\theta)^2$$

$$\frac{I}{I_0} = \frac{(E_0 \cos\theta)^2}{E_0^2} = \cos^2\theta$$

$$\therefore \quad I = I_0 \cos^2\theta$$

$\therefore$ $I \propto \cos^2\theta$ this proves law of Malus.

when $\theta = 0°$ (or $180°$)

$$I = I_0 \cos^2 0° = I_0$$

That is the intensity of light transmitted by the analyser is maximum when the transmission axes of the analyser and the polarizer are parallel.

when $\theta = 90°$.

$$I = I_0 \cos^2 90° = 0$$

That is the intensity of light trans-mitted by the analyser is minimum when the trans-mitted by the analyser and polarize are perpen dicular to each other.

THE END