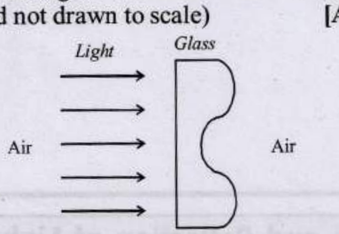
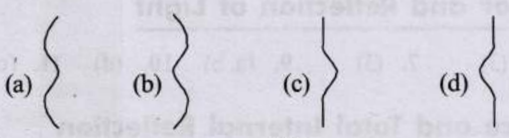
Chapter - Wave Optics

Topic-1: Wavefront, Interference of Light, Coherent and Incoherent Sources

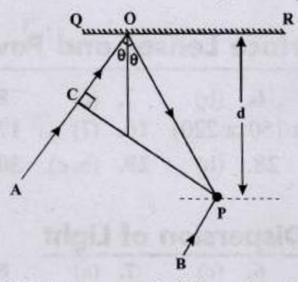
1 MCQs with One Correct Answer

1. A parallel beam of light strikes a piece of transparent glass having cross section as shown in the figure below. Correct shape of the emergent wavefront will be (figures are schematic and not drawn to scale) **[Adv 2020]**





2. In the adjacent diagram, CP represents a wavefront and AO & BP, the corresponding two rays. Find the condition on θ for constructive interference at P between the ray BP and reflected ray OP. **[2003S]**



(a) $\cos\theta = 3\lambda/2d$

(b) $\cos\theta = \lambda/4d$

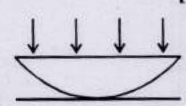
(c) $\sec\theta - \cos\theta = \lambda/d$

(d) $\sec\theta - \cos\theta = 4\lambda/d$

3. Two beams of light having intensities I and $4I$ interfere to produce a fringe pattern on a screen. The phase difference between the beams is $\pi/2$ at point A and π at point B. Then the difference between the resultant intensities at A and B is **[2001S]**

(a) $2I$ (b) $4I$ (c) $5I$ (d) $7I$

4. A thin slice is cut out of a glass cylinder along a plane parallel to its axis. The slice is placed on a flat glass plate as shown in Figure. The observed interference fringes from this combination shall be **[1999S - 2 Marks]**



(a) straight

(b) circular

(c) equally spaced

(d) having fringe spacing which increases as we go outwards

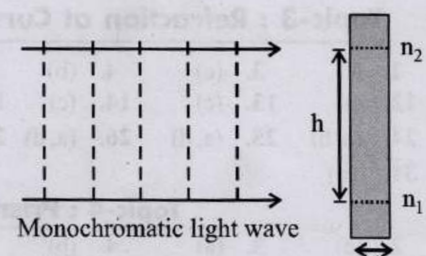
5. Two coherent monochromatic light beams of intensities I and $4I$ are superposed. The maximum and minimum possible intensities in the resulting beam are **[1988 - 1 Mark]**

(a) $5I$ and I (b) $5I$ and $3I$

(c) $9I$ and I (d) $9I$ and $3I$

6 MCQs with One or More than One Correct Answer

6. A monochromatic light wave is incident normally on a glass slab of thickness d, as shown in the figure. The refractive index of the slab increases linearly from n_1 to n_2 over the height h. Which of the following statement(s) is(are) true about the light wave emerging out of the slab? **[Adv. 2023]**



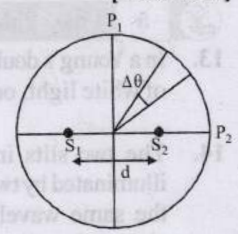
(a) It will deflect up by an angle $\tan^{-1}\left[\frac{(n_2^2 - n_1^2)d}{2h}\right]$.

(b) It will deflect up by an angle $\tan^{-1}\left[\frac{(n_2 - n_1)d}{h}\right]$.

(c) It will not deflect.

(d) The deflection angle depends only on $(n_2 - n_1)$ and not on the individual values of n_1 and n_2.

7. Two coherent monochromatic point sources S_1 and S_2 of wavelength $\lambda = 600$ nm are placed symmetrically on either side of the centre of the circle as shown. The sources are separated by a distance d = 1.8 mm. This arrangement produces interference fringes visible as alternate bright and dark spots on the circumference of the circle. The angular separation between two consecutive bright spots is $\Delta\theta$. Which of the following options is/are correct? **[Adv. 2017]**



(a) A dark spot will be formed at the point P_2

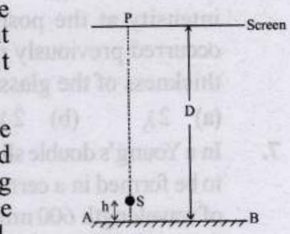
(b) At P_2 the order of the fringe will be maximum

(c) The total number of fringes produced between P_1 and P_2 in the first quadrant is close to 3000

(d) The angular separation between two consecutive bright spots decreases as we move from P_1 to P_2 along the first quadrant

10 Subjective Problems

8. A point source *S* emitting light of wavelength 600 nm is placed at a very small height h above a flat reflecting surface *AB* (see figure). The intensity of the reflected light is 36% of the incident intensity.



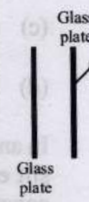
Interference fringes are observed on a screen placed parallel to the reflecting surface at a very large distance *D* from it. **[2002 - 5 Marks]**

(a) What is the shape of the interference fringes on the screen?

(b) Calculate the ratio of the minimum to the maximum intensities in the interference fringes formed near the point *P* (shown in the figure).

(c) If the intensity at point *P* corresponds to a maximum, calculate the minimum distance through which the reflecting surface *AB* should be shifted so that the intensity at *P* again becomes maximum.

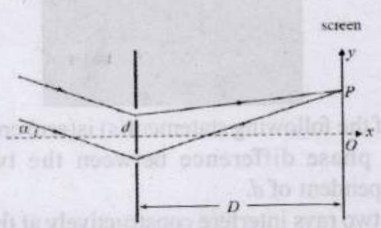
9. A narrow monochromatic beam of light of intensity I is incident on a glass plate as shown in figure. Another identical glass plate is kept close to the first one and parallel to it. Each glass plate reflects 25 per cent of the light incident on it and transmits the remaining. Find the ratio of the minimum and the maximum intensities in the interference pattern formed by the two beams obtained after one reflection at each plate. **[1990 - 7 Mark]**



Topic-2: Young's Double Slit Experiment

1 MCQs with One Correct Answer

1. In a Young's double slit experiment, the slit separation *d* is 0.3 mm and the screen distance *D* is 1 m. A parallel beam of light of wavelength 600 nm is incident on the slits at angle α as shown in figure. On the screen, the point *O* is equidistant from the slits and distance PO is 11.0 mm. Which of the following statement(s) is/are correct? **[Adv. 2019]**



(a) For $\alpha = 0$, there will be constructive interference at point *P*.

(b) Fringe spacing depends on α

(c) For $\alpha = \frac{0.36}{\pi}$ degree, there will be destructive interference at point *P*.

