**Name of Paper : Waves & Optics**
**Name of the Course : B.Sc. (Prog.) CBCS (Core)**
**Semester : IV**
**Duration : 3 Hours**
**Maximum Marks : 75**

**2022**

*Answer five questions in all.*
*Question No. 1 is compulsory.*
*All questions carry equal marks.*
*Non-programmable scientific calculator is allowed.*

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**(*a*) The time period of tuning fork is $\frac{1}{256}$ and it produces 4 beats/ second, when sounded with another fork. Calculate the frequency of the second fork.**

**Sol.** Time period of turning fork $\frac{1}{256}$

So frequency $(v_1) = 256$ Hz

It produces 4 beats/sec, when sounded with another fork

$$v_2 = v_1 \pm 4 = 256 \pm 4$$

**(*b*) If the phase velocity is given by $V_P = \left(\frac{2\pi s}{\rho\lambda}\right)^2$ (Here, S and ρ are constant), then derive the relation between group velocity and phase velocity.**

**Sol.**
$$V_p = \left(\frac{2\pi s}{\rho\lambda}\right)^{\frac{1}{2}} ; \text{S \& } \rho \text{ are constants}$$

$$Vg = V_p + K\frac{dV_\rho}{dk} \qquad K = \frac{2\pi}{\lambda}$$

or
$$Vg = V_p - \frac{\lambda \partial V_\rho}{\partial\lambda}$$

$$= \left(\frac{2\pi s}{\rho\lambda}\right)^{\frac{1}{2}} - \lambda\left[\frac{\partial}{\partial\lambda}\left(\frac{2\pi s}{\rho\lambda}\right)^{\frac{1}{2}}\right]$$

$$= \left(\frac{2\pi s}{\rho\lambda}\right)^{\frac{1}{2}} - \lambda\left(\frac{-1}{2}\right)\left(\frac{2\pi s}{\rho}\right)^{\frac{1}{2}}\left(\frac{1}{\lambda}\right)^{\frac{3}{2}}$$

$$= \left(\frac{2\pi s}{\rho\lambda}\right)^{\frac{1}{2}} + \frac{1}{2}\left(\frac{2\pi s}{\rho\lambda}\right)^{\frac{1}{2}}$$

$$V_g = \frac{3}{2}\left(\frac{2\pi s}{\rho\lambda}\right)^{\frac{1}{2}} = \frac{3}{2}V_P$$

$$V_g = \frac{3}{2}V_P$$

**(*c*) Give three differences between travelling waves and stationery waves.**

**Sol.** Traveling waves are observed when wave is not confined to given space along a medium.

1. They actually move from one place to another.
2. They transport the energy.
3. Most common example is ocean wave.
4. Standing waves ,also called stationary waves are the waves which oscillates in time but peak amplitude remain same.
5. They don't move from one place to another.
6. They don't transport energy.
7. Oscillations of these waves are in a phase.
8. Example you consider as, plucking strings of guitar.

**(*d*) Explain why the reverberation time is larger for an empty hall than for a crowded hall.**

**Sol.** Because in an empty hall the sound strikes the walls which are of very low absorption coefficient and hence sound persists for longer. Whereas, in a crowded hall human body and their accessories have higher absorption coefficient. We also that the reverberation time is inversely proportional to the absorption coefficient.

**(*e*) What do you understand by wave front? Name one experiment each, which is based on division of wave front.**

**Sol.** A wavefront is the set of all locations in a medium where the wave is at the same phase. This could be where all the crests are, where all the troughs are, or any phase in between.

Examples of division of wavefront – double slit experiment, Lloyd mirror, fresnal biprism.

**Sol.** White light has different wavelengths in it. At different angles, different wavelengths show constructive interference so it looks coloured.

