Date: 12-Jul-2026
Time: 60min

Wave Optics **Marks: 20**

SECTION A

Q.1 **Select and write the correct answer for the following multiple choice type of questions:** **(3)**

i **Huygens' Wave Theory of light could not explain _______.**

- [ ] (A) reflection
- [ ] (B) refraction
- [ ] (C) interference
- [x] (D) Photoelectric effect

Ans:

Explanation:

ii **A parallel beam of light travelling in water is incident obliquely on a glass surface. After refraction its width _______.**

- [ ] (A) decreases
- [x] (B) increases
- [ ] (C) remains the same
- [ ] (D) becomes zero

Ans:

Explanation:

iii **According to Newton's corpuscular theory of light, light of different colours corresponds to corpuscles of**

- [ ] (A) different phases
- [ ] (B) different states
- [ ] (C) different stabilities
- [x] (D) different sizes

Ans: (D)

Explanation: According to Newton's corpuscular theory of light, different colors of light are due to the different **sizes** of the corpuscles. This theory is based on the idea that light is made up of tiny particles called corpuscles. The larger the corpuscles, the more readily they are refracted, and the more the light is bent. This explains why red light is refracted less than blue light.

Q.2 **Answer the following questions:** **(3)**

i **State Huygens' principle.**

Statement: 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.

ii **Explain what is meant by polarization.**

The phenomenon of restriction of the vibration of light waves in a particular plane perpendicular to direction of wave motion is called polarization of light.

iii **What is meant by coherent sources?**

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

Examples: Monochromatic light, laser light, etc.

SECTION B

Attempt any TWO questions of the following: **(4)**

Q.3 **The optical path of a ray of light of a given wavelength travelling a distance of 3 cm in flint glass having refractive index 1.6 is same as that on travelling a distance x cm through a medium having refractive index 1.25. Determine the value of x.**

Ans: The value of x is **3.84 cm.**

Explanation:

Given: d_1 = 3 cm, n_1 = 1.6, n_2 = 1.25

To find: Optical path in medium 2 (d_2)

Formula: $n_1 d_1 = n_2 d_2$

Calculation: From formula,

$1.6 \times 3 = 1.25 \times d_2$

$\therefore \quad d_2 = \frac{1.6\times3}{1.25}$ = **3.84 cm**

Q.4 **(A) What is wavefront?**

The locus of all points having the same phase at a given instant of time is called a wavefront.

(B) What is the shape of the wavefront at a point far away from the source of light?

Plane

Q.5 **State drawbacks of Newton's corpuscular theory.**

Drawbacks of Newton's corpuscular theory:

i. The theory predicted that speed of light in a denser medium is more than the speed of light in a rarer medium which was experimentally proved wrong. Hence Newton's corpuscular theory was rejected.

ii. It could not explain phenomena such as interference, diffraction or polarization of light.

Q.6 **Two coherent sources whose intensity ratio is 25:1 produce interference fringes. Calculate the ratio of amplitudes of light waves coming from them.**

Ans: The ratio of the amplitudes is **5 : 1**

Explanation:

Given: $\frac{I_1}{I_2} = \frac{25}{1}$

To find: Ratio of amplitudes $\left(\frac{a_1}{a_2}\right)$

Formula: $\frac{I_1}{I_2} = \frac{{a_1}^2}{{a_2}^2}$

Calculation: From formula,

$$\frac{25}{1} = \frac{{a_1}^2}{{a_2}^2}$$

$$\therefore \frac{a_1}{a_2} = \frac{5}{1}$$

$\therefore$ $a_1 : a_2$ **= 5 : 1**

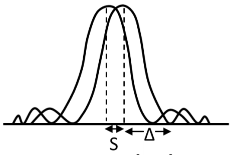
SECTION C

Attempt any TWO questions of the following: **(6)**

Q.7 Describe what is Rayleigh's criterion for resolution.

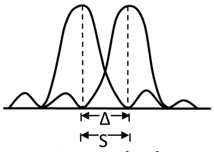
i. According to Lord Rayleigh, the ability of an optical instrument to distinguish between two closely spaced objects depends upon the diffraction patterns of the two objects (slits, point objects, stars, etc.), produced at the screen (retina, eyepiece, etc.).

ii. The two objects are said to be unresolved, if the separation between the central maximum of the two object is less than the distance between the central maximum and first minimum of any of the two objects i.e., S < Δ



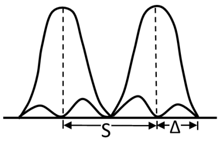
Unresolved

iii. Two objects are said to be just resolved when the separation between the central maxima of the two objects is just equal to the distance between the central maximum and the first minimum of any of the two objects i.e., S = Δ.