(d) For $\alpha = \frac{0.36}{\pi}$ degree, there will be destructive interference at point *O*.

2. In the Young's double slit experiment using a monochromatic light of wavelength λ, the path difference (in terms of an integer *n*) corresponding to any point having half the peak intensity is **[Adv. 2013]**

(a) $(2n+1)\frac{\lambda}{2}$ (b) $(2n+1)\frac{\lambda}{4}$ (c) $(2n+1)\frac{\lambda}{8}$ (d) $(2n+1)\frac{\lambda}{16}$

3. Young's double slit experiment is carried out by using green, red and blue light, one color at a time. The fringe widths recorded are b_G, b_R and b_B, respectively. Then, **[2012]**

(a) $b_G > b_B > b_R$ (b) $b_B > b_G > b_R$
(c) $b_R > b_B > b_G$ (d) $b_R > b_G > b_B$

4. In Young's double slit experiment intensity at a point is (1/4) of the maximum intensity. Angular position of this point is **[2005S]**

(a) $\sin^{-1}(\lambda/d)$ (b) $\sin^{-1}(\lambda/2d)$
(c) $\sin^{-1}(\lambda/3d)$ (d) $\sin^{-1}(\lambda/4d)$

5. Monochromatic light of wavelength 400 nm and 560 nm are incident simultaneously and normally on double slits apparatus whose slits separation is 0.1 mm and screen distance is 1m. Distance between areas of total darkness will be **[2004S]**

(a) 4mm (b) 5.6mm (c) 14mm (d) 28mm

6. In the ideal double-slit experiment, when a glass-plate (refractive index 1.5) of thickness t is introduced in the path of one of the interfering beams (wave-lenght λ), the

intensity at the position where the central maximum occurred previously remains unchanged. The minimum thickness of the glass-plate is **[2002S]**

(a) 2λ (b) $2\lambda/3$ (c) $\lambda/3$ (d) λ

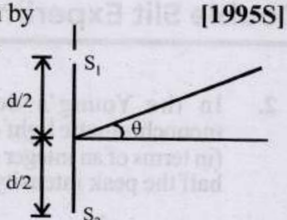
7. In a Young's double slit experiment, 12 fringes are observed to be formed in a certain segment of the screen when light of wavelength 600 nm is used. If the wavelength of light is changed to 400 nm, number of fringes observed in the same segment of the screen is given by **[2001S]**

(a) 12 (b) 18 (c) 24 (d) 30

8. In a double slit experiment instead of taking slits of equal widths, one slit is made twice as wide as the other. Then, in the interference pattern **[2000S]**

(a) the intensities of both the maxima and the minima increase
(b) the intensity of the maxima increases and the minima has zero intensity
(c) the intensity of the maxima decreases and that of the minima increases
(d) the intensity of the maxima decreases and the minima has zero intensity

9. In an interference arrangement similar to Young's double-slit experiment, the slits S_1 and S_2 are illuminated with coherent microwave sources, each of frequency 10^6 Hz. The sources are synchronized to have zero phase difference. The slits are separated by a distance d = 150.0 m. The intensity $I(\theta)$ is measured as a function of θ, where θ is defined as shown. If I_0 is the maximum intensity, then $I(\theta)$ for $0 \le \theta \le 90°$ is given by **[1995S]**



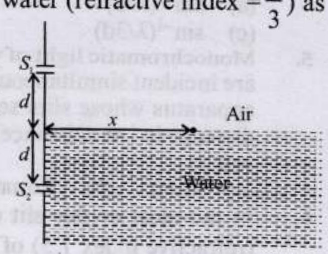
(a) $I(\theta) = I_0/2$ *for* $\theta = 30°$
(b) $I(\theta) = I_0/4$ *for* $\theta = 90°$
(c) $I(\theta) = I_0$ *for* $\theta = 0°$
(d) $I(\theta)$ is constant for all values of θ.

10. In Young's double-slit experiment, the separation between the slits is halved and the distance between the slits and the screen is doubled. The fringe width is **[1981- 2 Marks]**

(a) unchanged. (b) halved.
(c) doubled (d) quadrupled

2 Integer Value Answer

11. A Young's double slit interference arrangement with slits S_1 and S_2 is immersed in water (refractive index $= \frac{4}{3}$) as shown in the figure. The positions of maximum on the surface of water are given by $x^2 = p^2m^2\lambda^2 - d^2$, where λ is the wavelength of light in air (refractive index = 1), $2d$ is the separation between the slits and m is an integer. The value of p is **[Adv. 2015]**



4 Fill in the Blanks

12. In Young's double-slit experiment, the two slits act as coherent sources of equal amplitude 'A' and of wavelength 'λ'. In another experiment with the same set-up the two slits are sources of equal amplitude 'A' and wavelength 'λ', but are incoherent. The ratio of the intensity of light at the midpoint of the screen in the first case to that in the second case is .... **[1986 - 2 Marks]**

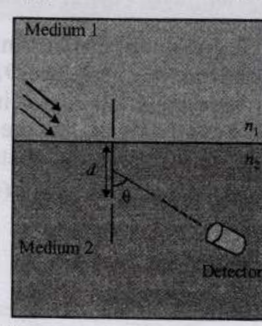
5 True / False

13. In a Young's double slit experiment performed with a source of white light, only black and white fringes are observed. **[1987 - 2 Marks]**

14. The two slits in a Young's double slit experiment are illuminated by two different sodium lamps emitting light of the same wavelength. No interference pattern will be observed on the screen. **[1984- 2 Marks]**

6 MCQs with One or More than One Correct Answer

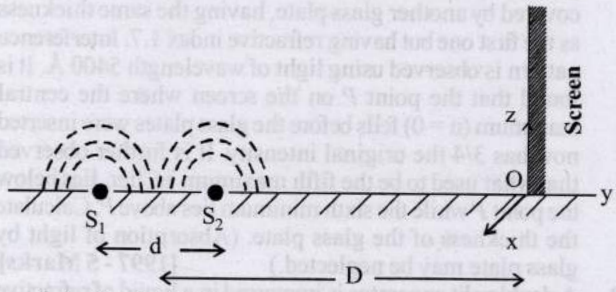
15. A double slit setup is shown in the figure. One of the slits is in medium 2 of refractive index n_2. The other slit is at the interface of this medium with another medium 1 of refractive index $n_1 (\neq n_2)$. The line joining the slits is perpendicular to the interface and the distance between the slits is d. The slit widths are much smaller than d. A monochromatic parallel beam of light is incident on the slits from medium 1. A detector is placed in medium 2 at a large distance from the slits, and at an angle θ from the line joining them, so that θ equals the angle of refraction of the beam. Consider two approximately parallel rays from the slits received by the detector. **[Adv. 2022]**



Which of the following statement(s) is(are) correct?