**(*g*) How many orders will be visible if the wavelength of incident radiation is 4800 Å and the number of lines on a diffraction grating is 2500 per inch.**

**Sol.** Here $(a + b) \sin \theta = n\lambda$ [Here (a + *b*) is thegrating element]

Take, the max. possible value of sin θ, i.e., 1

Given $(a + b) = 2500$ lines/inch

$$n = \frac{(a+b)}{\lambda} = \frac{2.54}{2500} \times \frac{1}{4800 \times 10^{-8}} = 21$$

$$n = 21$$

**Q. 2. (*a*) What are Lissajous Figures ? For the cases analytical representation of the Lissajous Figures (with direction) for the motion of a particle which is subjected to two perpendicular simple harmonic motions given by,**

$$\boldsymbol{x = 3 \cos (\omega t)}$$

$$\boldsymbol{y = 2 \cos (2\omega t + \alpha), \text{ where } \alpha = 0}$$

**Sol. Lissajous Figures :** When a particle has super imposed upon it two mutually perpendicular SHMs simultaneously, the resultant path of the particle is known as a "Lissajous figure". The form of the figure depends upon the ratio of the frequencies (or periods), the individual amptitudes and the relative phases of the component motions.

Lissajous figure for the motion of particle which is subjected to two perpendicular SHMs given by

$$x = 3 \cos wt \qquad ...(1)$$

$$y = 2 \cos (2wt + \alpha), \text{ where } \alpha = 0 \qquad ...(2)$$

Now
$$\frac{y}{2} = \cos (2w + \alpha)$$

$$= \cos 2wt \cos \alpha - \sin 2wt + \sin \alpha$$

$$= (2 \cos^2 wt - 1) \cos \alpha - 2 \sin w + \cos w + \sin \alpha$$

$$\left[\begin{array}{l} \because \cos 2wt = \cos^2 wt - 1 \\ \because \sin 2wt = 2 \sin wt \cos wt \end{array}\right.$$

$$\Rightarrow \quad \frac{y}{2} = \left[2\left(\frac{x}{3}\right)^2 - 1\right]\cos\alpha - 2\left[\sqrt{1-\left(\frac{x}{3}\right)^2}\left(\frac{x}{3}\right)\right]\sin\alpha$$

$\because$ From eq (1)

$$\cos wt = \frac{x}{3}$$

$$\sin wt = \sqrt{1-\left(\frac{x}{3}\right)^2}$$

$$\Rightarrow \quad \left[\frac{y}{2}+\cos\alpha\right] = \left[2\left(\frac{x}{3}\right)^2\right]\cos\alpha = 2\left[\sqrt{1-\left(\frac{x}{3}\right)^2}\left(\frac{x}{3}\right)\right]\sin\alpha$$

On Squaring both sides

$$\Rightarrow \left[\frac{y}{2}+\cos\alpha\right]^2 + 4\left(\frac{x}{3}\right)^4\cos^2\alpha - 4\left(\frac{y}{2}+\cos\alpha\right)\left(\frac{x}{3}\right)^2\cos\alpha$$

$$= 4\left[\left(1-\left(\frac{x}{3}\right)^2\right)\left(\frac{x}{3}\right)^2\right]\sin^2\alpha$$

On rearranging

$$\Rightarrow \quad \left[\frac{y}{2}+\cos\alpha\right]^2 = 4\left[\left(\frac{x}{3}\right)^4(-\cos^2\alpha - \sin^2\alpha + \left(\frac{x}{3}\right)^2\right.$$

$$\left.(\cos^2\alpha + \sin^2\alpha) + \left(\frac{y}{2}\right)\left(\frac{x}{3}\right)^2\cos\alpha\right]$$

$$\Rightarrow \quad \left[\frac{y}{2}+\cos\alpha\right]^2 = 4\left(\frac{x}{3}\right)^2\left[\left(\frac{x}{3}\right)^2 + 1 + \left(\frac{y}{2}\right)\cos\alpha\right]$$

$$\Rightarrow \left[\frac{y}{2}+\cos\alpha\right]^2 + 4\left(\frac{x}{3}\right)^2\left[\left(\frac{x}{3}\right)^2 - 1 - \frac{y}{2}\cos\alpha\right] = 0 \qquad ...(3)$$