Just resolved

iv. The two objects are said to be well resolved, if the separation between the central maximum of the two objects is greater than the distance between the central maximum and first minimum of any of the two objects i.e., S > Δ.



Well resolved

v. Thus, depression in the resultant envelope is not noticeable in unresolved diffraction pattern, noticeable in just resolve diffraction pattern and clearly noticeable in well resolved pattern.

Q.8 What is Brewster's law? Derive the formula for Brewster angle.

Brewster's law is based upon phenomenon of polarization by reflection.

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

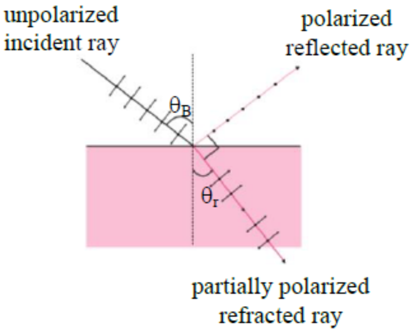
According to Brewster's law, $\tan \theta_B = \frac{n_2}{n_1}$

where, n_1 and n_2 are refractive indices of two media.

Derivation of Brewster angle:

i. 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.

ii. Consider unpolarized light incident from rarer medium of refractive index n_1 on such a boundary that is perpendicular to the plane of the paper, as shown below,



Polarization by reflection

iii. 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 (θ_B).

iv. For this angle of incidence, the refracted and reflected rays are perpendicular to each other.

∴ For angle of refraction θ_r,

$\theta_B + \theta_r = 90°$ ....(1)

From laws of refraction, $n_1 \sin\theta_B = n_2 \sin\theta_r$

$n_1 \sin\theta_B = n_2 \sin(90 - \theta_B)$ ....[Using (1)]

∴ $\frac{n_2}{n_1} = \tan\theta_B$,

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

This is the expression for Brewster's angle.

Q.9 (A) A transparent thin plate of polaroid is placed on another similar plate such that angle between their axes is 60°. What is the ratio of intensities of emergent and unpolarized incident light?

Ans: Thus, ratio of intensities of emergent (I_2) light to upolarized incident light (I_0) is **1:8**.

Explanation:

Let I_0 be intensity of incident unpolarized light.

∴ Intensity of light emerging out of 1st polaroid is

$I_1 = \frac{I_0}{2}$

Light of intensity I_1 will pass through second polaroid plate.

Using Malus' law,

intensity of light emerging from second plate,

$I_2 = I_1 \cos^2\theta$

$= \frac{I_0}{2}\cos^2 60° = \frac{I_0}{2} \times \left(\frac{1}{2}\right)^2$

∴ $\frac{I_2}{I_0} = \frac{1}{8}$

(B) The optical path difference between two identical light waves arriving at a point is 60.5 wavelengths. Is the point bright or dark? Explain.

Given: Path difference, $\Delta l = 60.5\lambda = (121)\frac{\lambda}{2} = \frac{121\lambda}{2}$

Since the path difference is odd multiple of $\frac{\lambda}{2}$, the point is **dark.**

SECTION D

Attempt any ONE question of the following: (4)

Q.10 (A) Plane wavefront of light of wavelength 5500 Å 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 away is 2 cm, find the distance between the slits.

Ans: The distance between two slits is $\mathbf{5.5 \times 10^{-4}}$ **m.**

Explanation:

Given: λ = 5500 Å, D = 2 m

Distance between 10 fringes = 2 cm

= 0.02 m.

fringe width W = 0.02/10

= 0.002 m = 2×10^{-3} m

To find: Distance between slits (d)

Formula: $W = \frac{\lambda\ D}{d}$

Calculation: From formula,

$$2 \times 10^{-3} = \frac{5500 \times 10^{-10} \times 2}{d}$$

$$\therefore \quad d = \frac{5.5 \times 10^{-7} \times 2}{2 \times 10^{-3}}$$

$$= \mathbf{5.5 \times 10^{-4}\ m}$$

(B) In an oil immersion objective microscope, oil of R.I 1.412 is used. The wavelength of illuminating light is 4850 Å and the semi-vertical angle is 45°. Find the limit of resolution and the R.P.

Ans: i. The limit of resolution is $\mathbf{2.425 \times 10^{-7}}$ **m**.

ii. The resolving power is $\mathbf{4.124 \times 10^{-6}}$ **/m**.