(a) The phase difference between the two rays is independent of d.
(b) The two rays interfere constructively at the detector.
(c) The phase difference between the two rays depends on n_1 but is independent of n_2.
(d) The phase difference between the two rays vanishes only for certain values of d and the angle of incidence of the beam, with θ being the corresponding angle of refraction.

16. While conducting the Young's double slit experiment, a student replaced the two slits with a large opaque plate in the x-y plane containing two small holes that act as two coherent point sources (S_1, S_2) emitting light of wavelength 600 nm. The student mistakenly placed the screen parallel to the x-z plane (for $z > 0$) at a distance $D = 3$ m from the mid-point of S_1S_2, as shown schematically in the figure. The distance between the sources $d = 0.6003$ mm. The origin O is at the intersection of the screen and the line joining S_1S_2. Which of the following is(are) true of the intensity pattern on the screen? **[Adv. 2016]**



(a) Straight bright and dark bands parallel to the x-axis
(b) The region very close to the point O will be dark
(c) Hyperbolic bright and dark bands with foci symmetrically placed about O in the x-direction
(d) Semi circular bright and dark bands centered at point.

17. A light source, which emits two wavelength $\lambda_1 = 400$ nm and $\lambda_2 = 600$ nm, is used in a Young's double slit experiment. If recorded fringe widths for λ_1 and λ_2 are β_1 and β_2 and the number of fringes for them within a distance y on one side of the central maximum are m_1 and m_2 respectively, then **[Adv. 2014]**

(a) $\beta_2 > \beta_1$
(b) $m_1 > m_2$
(c) Form the central maximum, 3[rd] maximum of λ_2 overlaps with 5[th] minimum of λ_1
(d) The angular separation of fringes for λ_1 is greater than λ_2.

18. In a Young's double slit experiment, the separation between the two slits is d and the wavelength of the light is λ. The intensity of light falling on slit 1 is four times the intensity of light falling on slit 2. Choose the correct choice(s). **[2008]**

(a) If $d = \lambda$, the screen will contain only one maximum
(b) If $\lambda < d < 2\lambda$, at least one more maximum (besides the central maximum) will be observed on the screen
(c) If the intensity of light falling on slit 1 is reduced so that it becomes equal to that of slit 2, the intensities of the observed dark and bright fringes will increase
(d) If the intensity of light falling on slit 2 is increased so that it becomes equal to that of slit 1, the intensities of the observed dark and bright fringes will increase

19. White light is used to illuminate the two slits in a Young's double slit experiment. The separation between the slits is b and the screen is at a distance $d (> b)$ from the slits. At a point on the screen directly in front of one of the slits, certain wavelengths are missing. Some of these missing wavelengths are **[1984- 2 Marks]**

(a) $\lambda = \frac{b^2}{d}$ (b) $\lambda = \frac{2b^2}{d}$ (c) $\lambda = \frac{b^2}{3d}$ (d) $\lambda = \frac{2b^2}{3d}$

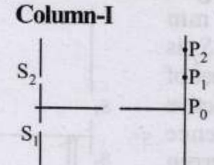
20. In the Young' s double slit experiment, the interference pattern is found to have an intensity ratio between the bright and dark fringes as 9. This implies that **[1982 - 3 Marks]**

(a) the intensities at the screen due to the two slits are 5 units and 4 units respectively
(b) the intensities at the screen due to the two slits are 4 units and 1 units respectively
(c) the amplitude ratio is 3
(d) the amplitude ratio is 2

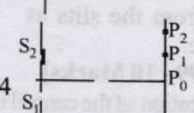
7 Match the Following

21. **Column-I** shows four situations of standard Young's double slit arrangement with the screen placed far away from the slits S_1 and S_2. In each of these cases $S_1P_0 = S_2P_0$, $S_1P_1 - S_2P_1 = \lambda/4$ and $S_1P_2 - S_2P_2 = \lambda/3$, where λ is the wavelength of the light used. In the cases B, C and D, a transparent sheet of refractive index μ and thickness t is pasted on slit S_2. The thicknesses of the sheets are different in different cases. The phase difference between the light waves reaching a point P on the screen from the two slits is denoted by δ (P) and the intensity by I(P). Match each situation given in **Column-I** with the statetment(s) in **Column-II** valid for that situation. **[2009]**

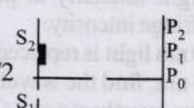
Column-I **Column-II**

(A) 

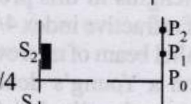
(p) $\delta(P_0) = 0$

(B) $(\mu - 1)t = \lambda/4$ 

(q) $\delta(P_1) = 0$

(C) $(\mu - 1)t = \lambda/2$ 

(r) $I(P_1) = 0$

(D) $(\mu - 1)t = 3\lambda/4$ 

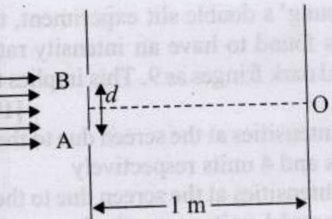
(s) $I(P_0) > I(P_1)$

(t) $I(P_2) > I(P_1)$

8 Comprehension/Passage Based Questions

Passage

In a Young's double slit experiment, each of the two slits A and B, as shown in the figure, are oscillating about their fixed center and with a mean separation of 0.8 mm. The distance between the slits at time t is given by $d = (0.8 + 0.04 \sin \omega t)$ mm, where $\omega = 0.08$ rad s^{-1}. The distance of the screen from the slits is 1 m and the wavelength of the light used to illuminate the slits is 6000 Å. The interference pattern on the screen changes with time, while the central bright fringe (zeroth fringe) remains fixed at point O. **[Adv. 2024]**



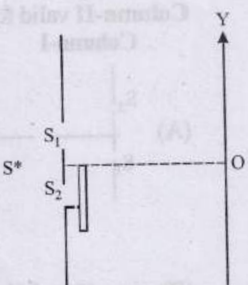
22. The 8[th] bright fringe above the point O oscillates with time between two extreme positions. The separation between these two extreme positions, in micrometer (μm), is ______.

23. The maximum speed in μm/s at which the 8[th] bright fringe will move is ______.

10 Subjective Problems

24. In *YDSE* a light containing two wavelengths 500 nm and 700 nm are used. Find the minimum distance where maxima of two wavelengths coincide. Given $D/d = 10^3$, where D is the distance between the slits and the screen and d is the distance between the slits. **[2004 - 4 Marks]**

25. The Young's double slit experiment is done in a medium of refractive index 4/3. A light of 600 nm wavelength is falling on the slits having 0.45 mm separation. The lower slit S_2 is covered by a thin glass sheet of thickness 10.4 μm and refractive index 1.5. The interference pattern is observed on a screen placed 1.5 m from the slits as shown in Figure. **[1999 - 10 Marks]**



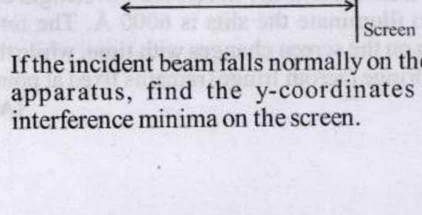
(a) Find the location of the central maximum (bright fringe with zero path difference) on the y – axis.