So, this equation is the combined form of equation (1) and (2)

At $\alpha = 0$;

equation (3) becomes

$$\left[\frac{y}{2}+1\right]^2 + 4\left(\frac{x}{3}\right)^2\left[\left(\frac{x}{3}\right)^2 - 1 - \frac{y}{2}\right] = 0$$

$$\left(\frac{y}{2}+1\right)^2 + \left[2\left(\frac{x}{3}\right)^2\right] - 2\left[2\left(\frac{x}{3}\right)^2\left(1+\frac{y}{2}\right)\right] = 0$$

$$\Rightarrow \quad \left[2\left(\frac{x}{3}\right)^2 - \left(\frac{y}{2}+1\right)\right]^2 = 0$$

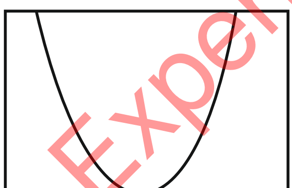
$$\Rightarrow \quad 2\left(\frac{x}{3}\right)^2 = \left(\frac{y}{2}+1\right)$$

$$\Rightarrow \quad x^2 = \frac{9}{2\,(2)}(y+2)$$

$$\Rightarrow \quad x^2 = \frac{9}{24}(y+2)$$

This is a equation of a parabola.

So Graphically, we can present the motion of this particle like this :



for $\alpha = 0$

**(*b*) Prove that the principle of superposition holds only for linear homogeneous differential equation.**

**Sol.** Let If $y_1$ and $y_2$ are solutions to a linear homogenous differential equation, say

$$A(x)y'' + B(x)y' + C(x)y = 0 \qquad \text{...(1)}$$

So by principle of superposition, we need to prove ($C_1y_1 + C_2y_2$ is also a solution of this equation.

**Proof :** As $y_1$ & $y_2$ are solutions of equation (1), so we can write

$$A(x)y''_1 + B(x)y'_1 + C(x)y_1 = 0 \qquad \text{...(2)}$$

$$A(x)y''_2 + B(x)y'_2 + C(x)y_2 = 0 \qquad \text{...(3)}$$

On multiplying equatioon (2) with $C_1$ & equation (3) with $C_2$ and adding them

$$C_1\,[A(x)y''_1 + B(x)y'_1 + C(x)y_1 = 0] + C_2\,[A(x)y''_2 + B(x)y'_2 + C(x)y_2 = 0]$$

$$\Rightarrow \quad A(x)\,[C_1y''_1 + C_2y''_2] + B(x)\,[C_1y''_1 + C_2y''_2] + C(x)\,[C_1y''_1 + C_2y''_2] = 0$$

$$\Rightarrow \quad A(x)\,[C_1y''_1 + C_2y''_2]'' + B(x)\,[C_1y''_1 + C_2y''_2]' + C(x)\,[C_1y''_1 + C_2y''_2] = 0$$

So ($C_1y_1 + C_2y_2$) is also a solution of equation (1)

**string.**

**Sol.** Let us cosider two harmonic waves of the same amptitude and period T and wavelenght λ travelling with the same speed in the opposite direction.

$$y_1 = \text{A} \sin (kx - \omega t)$$

$$y_2 = \text{A} \sin (kx - \omega t)$$

Considering the principle of superposition the resultant can be calculated as

Resultant $\quad y = y_1 + y_2$

$$= \text{A} \sin (kx - \omega t) + \text{A} \sin (kx + \omega t)$$

$$y = A.2\sin\left[\frac{(kz - wt) + (kz + wt)}{(2)}\right] \cos\left[\frac{(kz - wt) - (kz - wt)}{(2)}\right]$$

$$y = 2\text{A} \sin (kx) \cos (\omega t)$$

The equation represents the SHM of the collection of particles. Here the term 2A sin $(kx)$ is the amplitude of the resultant wave. From the expression o amplitude, it can be concluded that the amplitude of the particles execution SHM depends upon the location of the particles.

