SHIKSHA CLASSES

Subject : Physics **BOARD ANSWER PAPER** **Total Marks : 20**
Class : XII **Topic: 7. Wave Optics**

Section (A)

Q.1 : A) Select and write the most appropriate answer from given alternatives in each sub-question. [5]

1) If the two waves represented by $y_1 = 4\sin\omega t$ **and** $y_2 = 3\sin(\omega t + \frac{\pi}{3})$ **interfere at a point, the amplitude of the resulting wave will be about…**

Ans. : b) 6

Given : $\phi = \pi/3$

$$A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\phi}$$

$$A = \sqrt{16 + 9 + 2(4)(3)\cos 60^0}$$

$$A = \sqrt{37} \approx 6$$

2) The light of wavelength 6328 A^0 is incident on a slit of width 0.20 mm perpendicularly; the angular fridge width will be

Ans. : a) 0.36^o

Angular fridge width

$$\theta = \frac{\lambda}{d}$$

$$= \frac{6328\times10^{-10}}{0.20\times10^{-3}}$$

$$\theta = 31640\times10^{-7}\ \text{rad}$$

$$\theta = \frac{31640\times10^{-7}\times180}{\pi}$$

$$\boxed{\theta = 0.18^0}$$

Total width of central maxima

$$2.\theta = 2\times0.18 = 0.36^0$$

3) If the ratio of maximum and minimum intensities of an interference pattern is 36:1, then the ratio of amplitude of two interfering waves will be.

Ans. : d) 7:5

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

$$\frac{a_1 + a_2}{a_2 - a_2} = \sqrt{\frac{36}{1}}$$

$$\frac{a_1 + a_2}{a_1 - a_2} = 6$$

$$a_1 + a_2 = 6a_1 - 6a_2$$

$$a_2 + 6a_2 = 6a_1 - a_1$$

$$7a_2 = 5a_1$$

$$\boxed{\frac{a_1}{a_2} = \frac{7}{5}}$$

4) In Young's double slit experiment, if the distance between the slit is halved and the distance between slit and the screen is doubled, the fringe width becomes.

Ans. : c) Four times

$\beta = \frac{\lambda D}{d} \Rightarrow D$ because twice and d becomes half.

So β becomes four times.

5) **In the interference pattern by two identical slits, intensity of central maxima is I. if one of two slits is closed, the intensity of light at the same spot will be…**

Ans. : b) I/4

$I_1 = I_2 = a^2$

$I_{max} = (a+a)^2 = (2a)^2 = 4a^2 = I$

when one of the slits is closed, intensity is

$I_1 = a^2 = \frac{I}{4}$

Q.1 : B) Very short answers type questions. [2]

1) **What is the primary and secondary source of light?**

Ans. : Primary sources are sources that emit light of their own

Secondary sources are those sources which do not produce light of their own but receive light from some other source and either reflect or scatter it around.

2) **What is mean by coherent sources?**

Ans. : Two sources which emit waves of the same frequency having a constant phase difference, independent of time, are called coherent sources.

Section (B)

Q.2 : Attempt any THREE. [6]

1) **What are the conditions for obtaining good interference pattern?**

Ans. : i) The two sources of light should be coherent

ii) The two sources of light must be monochromatic

iii) The two interfering waves must have the same amplitude

iv) The two slits should be narrow

v) The two waves should be in the same state of polarization

vi) The separation between the two slits must be small in comparison to the distance between the plane containing the slits and the observing screen.

2) **State Huygen's principle.**

Ans. : "Each point on a wavefront acts as a secondary source of light emitting secondary light waves called wavelets in all directions which travel with the speed of light in the medium. The new wavefront can be obtained by taking the envelope of these secondary wavelets travelling in the forward direction and is thus, the envelope of the secondary wavelets in forward direction. The wavelets travelling in the backward direction are ineffective".

3) **In the Young's double slit using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, k is units. What is the intensity of light at point where path difference is $\frac{\lambda}{3}$?**

Ans. : At path difference, λ maximum intensity obtained.

$I_{max} = K$

$\Delta n = \lambda / 3$

$\therefore \phi = \frac{2\pi}{\lambda}\Delta n = \frac{2\pi}{3}$

$\phi/2 = \frac{\pi}{3} = 60^0$

$I = I_{max} \cos^2 \phi/2$

$= K \cos^2 \phi/2$

$= K \cos^2 60^0$

$\boxed{I = K/4}$.

4) Plane wave front of light of wavelength 6000 A^0 is incident on two slits in a screen perpendicular to the direction of light rays. If the total separation of 10 bright fringes on a screen 2 m always is 2 cm, find the distance between the slits.