(b) Find the light intensity at point *O* relative to the maximum fringe intensity.

(c) Now, if 600 nm light is replaced by white light of range 400 to 700 nm, find the wavelengths of the light that form maxima exactly at point *O*.

[All wavelengths in this problem are for the given medium of refractive index 4/3. Ignore dispersion]

26. A coherent parallel beam of microwaves of wavelength λ = 0.5 mm falls on a Young's double slit apparatus. The separation between the slits is 1.0 mm. The intensity of microwaves is measured on a screen placed parallel to the plane of the slits at a distance of 1.0 m from it as shown in Fig.



(a) If the incident beam falls normally on the double slit apparatus, find the y-coordinates of all the interference minima on the screen.

(b) If the incident beam makes an angle of 30° with the *x* axis (as in the dotted arrow shown in Figure), find the *y*-coordinate of the first minima on either side of the central maximum. **[1998 - 8 Marks]**

27. In Young's experiment, the upper slit is covered by a thin glass plate of refractive index 1.4 while the lower slit is covered by another glass plate, having the same thickness as the first one but having refractive index 1.7. Interference pattern is observed using light of wavelength 5400 Å. It is found that the point *P* on the screen where the central maximum (n = 0) fells before the glass plates were inserted now has 3/4 the original intensity. It is further observed that what used to be the fifth maximum earlier, lies below the point *P* while the sixth minimum lies above *P*. Calculate the thickness of the glass plate. (Absorption of light by glass plate may be neglected.) **[1997 - 5 Marks]**

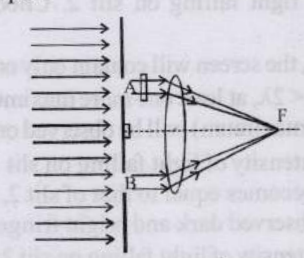
28. A double-slit apparatus is immersed in a liquid of refractive index 1.33. It has slit separation of 1mm, and distance between the plane of slits and screen is 1.33 m. The slits are illuminated by a parallel beam of light whose wavelength in air is 6300 Å. **[1996 - 3 Marks]**

(i) Calculate the fringe-width.

(ii) One of the slits of the apparatus is covered by a thin glass sheet of refractive index 1.53. Find the smallest thickness of the sheet to bring the adjacent minimum on the axis.

29. In a modified Young's double slit experiment, a monochromatic uniform and parallel beam of light of wavelength 6000 Å and intensity $(10/\pi)$ W m^{-2} is incident normally on two circular apertures A and B of radii 0.001 m and 0.002 m respectively. A perfectly transparent film of thickness 2000 Å and refractive index 1.5 for the wavelength of 6000 Å is placed in front of aperture *A*, see fig. Calculate the power (in watts) received at the focal spot *F* of the lens.

The lens is symmetrically placed with respect to the apertures. Assume that 10% of the power received by each aperture goes in the original direction and is brought to the focal spot. **[1989 - 8 Mark]**



30. A beam of light consisting of two wavelengths, 6500Å and 5200Å, is used obtain interference fringes in a Young's double slit experiment : **[1985 - 6 Marks]**

(i) Find the distance of the third bright fringe on the screen from the central maximum for wavelength 6500Å.

(ii) What is the least distance from the central maximum where the bright fringes due to both the wavelengths coincide?

The distance between the slits is 2 mm and the distance between the plane of the slits and the screen is 120 cm.

Topic-3: Diffraction, Polarisation of Light and Resolving Power

1 MCQs with One Correct Answer

1. Yellow light is used in a single slit diffraction experiment with slit width of 0.6 mm. If yellow light is replaced by X– rays, then the observed pattern will reveal, **[1999S - 2 Marks]**

(a) that the central maximum is narrower
(b) more number of fringes
(c) less number of fringes
(d) no diffraction pattern

2. Consider Fraunhoffer diffraction pattern obtained with a single slit illuminated at normal incidence. At the angular position of the first diffraction minimum the phase difference (in radians) between the wavelets from the opposite edges of the slit is **[1995S]**

(a) $\pi/4$ (b) $\pi/2$ (c) 2π (d) π

3. A beam of light of wave length 600 nm from a distance source falls on a single slit 1 mm wide and a resulting diffraction pattern is observed on a screen 2m away. The distance between the first dark fringes on either side of central bright fringe is **[1994 - 1 Mark]**

(a) 1.2 cm (b) 1.2 mm (c) 2.4 cm (d) 2.4 mm

4. A parallel monochromatic beam of light is incident normally on a narrow slit. A diffraction pattern is formed on a screen placed perpendicular to the direction of the incident beam. At the first minimum of the diffraction pattern, the phase difference between the rays coming from the two edges of the slit is **[1998 - 2 Marks]**

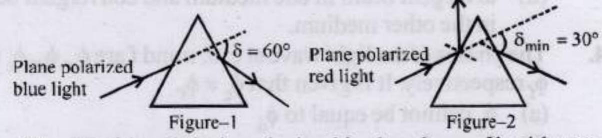
(a) 0 (b) $\pi/2$ (c) π (d) 2π

2 Integer Value Answer

5. A point source S emits unpolarized light uniformly in all directions. At two points A and B, the ratio $r = \frac{I_A}{I_B}$ of the intensities of light is 2. If a set of two polaroids having 45° angle between their pass-axes is placed just before point B, then the new value of r will be ____. **[Adv. 2024]**

6 MCQs with One or More than One Correct Answer

6. A plane polarized blue light ray is incident on a prism such that there is no reflection from the surface of the prism. The angle of deviation of the emergent ray is $\delta = 60°$ (see Figure-1). The angle of minimum deviation for red light from the same prism is $\delta_{min} = 30°$ (see Figure-2). The refractive index of the prism material for blue light is $\sqrt{3}$. Which of the following statement(s) is(are) correct? **[Adv. 2023]**



(a) The blue light is polarized in the plane of incidence.
(b) The angle of the prism is 45°.
(c) The refractive index of the material of the prism for red light is $\sqrt{2}$.
(d) The angle of refraction for blue light in air at the exit plane of the prism is 60°.

7. The electric field associated with an electromagnetic wave propagating in a dielectric medium is given $\vec{E} = 30(2\hat{x} + \hat{y})\sin\left[2\pi\left(5\times10^{14}t - \frac{10^7}{3}z\right)\right] Vm^{-1}$. Which of the following option(s) is (are) correct? **[Adv. 2023]**
[Given: The speed of light in vacuum, $c = 3\times10^8$ m s^{-1}]

(a) $B_x = -2\times10^{-7}\sin\left[2\pi\left(5\times10^{14}t - \frac{10^7}{3}z\right)\right]$ Wb m^{-2}.
(b) $B_y = 2\times10^{-7}\sin\left[2\pi\left(5\times10^{14}t - \frac{10^7}{3}z\right)\right]$ Wb m^{-2}.
(c) The wave is polarized in the xy-plane with polarization angle 30° with respect to the x-axis.
(d) The refractive index of the medium is 2.