**Nodes :** The amplitude of the wave is zero for all the values of $kx$ that give sin $kx = 0$. It means for $kx$, π, 2π...$n$π the amplitude of vibration of the particles will be zero. Here $n$ is an integer.

By substituting $k = 2\pi/\lambda$ we get

$$(2\pi/\lambda) = n\pi$$

$$= x\ n\pi/2$$

Therefore, $x = 0, \lambda/2, \lambda, 3\lambda/2$.......

These points of zero displacements of the particles are called the nodes.

**Antitodes :** The amplitude will have maximum value of 2A for all values of $kx$ give sin $kx = \pm 1$. This means for $kx = \pi/2, 3\pi/2 \ldots\ldots (n + ½)\pi$ the amoplitude of vibration of the particles will be maximum.

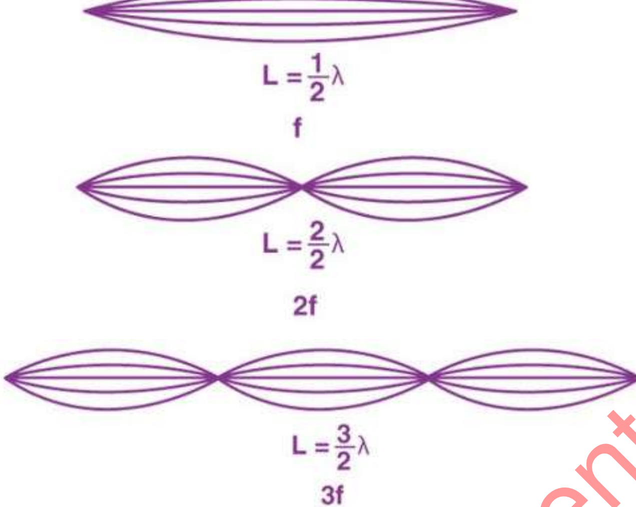
By substituting $k = 2n + 1\pi/\lambda$ we get

$$(2\pi/\lambda)x = (2n + 1)\ \pi/2$$

$\Rightarrow \quad x = (2n + 1)\ \lambda/4$

$\Rightarrow \quad x = \lambda/4, \lambda, 3\lambda/4, 5\lambda/4$......

These points at which the displacement of the particles are maximum are called antinodes. The nodes and the antinodes in a standing wave are equally spaced, the distance is equal to λ/2, where λ is the wavelength of the wave.




Consider a uniform string of lenght L which is stretched between two fixed ends. A wave that travels in one direction along the string at the end and returns inverted because of the fixed ends. These two identical waves travelling in the opposite direction form the standing wave on the string. The length of the string is given as L so the wavelenght of the wave is restricted by the boundary condition.

$$\lambda = 2L/n, \text{ here } n \text{ 1, 2, 3......}$$

The standing waves are formed in the string only if the wavelength satisfies the relationship with L. If v is the speed with which the waves travel along the string, then the frequency of the standing wave is

$$f = v/\lambda = nv/2L, \; n = 1, 2, 3......$$

Nodea are formed at the fixed ends in addition the nodes if an antinode will exist at the centre of the string, the stretched is said to vibrate in the fundamental frequency. The lowest resonance frequency corresponding to $n = 1$ is the fundamental frequency. The higher frequencies are called the harmonics. Harmonics are the integer multiples of the fundamental frequency.