Explanation:

Given: n = 1.412, λ = 4850 Å = 4850×10^{-10} m

α = 45°

To find: i. Limit of resolution ($d\theta$) ii. Resolving power (R.P)

Formulae: i. $d\theta = \frac{\lambda}{2n\ \sin\ \alpha}$ ii. $R.P = \frac{1}{d\ \theta}$

Calculation: From formula (i),

$$d\theta = \frac{4820 \times 10^{-10}}{2 \times 1.412 \times \sin(45^\circ)}$$

$$= \frac{4820 \times 10^{-10}}{2 \times 1.412 \times \frac{1}{1.412}}$$

$$= \mathbf{2.425 \times 10^{-7}\ m}$$

From formula (ii),

$$R.P. = \frac{1}{2.425 \times 10^{-7}} = \mathbf{4.124 \times 10^{-6}\ /m}$$

Q.11 Derive conditions for occurrence of dark and bright fringes on screen in Young's double slit interference experiment. Define fringe width and derive formula for it.

i. Let S_1 and S_2 be the two coherent monochromatic sources which are separated by short distance d. They emit light waves of wavelength λ.

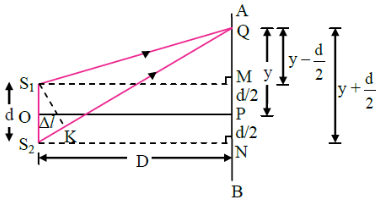
ii. Let D = horizontal distance between screen and source.

iii. Draw S_1M and $S_2N \perp AB$

OP = perpendicular bisector of slit.

Since $S_1P = S_2P$, the path difference between waves reaching P from S_1 and S_2 is zero, therefore there is a bright point at P.

iv. Consider a point Q on the screen which is at a distance y from the central point P on the screen. Light waves from S_1 and S_2 reach at Q simultaneously by covering path S_1Q and S_2Q, where they superimpose.



Derivation:

In Δ S_1MQ, $(S_1Q)^2 = (S_1M)^2 + (MQ)^2$

$(S_1Q)^2 = D^2 + \left[y - \frac{d}{2}\right]^2$ ….(1)

In Δ S_2NQ, $(S_2Q)^2 = (S_2N)^2 + (NQ)^2$

∴ $(S_2Q)^2 = D^2 + \left[y + \frac{d}{2}\right]^2$ ….(2)

Subtract equation (1) from (2),

$(S_2Q)^2 - (S_1Q)^2 = \left[D^2 + \left(y + \frac{d}{2}\right)^2\right] - \left[D^2 + \left(y - \frac{d}{2}\right)^2\right]$

$= D^2 + \left(y + \frac{d}{2}\right)^2 - D^2 - \left(y - \frac{d}{2}\right)^2$

$= \left(y + \frac{d}{2}\right)^2 - \left(y - \frac{d}{2}\right)^2$

$= \left(y^2 + \frac{d^2}{4} + yd\right) - \left(y^2 + \frac{d^2}{4} - yd\right)$

$= y^2 + \frac{d^2}{4} + yd - y^2 - \frac{d^2}{4} + yd$

$(S_2Q)^2 - (S_1Q)^2 = 2yd$

∴ $(S_2Q + S_1Q)(S_2Q - S_1Q) = 2yd$

∴ $S_2Q - S_1Q = \frac{2yd}{S_2Q + S_1Q}$ ….(3)

If y << D and d << D then, $S_1Q \approx S_2Q \approx D$

$S_2Q + S_1Q = 2D$

∴ Equation (3) becomes,

$S_2Q - S_1Q = \frac{2yd}{2D}$

∴ $S_2Q - S_1Q = \frac{yd}{D}$

∴ $\Delta l = \frac{yd}{D}$ ….(4)

Equation (4) gives the path difference of two interfering light waves.

Point Q will be bright if,

$\Delta l = n\lambda = 2n\frac{\lambda}{2}$

where n = 0, 1, 2,….

$\therefore \quad \frac{y_n d}{D} = n\lambda = 2n\frac{\lambda}{2}$ ….[From equation (4)]

$\therefore \quad y_n = n\frac{\lambda D}{d}$ ….(5)

Equation (5) represents distance of n^{th} bright fringe from central bright fringe.

Point Q will be dark point if,

$\Delta l = (2n-1)\frac{\lambda}{2}$

where n = 1, 2, 3,……

$\therefore \quad \frac{y'_n d}{D} = (2n-1)\frac{\lambda}{2}$

$\therefore \quad y'_n = (2n-1)\frac{\lambda D}{2d} = \left(n - \frac{1}{2}\right)\frac{\lambda D}{d}$ ….(6)

Equation (6) represents distance of n^{th} dark fringe from central maximum.

Fringe width:

The distance between any two successive dark or any two successive bright fringes is equal. This is called the fringe width and is given by,

Fringe width = $W = \Delta y = y_{n+1} - y_n = y'_{n+1} - y'_n$

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

Thus, both dark and bright fringes are equidistant and have equal widths.