Topic-4: Miscellaneous (Mixed Concepts) Problems

4 Fill in the Blanks

1. A point source emits sound equally in all directions in a non-absorbing medium. Two points P and Q are at a distance of 9 meters and 25 meters respectively from the source. The ratio of amplitudes of the waves at P and Q is .... **[1989 - 2 Marks]**

7 Match the Following

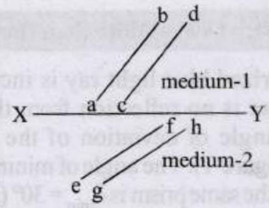
2. A simple telescope used to view distant objects has eyepiece and objective lens of focal lengths f_e and f_o, respectively. Then **[2006 - 6M]**

Column I	Column II
(A) Intensity of light received by lens	(p) Radius of aperture
(B) Angular magnification	(q) Dispersion of lens
(C) Length of telescope	(r) Focal length of objective lens and eyepiece lens
(D) Sharpness of image	(s) Spherical aberration

8 Comprehension/Passage Based Questions

Passage

The figure shows a surface XY separating two transparent media, medium-1 and medium-2. The line ab and cd represent waveforms of a light wave travelling in medium-1 and incident on XY. The lines ef and gh represent wavefronts of the light wave in medium-2 after refraction. **[2007]**



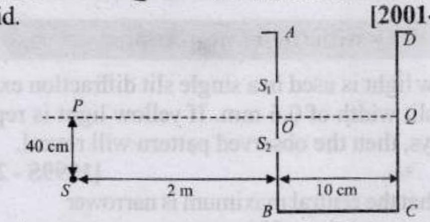
3. Light travels as a
(a) parallel beam in each medium
(b) convergent beam in each medium
(c) divergent beam in each medium
(d) divergent beam in one medium and convergent beam in the other medium.

4. The phases of the light wave at c, d, e and f are ϕ_c, ϕ_d, ϕ_e and ϕ_f respectively. It is given that $\phi_c \neq \phi_f$.
(a) ϕ_c cannot be equal to ϕ_d
(b) ϕ_d can be equal to ϕ_e
(c) $(\phi_d - \phi_f)$ is equal to $(\phi_c - \phi_e)$
(d) $(\phi_d - \phi_c)$ is not equal to $(\phi_f - \phi_e)$

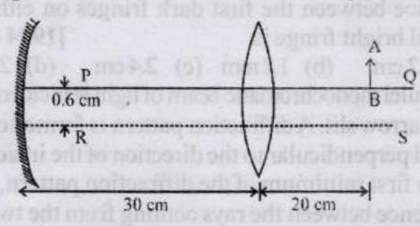
5. Speed of light is
(a) the same in medium-1 and medium-2
(b) larger in medium-1 than in medium-2
(c) larger in medium-2 than in medium-1
(d) different at b and d.

10 Subjective Problems

6. A vessel $ABCD$ of 10 cm width has two small slits S_1 and S_2 sealed with identical glass plates of equal thickness. The distance between the slits is 0.8 mm. POQ is the line perpendicular to the plane AB and passing through O, the middle point of S_1 and S_2. A monochromatic light source is kept at S, 40 cm below P and 2 m from the vessel, to illuminate the slits as shown in the figure below. Calculate the position of the central bright fringe on the other wall CD with respect to the line OQ. Now, a liquid is poured into the vessel and filled upto OQ. The central bright fringe is found to be at Q. Calculate the refractive index of the liquid. **[2001-5 Marks]**



7. (a) A convex lens of focal length 15 cm and a cancave mirror of focal length 30 cm are kept with their optic axes PQ and RS parallel but separated in vertical direction by 0.6 cm as shown. The distance between the lens and mirror is 30 cm. An upright object AB of height 1.2 cm is placed on the optic axis PQ of the lens at a distance of 20 cm from the lens. If $A'B'$ is the image after refraction from the lens and reflection from the mirror, find the distance of $A'B'$ from the pole of the mirror and obtain its magnification. Also locate position of A' and B' with respect to the optic axis RS. **[2000 - 6 Marks]**



(b) A glass plate of refractive index 1.5 is coated with a thin layer of thickness t and refractive index 1.8. Light of wavelength λ travelling in air is incident normally on the layer. It is partly reflected at the upper and the lower surface of the layer and the two reflected rays interfere. Write the condition for their constructive interference. If $\lambda = 648$ nm, obtain the least value of t for which the rays interfere constructively. **[2000 - 4 Marks]**

Answer Key

Topic-1 : Wavefront, Interference of Light, Coherent and Incoherent Sources

1. (a) **2.** (b) **3.** (b) **4.** (a) **5.** (c) **6.** (b, d) **7.** (b, c)

Topic-2 : Young's Double Slit Experiment

1. (c) **2.** (b) **3.** (d) **4.** (c) **5.** (d) **6.** (a) **7.** (b) **8.** (a) **9.** (c) **10.** (d)
11. (3) **13.** (False) **14.** (True) **15.** (a, b) **16.** (b, d) **17.** (a,b,c) **18.** (a, b) **19.** (a, c) **20.** (b, d)
21. (A-p, s; B-q; C-t; D-r, s, t) **22.** (601.50) **23.** (24)

Topic-3 : Diffraction, Polarisation of Light and Resolving Power

1. (d) **2.** (c) **3.** (d) **4.** (d) **5.** (8) **6.** (a, c, d) **7.** (a, d)

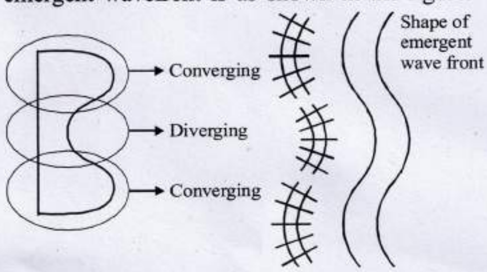
Topic-4 : Miscellaneous (Mixed Concepts) Problems

2. (A) $\rightarrow$ (p); (B) $\rightarrow$ (r); (C) $\rightarrow$ (r); (D) $\rightarrow$ (p), (q), (r) **3.** (a) **4.** (c) **5.** (b)

Hints & Solutions

Topic-1: Wavefront, Interference of Light, Coherent and Incoherent Sources

1. **(a)** Clearly middle part of glass is diverging and upper and lower part are converging so correct shape of the emergent wavefront is as shown in the figure.