**(*b*) For a stationary wave, the displacement (in cm) is given by,**

$$y = 4 \sin\left(\frac{\pi x}{15}\right) \cos(96\pi t)$$

**What is the distance between a node and the next anti-node ?**

**Sol.** For a stationary wave, the displacement (in cm) is givenn by

$$y = 4\sin\left(\frac{\pi x}{1.5}\right)\cos(96\pi t)$$

On comparing this equation with standard equation

$$y = 2a\sin\frac{2\pi x}{\lambda}\cos\frac{\ldots}{\lambda}$$

$$\frac{2\pi}{\lambda} = \frac{\pi}{15}$$

$$\Rightarrow \qquad \lambda = 30$$

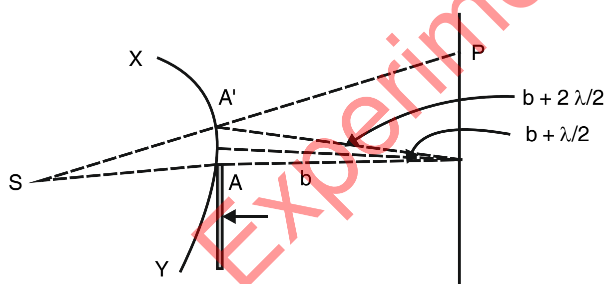
Distance between nearest node and antinode $= \frac{\lambda}{4} = \frac{30}{4} = 7.5$

**Q. 4. (*a*) What do you mean by Fresnel's half period zones? What are the radii of zones of a zone plate ?**

**Sol.** See Page No. 91-94 of this book for the solution to this question.

**(*b*) Explain with the help of a diagram, the intensity distincity due to diffraction at a straight edge.**

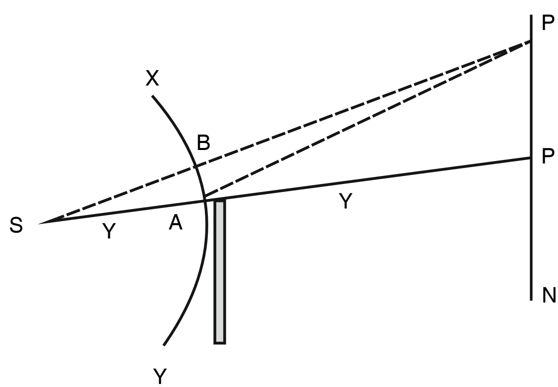
**Sol.** With reference to P the wavefront is divided into a number of half-period strips.




With A as pole as wave front & AM, $M_1M_2$, $M_2M_3$ measure the thickness of 1st, 2nd, 3rd etc half-period strips.

**Positions of maximum and minimum intensity :** To calculate the usualtant effect a P' due to wavefront xv. Join SP'

Now B is pole of wavefront w.r.t. P' & intensity at P' will depend on the number of half-period strips enclosed between A & B.



different at different points due to wavefront between B and A.

P' → maximum when no. of half period strips b/w B & A is odd.

P' → minimum when no. of half period strips enclosed b/w B & A is even.

Path difference $\delta = AP' - BP$

$$= \sqrt{b^2 + x^2} - \left[\sqrt{(a+b)^2 7x^2 - 1}\right]$$

$$= b\left(1 + \frac{x^2}{b^2}\right)^{\frac{1}{2}} - (a+b)\left(1 + \frac{x^2}{(a+b)}\right)^{\frac{1}{2}} + a\,'$$

$$= b\left[1 + \frac{x^2}{2b^2}\right] - (a+b)\left[1 + \frac{x^2}{2(a+b)^2}\right] + a$$

$$\delta = \frac{x^2}{2}\left[\frac{1}{b} - \frac{1}{a+b}\right] = \frac{x^2 a}{2b(a+b)}$$

P' is maximum when $\delta = (2n + 1)\,\lambda/2$

$$(2n+1)\frac{\lambda}{2} = \frac{a{x_n}^2}{2b(a+b)}$$

$${x_n}^2 = \frac{(2n+a)(a+b)\lambda}{a}$$

$$x_n = \sqrt{\frac{(2n+a)(a+b)\lambda}{a}}$$

$z_n$ is distance of $n^{th}$ bright band form P.

P' is minimum if $\delta = 2n\lambda/2$.