Ans. : **Given :** $\lambda = 6000\ A^0$ $D = 2m$

distance between 10 frings = 2 cm

$= 0.02$ m

The fringe width (w) $= \frac{\lambda D}{d}$

$W = \frac{0.02}{10}$ | $\therefore W = \frac{\lambda D}{d}$

$W = 0.002$ | $d = \frac{\lambda D}{W}$

$= \frac{6000 \times 10^{-10} \times 2}{0.002}$

$d = \frac{6000 \times 10^{-10} \times \cancel{2}}{\cancel{2} \times 10^{-3}}$

$d = 6000 \times 10^{-10} \times 10^{3}$

$d = 6000 \times 10^{-7}$

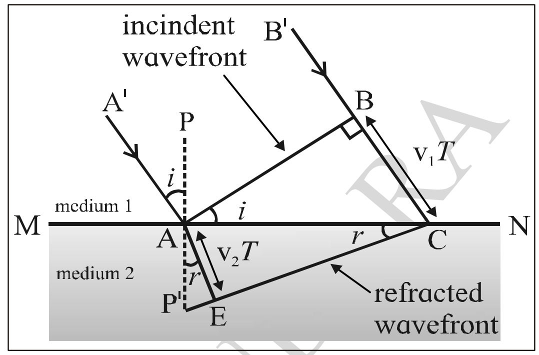
$\boxed{d = 6 \times 10^{-4} m}$.

Section (C)

Q.3 : Attempt any two of following. [3]

1) Drive the laws of refraction of light using Huygens's principle.

Ans. : Consider a wavefront AB, incident on a plane boundary MN, separating two uniform and optically transparent media as shown in Fig. At time t = 0, A has just reached the boundary surface, while B reaches the surface at C at a later time t = T. Let the speed of light be v_1 in medium 1 and v_2 in medium 2. Thus, BC = v_1 T. At time t =T, the radius (AE) of the secondary wavelet emitted from A will be v_2T. The refracted wavefront will be the envelope of wavelets successively emitted by all the points between A and C between time t = 0 and t = T. CE is the tangent to the secondary wavelet emitted from A. It is also the common tangent to all the secondary wavelets emitted by points between A and C. The normal to the boundary at A is shown by PP'.



Refraction of light.

$\angle A'AP = \angle BAC =$ the angle of incidence = i

$\angle P'AE = \angle ACE =$ angle of refraction = r

From ΔABC,

sin i = v_1 T /AC --- (i)

From ΔAEC,

sin r = v_2T /AC --- (ii)

From Eqs. (i) and (ii) we get

sin i /sin r = $v_1 / v_2 = (c/v_2)/(c/v_1) = n_2/n_1$, --- (iii)

Here, n_1 and n_2 are the absolute refractive indices of media 1 and 2 respectively. Eq. (iii) is the law of refraction and is also called the Snell's law.

2) In a single slit diffraction experiment first minimum for a light of wavelength 6800 A^0 coincides with first maximum of some other unknown wavelength. Calculate unknown wavelength.

Ans. : **Given :** $\lambda = 6800A^0 = 6.8 \times 10^{-7}$ m

$\lambda^1 = ?$

For first minima $\sin\theta = \frac{n\lambda}{a}$

$\therefore \sin\theta = 1 \times \lambda/a$

For first maxima

$\sin\theta_1 = \frac{3\lambda}{2a}$

Since first minimum coincider with first maximum

$\therefore \sin\theta = \sin\theta_1$

$\frac{\lambda}{a} = \frac{3\lambda^1}{2a}$

$$\lambda^1 = \frac{2\lambda}{3} = \frac{2\times 6.8\times 10^{-7}}{3}$$

$$\lambda^1 = 4.533\times 10^{-7}\,m$$

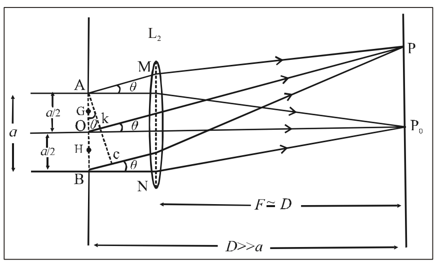
$$\boxed{\lambda^1 = 4533A^0}$$

Section (D)

Q.4 : Attempt any one. [4]

a) Derive an expression for the width of the central maxima for diffraction of light at a single slit. How does this width change with increase in width of the slit?

Ans. :



Fraunhofer diffraction

Diverging light from monchromatic source made parallel after refraction through convex lens L_1.

The referacted light from L_1 is propagated in the form of plane wave front WW^1 as shown in figure the plane wavelength WW^1 is incident on the slit AB of width 'd'.