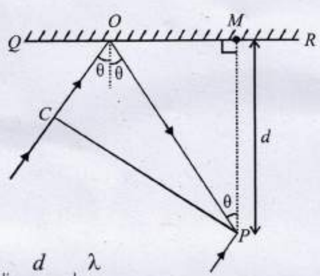


2. **(b)** In ΔOPM,

$$OP = \frac{d}{\cos\theta}$$

In ΔCOP,

$$OC = \frac{d\cos 2\theta}{\cos\theta}$$



Path difference between the two rays reaching P

$$= CO + OP + \frac{\lambda}{2} = \frac{d\cos 2\theta}{\cos\theta} + \frac{d}{\cos\theta} + \frac{\lambda}{2}$$

$$= \frac{d}{\cos\theta}(\cos 2\theta + 1) + \frac{\lambda}{2} = 2d\cos\theta + \frac{\lambda}{2}$$

For constructive interference at P, path difference $= n\lambda$

$$\therefore \quad 2d\cos\theta + \frac{\lambda}{2} = n\lambda \;\Rightarrow\; \cos\theta = \frac{(2n-1)}{4}\frac{\lambda}{d}$$

For $n = 1$, $\cos\theta = \frac{\lambda}{4d}$

3. **(b)** As we know, $I = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$

When phase difference is $\pi/2$

$$I_{\pi/2} = I + 4I \;\Rightarrow\; I_{\pi/2} = 5I$$

Again when d phase difference is π

$$I_\pi = I + 4I + 2\sqrt{I}\sqrt{4I}\cos\pi = I$$

$$\therefore \quad I_{\pi/2} - I_\pi = 5I - I = 4I$$

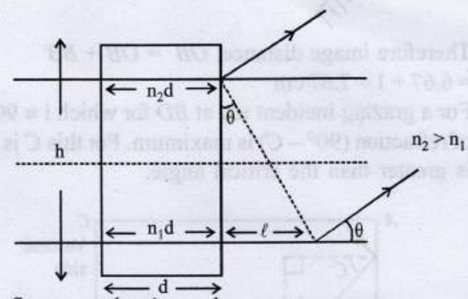
4. **(a)** Locus of equal path difference are lines running parallel to axis of the cylinder. Hence straight interference fringes will be observed.

5. **(c)** Let $I_1 = I$ and $I_2 = 4I$

$$\therefore \quad I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2 = (\sqrt{I} + \sqrt{4I})^2 = (3\sqrt{I})^2 = 9I$$

and $I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2 = (\sqrt{I} - \sqrt{4I})^2 = I$

6. **(b, d)**



From figure, $n_1 d + \ell = n_2 d$

$\therefore \ell = n_2 d - n_1 d = (n_2 - n_1)\,d$

$$\therefore \tan\theta = \frac{\ell}{h} = \frac{(n_2 - n_1)d}{h}$$

$\therefore$ Light wave emerging out of the slab is deflected by an angle $\theta = \tan^{-1}\left[\frac{(n_2 - n_1)d}{h}\right]$

It depends only on $(n_2 - n_1)$ and not on the individual values of n_1 and n_2

7. **(b, c)** At P_2,

$\Delta x = 0$. So we will have maxima there. It will be very much like central maxima in YDSE with $n = 0$. So (a) is incorrect.

At P_1

$\Delta x = S_1P - S_2P = d = 1.8$ mm

For maxima, $\Delta x = n\lambda$

$$n = \frac{\Delta x}{\lambda} = \frac{1.8 \times 10^{-3}}{600 \times 10^{-9}} = \frac{1.8}{600} \times 10^6 = 3000.$$

So, number of fringes between P_1 and P_2 will be 3000. So, (c) is correct. And it will also be highest order fringe. So, (b) is correct.

As, for bright fringe,

$d\cos\theta = n\lambda$

$\Rightarrow \; -d\sin\theta\,\Delta\theta = \Delta n\lambda$

$$\Rightarrow \; \Delta\theta = -\frac{(\Delta n)\lambda}{d\sin\theta}$$

as, we move from P_1 to P_2, $\theta \downarrow\downarrow$. So $\sin\theta \downarrow\downarrow$, therefore $\Delta\theta \uparrow\uparrow$. So (d) is incorrect.

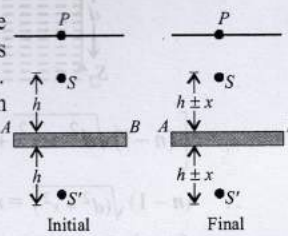
8. (a) Shape of the interference fringes will be circular.

(b) Intensity of light reaching on the screen directly from the source $I_1 = I_0$ (say) and intensity of light reaching on the screen after reflecting from the mirror is $I_2 = 36\%$ of $I_0 = 0.36 I_0$

$$\therefore \frac{I_1}{I_2} = \frac{I_0}{0.36 I_0} = \frac{1}{0.36} \text{ or } \sqrt{\frac{I_1}{I_2}} = \frac{1}{0.6}$$

$$\therefore \frac{I_{min}}{I_{max}} = \frac{\left(\sqrt{\frac{I_1}{I_2}}-1\right)^2}{\left(\sqrt{\frac{I_1}{I_2}}+1\right)^2} = \frac{\left(\frac{1}{0.6}-1\right)^2}{\left(\frac{1}{0.6}+1\right)^2} = \frac{1}{16}$$

(c) Initially path difference at P between two waves reaching from S and S' is 2h. Therefore, for maximum intensity at P:



$$2h = \left(n - \frac{1}{2}\right)\lambda \quad ...(i)$$

Now, let the reflecting surface AB is displaced by x. Then, new path difference will be $2h + 2x$ or $2h - 2x$ again for maximum intensity at P.

$$2h + 2x = \left[n + 1 - \frac{1}{2}\right]\lambda \quad ...(ii)$$

or $$2h - 2x = \left[n - 1 - \frac{1}{2}\right]\lambda \quad ...(iii)$$

Solving Eqs. (i) and (ii) or Eqs. (i) and (iii), we get

$$x = \frac{\lambda}{2} = \frac{600}{2} = 300 \text{ nm}$$

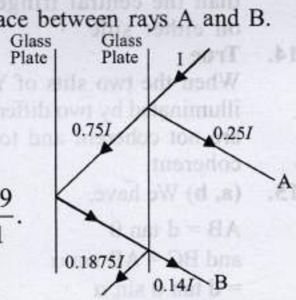
Note: Here, we have taken the condition of maximum intensity at P as : Path difference $\Delta x = \left(n - \frac{1}{2}\right)\lambda$

9. As shown in the figure, the interference will be between $0.25\,I = I_1$ and $0.14\,I = I_2$ as each plate reflects 25% and transmits 75% of light.

Interference pattern takes place between rays A and B.