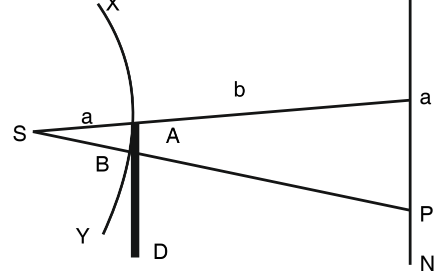
$$\frac{2n\lambda}{2} = \frac{axn^2}{2b(a+b)}$$

or $$x_n = \sqrt{\frac{2n(a+b)b\lambda}{a}}$$

$x_n$ is distance of $n^{th}$ dark band from P.

Hence diffraction bands of varying intensity will be observed abond the geometricallshadow (above P) & the bands disappear & uniform illamination occurs if P' is far away from P.

Itensity at a point inside the gemetrical shadow (straight edge)




B is the new pole for finding itensity at P' half-period strips below B arer cut off by the obstacle only the uncovered half-period strips above B will be effective in producting illumination at P' as P' moves away from P, more no. of half period strips above B is also cut off & intensity gradually falls

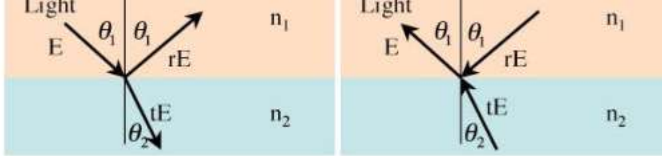
**Q. 5. (*a*) State the principle of reversibility of light. Determine the Stokes' relation for reflection of light from a optically denser medium.**

**Sol.** According to principle of reversibility of light, if the path of the light is reversed after suffering a number of reflections and refractions, then it retraces path. This means that if a light ray travels from medium 1 to medium 2 and has angle of incidence and angle of refraction as $i$ and $r$ respectively, then if the light is incident from medium 2 at an angle $r$, then the angle of refraction in medium 1 will be $i$.

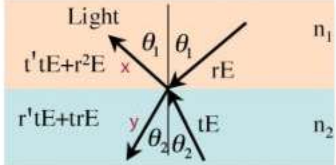

A reflection of the incoming field ($E$) is transmitted at the dielectric boundary to give $rE$ and $tE$ (where $r$ and $t$ are the amplitude reflection and transmission coefficients, respectively). Since there is no absorption this system is reversible, as shown in the second picture (where the direction of the beams has been reversed). If this reversed process were actually taking place, there will be parts of the incoming fields ($rE$ and $tE$) that are themselves transmitted and reflected at the boundary. In the third picture, this is shown by the coefficients $r$ and $t$ (for reflection and transmission of the reversed fields). Everything must interfere so that the second and third pictures agree; beam $x$ has amplitude $E$ and beam $y$ has amplitude $0$, providing Stokes relations.

The most interesting result here is that $r = -r'$. Thus, whatever phase is associated with reflection on one side of the interface, it is 180 degrees different on the other side of the interface. For example, if $r$ has a phase of 0, $r'$ has a phase of 180 degrees.

Explicit values for the transmission and reflection coefficients are provided by the Fresnel equations.




Backwards in time (showing all possible fields)




$$t'tE + r^2E = E$$

$$r'tE + trE = 0$$

$$\Rightarrow t't + r^2 = 1 \text{ and } r = -r'$$

(Stokes Relations)

(*b*) **Discuss the theory of interference due to two lines and find the expression for fringe width.**

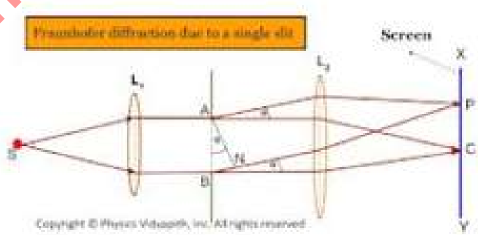
**Sol.** Refer this book for the solution to this question.