According to Huygen's principle, each point of slit AB acts as a source of secondary disturbance of wavelets.

Central maximum occurs at 0 on the screen, where angle θ is zero.

let f be the focal length of lens L_2 and the distance of first minimum on either side of central maximum be x. Then

$$\tan\theta = \frac{n}{f} \qquad \therefore \tan\theta = \frac{n}{D}$$

Since the lens L_2 is very close to the slit,

so $f = D \;\therefore \sin\theta = \frac{n}{D}$ ---(i)

Since θ is very small, so $\tan\theta \simeq \sin\theta$ also, for first minimum,

$d\sin\theta = \lambda$ or $\sin\theta = \lambda/d$ ---(ii)

we have, $\frac{n}{D} = \frac{\lambda}{d}$ or $n = \frac{\lambda D}{d}$

The distance of first minimum on either side from centre of the central maximum.

$\therefore$ Width of central maximum

$$= 2n = \frac{2\lambda D}{d}$$

b) The intensity of polarized becomes 1/20 th of its initial intensity after passing through analyzer .what is the angle between the axis of the analyzer and the initial amplitude of the beam?

Ans. : Here $I = \frac{1}{20} I_0 = 0.05\, I_0$

using $\quad 1 = I_0 = \cos^2\theta$

$$0.05\, I_0 = I_0 \cos^2\theta$$

$$\cos^2\theta = 0.05$$

$$\cos\theta = \sqrt{0.05} = 0.2236$$

$$\theta = \cos^{-1}(0.2236) = 77^0 5'$$

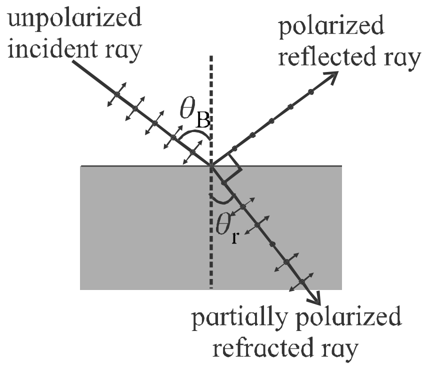
OR

a) What is the Brewster's law? Derive the formula of Brewster angle.

Ans. : The tangent of the polarising angle is equal to the refractive index of the refracting medium at which partial reflection takes place.

When light is incident at an angle on a boundary between two transparent media having refractive indices n_1 and n_2, part of it gets refracted and the rest gets reflected.

Let us consider unpolarized light incident from medium of refractive index n_1 on such a boundary perpendicular to the plane of the paper, as shown in fig.



The incident wave is unpolarized. Its electric field which is in the plane perpendicular to the direction of incidence, is resolved into two components, one parallel to the plane of the paper, shown by double arrows and the other perpendicular to the plane of the paper shown by dots. Both have equal magnitude. In general, the reflected and refracted rays do not have equal magnitudes of the two components and hence are partially polarized. It was experimentally discovered by D. Brewster in 1812 that for a particular angle of incidence θ_B (shown in the figure), the reflected wave is completely plane polarized with its electric field perpendicular to the plane of the paper while the refracted wave is partially polarized. This particular angle of incidence is called the Brewster's angle. For this angle of incidence, the refracted and reflected rays are perpendicular to each other. From the figure, for angle of refraction θ_r we have,

$$\theta_B + \theta_r = 90^0 \quad \text{---(i)}$$

From law of refraction we have,

$n_1 \sin\theta_B = n_2 \sin\theta_r$. This with Eq.(i) gives

$n_1 \sin\theta_B = n_2 \sin(90 - \theta_B)$, giving

$\frac{n_2}{n_1} = \tan\theta_B$, or

$$\theta_B = \tan^{-1}\left(\frac{n_2}{n_1}\right) \quad \text{---(ii)}$$

This is known as Brewster's law.

b) Aslit of width 'a' is illuminated by the light of wavelength 6000 A⁰. For what value of 'a' will the when maximum fall at an angle of diffraction of 30°?

Ans. : Here $\lambda = 6000A^0 = 6\times10^{-7}$ m

$\theta_1 = 30^0$, m = 1

a = First maximum of diffraction pattern,

$$\sin\theta\, m = \frac{\left(m+\frac{1}{2}\right)\lambda}{a}$$

$$\sin\theta_1 = \frac{3\lambda}{2a} \quad \text{or}$$

$$a = \frac{3\lambda}{2\sin\theta_1} = \frac{3\times6\times10^{-7}}{2\sin30^0}$$

$$= \frac{18\times10^{-7}}{2\times0.5} = 18\times10^{-6}\,\text{m}.$$

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