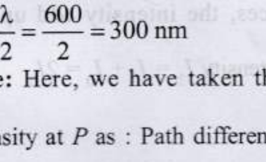
$$\frac{I_{max}}{I_{min}} = \frac{\left(\sqrt{I_1}+\sqrt{I_2}\right)^2}{\left(\sqrt{I_1}-\sqrt{I_2}\right)^2}$$

$$= \frac{[\sqrt{0.25\,I}+\sqrt{0.14\,I}]^2}{[\sqrt{0.25\,I}-\sqrt{0.14\,I}]^2} = \frac{49}{1}.$$



Topic-2: Young's Double Slit Experiment

1. **(c)** Path difference, $\Delta x = d \sin\alpha + d \sin\theta = d\alpha + \frac{yd}{D}$ [when α and θ are small]



(a) For α = 0, path difference $\Delta x = \frac{yd}{D}$

$$= \frac{0.3 \times 11}{1000} = 33 \times 10^{-4} \text{ mm}$$

Now $\frac{\Delta x}{\lambda} = \frac{33 \times 10^{-4}}{600 \times 10^{-6}} = \frac{11}{2}$

$\therefore \quad \Delta x = \frac{11}{2}\lambda \Rightarrow \Delta x = (2n-1)\frac{\lambda}{2}$

Hence interference at P is destructive.

(b) Fringe width $\beta = \frac{\lambda D}{d}$ is independent of α

(c) For $\alpha = \frac{0.36}{\pi}$ degree (at point P)

$$\Delta x = d\left[\alpha + \frac{y}{D}\right] = 0.3 \times 10^{-3}\left[\frac{0.36}{180} + \frac{11 \times 10^{-3}}{1}\right] \text{m} = 3900 \text{ nm}$$

Now $\frac{\Delta x}{\lambda} = \frac{3900}{600} = \frac{13}{2}\lambda$

Hence destructive interference at P.

(d) For $\alpha = \frac{0.36}{\pi}$ degree (at point O)

$\Delta x = d\alpha = 0.3 \times 10^{-3} \times \frac{0.36}{180}$

$= 600 \times 10^{-9}\text{m} = 600 \text{ nm}$

Now $\frac{\Delta x}{\lambda} = 1 \Rightarrow \Delta x = 1\lambda$

Hence constructive interference at O.

2. **(b)** Intensity $I = I_o \cos^2\frac{\phi}{2}$ where I_o is the peak intensity

Here $I = \frac{I_o}{2}, \therefore \frac{I_o}{2} = I_o \cos^2\frac{\phi}{2}, \therefore \phi = \frac{\pi}{2}(2n+1)$

$\therefore \quad \phi = \frac{\pi}{2}, \frac{3}{2}\pi, \frac{5}{2}\pi....$

And path difference,

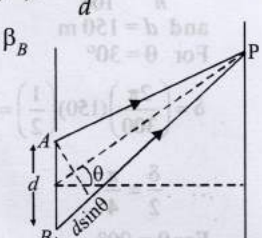
$$\Delta x = \left(\frac{\lambda}{2\pi}\right)\phi \quad \therefore \Delta x = \frac{\lambda}{4}, \frac{3}{4}\lambda ..... \frac{(2n+1)}{4}\lambda$$

3. **(d)** We know that fringe width, $\beta = \frac{\lambda D}{d}$

$\because \quad \lambda_R > \lambda_G > \lambda_B \therefore \beta_R > \beta_G > \beta_B$

4. **(c)** $I = I_{max}\cos^2\frac{\phi}{2}$

$= I_{max}\cos^2\frac{\pi d \sin\theta}{\lambda}$



$\phi = \frac{2\pi}{\lambda} d \sin\theta$

$\Rightarrow \quad \frac{I_{max}}{4} = I_{max}\cos^2\left(\frac{\pi d \sin\theta}{\lambda}\right)$

or, $\cos\frac{\pi d \sin\theta}{\lambda} = \frac{1}{2} \Rightarrow \frac{\pi d \sin\theta}{\lambda} = \frac{\pi}{3} \qquad \therefore \theta = \sin^{-1}\left(\frac{\lambda}{3d}\right)$

5. **(d)** At the area of total darkness minima will occur for both the wavelengths incident simultaneously and normally.

$\therefore \quad \frac{(2n+1)}{2}\lambda_1 = \frac{(2m+1)}{2}\lambda_2 \Rightarrow (2n+1)\lambda_1 = (2m+1)\lambda_2$

or $\frac{(2n+1)}{(2m+1)} = \frac{560}{400} = \frac{7}{5}$ or $10n = 14m + 2$

By inspection for $m = 2, n = 3$ and for $m = 7, n = 10$, the distance between them will be the distance between such points.

i.e., $\Delta s = \frac{D\lambda_1}{d}\left\{\frac{(2n_2+1)-(2n_1+1)}{2}\right\}$

Put $n_2 = 10, n_1 = 3$

$$\Delta s = \frac{1\times(400\times10^{-9})}{0.1\times10^{-3}}\left[\frac{21-7}{2}\right] = 28\text{mm}$$

6. **(a)** Path difference $= (\mu - 1)\,t = n\lambda$;

For minimum t, $n = 1$; $\therefore\ t = \frac{n\lambda}{(\mu-1)} = \frac{\lambda}{(1.5-1)} = 2\lambda$

7. **(b)** Fringe width, $\omega = \frac{12\lambda_1 D}{d} = \frac{k\lambda_2 D}{d}$

$\Rightarrow\ k = \frac{12\times600}{400} = 18$

Hence the number of fringes observed in the same segment of the screen = 18.

8. **(a)** When slits are of equal width.

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

$I_{min} \propto (a-a)^2\ (= 0)$

When one slit's width is twice that of other

$$\frac{I_1}{I_2} = \frac{W_1}{W_2} = \frac{a^2}{b^2} \Rightarrow \frac{W}{2W} = \frac{a^2}{b^2} \Rightarrow b = \sqrt{2}a$$

$\therefore\ I_{max} \propto (a + \sqrt{2}a)^2 = (5.8\,a^2)$

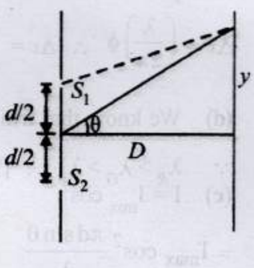
$I_{min} \propto (\sqrt{2}a - a)^2 = (= 0.17\,a^2)$

Clearly, the intensities of both the maxima and minima increase.

9. **(c)** We know that intensity of light

$I(\theta) = I_0\cos^2\frac{\delta}{2}$ where $\delta = \frac{2\pi d\tan\theta}{\lambda}$

$\therefore\ I(\theta) = I_0\cos^2\left(\frac{\pi d\sin\theta}{\lambda}\right)$



$\lambda = \frac{v}{h} = \frac{3\times10^8}{106} = 300m$

and $d = 150$ m

For $\theta = 30°$

$\delta = \left(\frac{2\pi}{300}\right)(150)\left(\frac{1}{2}\right) = \frac{\pi}{2}$

$\therefore\ \frac{\delta}{2} = \frac{\pi}{4}$ $\qquad \therefore\ I(\theta) = I_0\cos^2\left(\frac{\pi}{4}\right) = \frac{I_o}{2}$

For $\theta = 90°$

$\delta = \left(\frac{2\pi}{300}\right)(150)(1) = \pi$ or $\frac{\delta}{2} = \frac{\pi}{2}$ and $I(\theta) = 0$

For $\theta = 0°$, $\delta = 0$ or $\frac{\delta}{2} = 0$

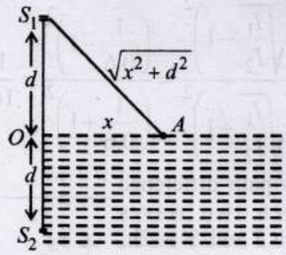
$\therefore\ I(\theta) = I_0$

10. **(d)** Here $\beta = \frac{\lambda D}{d}$ and $\beta' = \frac{\lambda(2D)}{d/2} = 4\frac{\lambda D}{d} = 4\beta$

The fringe width is quadrupled.