**Q. 6. (*a*) Derive the expression for intensity distribution in case of Fraunhofer diffraction due to single slit.**

**Sol.** $$A^2\left[\frac{\sin\left(\frac{5x}{2}\right)}{\frac{5x}{2}}\right]^{-2}$$



**Analytical Explanation :** Light from the source S is incident as a plane wavefront on the slit AB. According to Huygen's wave theory, every point in AB sends out secondary waves in all directions. The undeviated ray from AB is focused at C on the screen by the lens $L_2$ while the rays diffracted through an angle θ are focussed at point P on the screen. The rays from the ends A and B reach C in the same phase and hence the intensity is maximum.




To find the intensity at P, Let us draw normal AN on BN. Therefore the path difference between the extreme rays is

$$\Delta = BN$$

$$\Delta = AB \sin\theta$$

$$\Delta = e \sin\theta \qquad ...(1)$$

The phase difference

$$\Delta\phi = \frac{2\pi}{\lambda} e \ \sin\theta \qquad \text{...(2) [from eq(2)]}$$

Let AB is divided into a large number $n$ of equal parts then there may be infinitely large number of the point sources of secondary wavelets between A and B. The phase difference between any two consecutive parts is, therefore

$$\frac{1}{n}\Delta\phi = \frac{1}{n}\frac{2\pi}{\lambda} e \sin\theta$$

According to the theory of the composition of $n$ vibration each of the amplitude $a$ and common phase differences, $\delta$ between successive vibrations, the resultant amplitude at P is given by

$$R = a\frac{\sin\left(\frac{n\delta}{2}\right)}{\sin\left(\frac{\delta}{2}\right)} \qquad \text{...(4)}$$

Put the value of $\delta$ in equation (4) so

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

$$R = \frac{\sin\left(\frac{\pi}{\lambda} e \sin\theta\right)}{\sin\left[\frac{1}{n}\left(\frac{\pi}{\lambda} e \sin\theta\right)\right]} \qquad \text{...(5)}$$

Let $$a = \frac{\pi}{\lambda} e \sin\theta \qquad \text{...(6)}$$

Then from equation (5)

$$R = a\frac{\sin a}{\sin\left(\frac{a}{n}\right)} \qquad \text{...(7)}$$

For the large value of $n$, the value of $\frac{a}{n}$ is very small, Therefore $\sin a \approx \frac{a}{n}$

The equation (7) can be written as

$$R = a\frac{\sin a}{\frac{a}{n}}$$

$$R = \frac{\quad}{a}$$

$$R = \frac{A \sin a}{a} \qquad \ldots(8)$$

Where A is total amplitude of $n$ vibration. R is resultant amplitude of $n$ vibration. So the resultant intensity at P.

$$I = R_2$$

$$I = \frac{A^2 \sin^2 a}{a^2} \qquad \ldots(9)$$

**Condition of Principle Maxima :**

From equation (7)

$$R = \frac{A \sin a}{a}$$

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

$$R = A\left[1 - \frac{a^3}{3!} + \frac{a^5}{5!} - \frac{a^6}{7!} + \ldots\ldots\ldots\right]$$

If $a = 0$ then resultant amplitude will be maximum then

$$R = A$$

And $$\frac{\pi}{\lambda} e \sin\theta = 0$$ [From equation (6)]

$$\sin\theta = 0^\circ$$

$$\theta = 0^\circ$$

The resultant intensity at P will be the maximum. For $\theta = 0^\circ$ and called the principle maxima. Hence the intensity of the principle maxima :

$$I_0 = A_2$$

**Condition for Minima :** It is clear for from equation (8) that the intensity will be minimum when $\sin a = 0$ but $a \neq 0$.

So, $$\sin a = 0$$

$$\sin a = \sin(m\pi)$$

$$a = \pm m\pi$$

And $$\frac{\pi}{\lambda} e \sin\theta = \pm m\pi$$ [From equation (6)]

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

third,..........minima.

**Condition for Secondary Maxima :** In the diffraction patters, there are secondary maxima in addition to princial maxima. The condition of secondary maxima may be obtained by differentiating equation (9) withh respect to $a$ and equating it to zero.

Hence, $$\frac{dI}{da} = \frac{d}{da}\left(A^2 \frac{\sin^2 a}{a^2}\right)$$

$$\frac{dI}{da} = A^2 2\left(\frac{\sin a}{a}\left[\frac{a \cos - \sin a}{a^2}\right]\right)$$

But for maxima $$\frac{dI}{da} = 0$$

So $$A^2 2\left(\frac{\sin a}{a}\left[\frac{a \cos - \sin a}{a^2}\right]\right) = 0$$

$$\frac{a \cos a - \sin a}{a^2} = 0$$

$$a \cos a - \sin a = 0$$

$$a = \tan a$$

The above equation can be solved graphically by plotting the curves

$$y = a$$

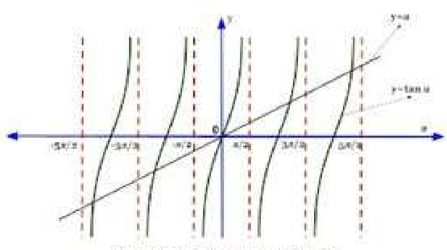
$$y = \tan a$$

The equation $y = a$ gives the straight line passing through the origin and making an angle 45° with the $x$-axis.

**(*b*) Show that the relative intensitites of the successive maxima are in the ratio of,**

$$\mathbf{1 : \left(\frac{2}{3\pi}\right)^2 : \left(\frac{2}{5\pi}\right)^2 \ldots}$$

**Sol.**



Position of maxima due to diffraction from a single slit the equation α = tan α. These point correspond to the value of

$$\alpha = 0, \frac{\pm 3x}{2}, \frac{\pm 5x}{2}, \frac{\pm 7x}{2}, \ldots\ldots\ldots\ldots$$

The first value a = , gives the position of principle maxima while the value of $\alpha = \frac{\pm 3x}{2}, \frac{\pm 5x}{2}, \frac{\pm 7x}{2}, \ldots\ldots\ldots\ldots$ gives the position first secondary maxima, second, secondary maxima and third secondary maxima and so on respectively.

The intensity of the first secondary maxima.

$$I_1 = A^2 \left[ \frac{\sin\left(\frac{3x}{2}\right)}{\frac{3x}{2}} \right]^2$$

$$I_1 = \frac{4}{9\pi^2} A^2 = \frac{A^2}{22} = \frac{I_n}{22}$$

Similarly, the intensities of secondary maxima

$$I_2 = A^2 \left[ \frac{\sin\left(\frac{5x}{2}\right)}{\frac{5x}{2}} \right]^2$$

$$I_2 = \frac{4}{25\pi^2} A^2 = \frac{A^2}{62} = \frac{I_n}{62}$$

Thus, It is obvious from the value of $I_0, I_1, I_2, \ldots\ldots\ldots$, etc that the diffraction pattern consists of a bright central maximum followed by minima of zero intensity and then secondary maxima of decreasing intensity on either side of it.

It is also obvious from the value of $I_0, I_1, I_2, \ldots\ldots\ldots$, etc that the relative intensities of successive maxima are nearly

$$I_0 : I_1 : I_2 : \ldots\ldots\ldots = 1 : \frac{4}{gx^2} : \frac{4}{25x^2} : \frac{4}{49x^2} : \ldots\ldots\ldots$$

**Q. 7. (*a*) Show that electromagnetic waves are transverse in nature.**

**Sol.** Refer to Page No. 100, Q. No. for the solution to this question.

**(*b*) Explain any two methods of polarizing an un-polarized beam of light.**

**Sol.** Refer Page No. 101, Q. No. 3. for its solution.