11. **(3)** For maxima, Path defference $= m\lambda$

$\therefore\ S_2A - S_1A = m\lambda$



$\therefore\ \left[(n-1)\sqrt{d^2+x^2} + \sqrt{d^2+x^2}\right] - \sqrt{d^2-x^2} = m\lambda$

$\therefore\ (n-1)\sqrt{(d^2+x^2)} = m\lambda$

$\therefore\ \left(\frac{4}{3}-1\right)\sqrt{d^2+x^2} = m\lambda\ \therefore\ \sqrt{d^2+x^2} = 3m\lambda$

$\therefore\ d^2 + x^2 = 9m^2\lambda^2\ \therefore\ x^2 = 9m^2\lambda^2\ d^2$

Comparing this equation with the given equation $x^2 = p^2m^2\lambda^2 - d^2$, we get

$p^2 = 9\ \therefore\ p = 3$

12. For coherent sources, for constructive interference

The amplitude at the mid point $= A + A = 2A$

$I_{max} \propto (2A)^2 \Rightarrow I_{max} = 4I_0 = I_1$

D_0 = Intensity due to one slit

For incoherent sources, the intensity add up normally (no interference).

Therefore, the total intensity $I_2 = I_0 + I_0 = 2I_0$ ... (ii)

From eqs. (i) and (ii)

$$\frac{I_1}{I_2} = \frac{4I_0}{2I_0} = 2$$

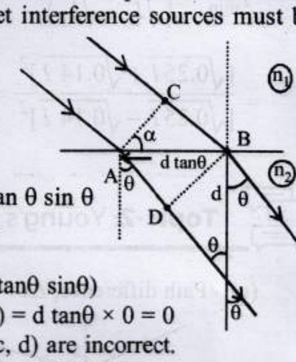
13. **False**

In Young's double slit experiment if source is of white light than the central fringe is white with coloured fringes on either side.

14. **True**

When the two slits of Young's double slit experiment are illuminated by two different sodium lamps, then the sources are not coherent and to get interference sources must be coherent.

15. **(a, b)** We have,



AB = d tan θ

and BC = AB sin α

= d tan θ sin α

Also, AD = AB sin θ = d tan θ sin θ

So, optical path difference

n_1 BC − n_2 AD

$= n_1\,(d\tan\theta\sin\alpha) - n_2\,(d\tan\theta\sin\theta)$

$= d\tan\theta\,(n_1\sin\alpha - n_2\sin\theta) = d\tan\theta \times 0 = 0$

So, (a, b) are correct and (c, d) are incorrect.

16. **(b, d)** Path difference at O = d = 0.6003mm

For $n\frac{\lambda}{2} = d$ we get n = 2001

As n is a whole number, the condition for minima is satisfied. Therefore 'O' will be dark. i.e., minima is formed at 'O'. Also, as the screen is perpendicular to the plane containing the slits S_1, S_2, therefore fringes obtained will be semi-circular (only top half of the screen is available)

17. **(a, b, c)** We know that fring width, $\beta = \frac{\lambda D}{d}$

$\because \quad \lambda_2 > \lambda_1 \therefore \beta_2 > \beta_1$

Number of fringes in a given width $m \propto \frac{1}{\beta} \therefore m_1 > m_2$

$$3 \times \frac{\lambda_2 D}{d} = \frac{(2\times 5-1)\lambda_1}{2}\frac{D}{d}$$

$3 \times 600 = 4.5 \times 400$

Angular separation $\frac{\lambda}{d} \propto \lambda$

So it is greater for λ_2.

18. **(a, b)** Condition to obtain maxima in young's double slit experiment is

$d \sin\theta = n\lambda$ where n is an integer

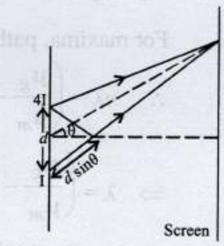
(a) When $d = \lambda$

$\lambda \sin\theta = n\lambda \Rightarrow \sin\theta = n$

When $n = 0,\ \theta = 0$

When $n = 1,\ \theta = 90°$

(This will be a point on the screen which will be at infinity and therefore not practical)



Other values of n are invalid as $-1 \le \sin\theta \le 1$.

Hence, only one maxima when $d = \lambda$.

(b) When $\lambda < d < 2\lambda$

$$\Rightarrow \lambda < \frac{n\lambda}{\sin\theta} < 2\lambda \qquad \left[\because d = \frac{n\lambda}{\sin\theta}\right]$$

$$\Rightarrow \quad 1 < \frac{n}{\sin\theta} < 2$$

$\therefore$ Possible values of n are 0, + 1, –1.

Hence, there is at least one more maxima besides the central maxima.

As we know,

$I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$ and $I_{min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$

Initially $I_1 = 4$ I and $I_2 = I$

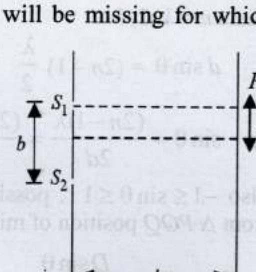
$\therefore \quad I_{max} = 9$ I and $I_{min} = I$

When $I_1 = I_2 = I$ then $I_{max} = 4$ I and $I_{min} = 0$

i.e., When the intensities become equal, I_{min} reduces to zero.

19. **(a, c)** Those wavelengths will be missing for which, path difference

$\Delta x = (2n-1)\lambda/2$



Here $y = (2n-1)\frac{\lambda}{2}\frac{D}{d}$

$= (2n-1)\frac{\lambda}{2}\frac{d}{b}$

$(\because d = b \text{ and } D = d)$

$\therefore \quad \frac{b}{2} = (2n-1)\frac{\lambda}{2}\frac{d}{b} \qquad (\because y = b/2)$

$$\Rightarrow \quad \lambda = \frac{b^2}{(2n-1)d} \text{ when } n = 1, 2$$

$$\lambda = \frac{b^2}{d}, \frac{b^2}{3d}, \ldots$$

20. **(b, d)** $\frac{I_{max}}{I_{min}} = \frac{\left(\sqrt{I_1}+\sqrt{I_2}\right)^2}{\left(\sqrt{I_1}-\sqrt{I_2}\right)^2} = \frac{9}{1} \quad \therefore \frac{I_1}{I_2} = 4$

Amplitude ratio, $\frac{A_1}{A_2} = \sqrt{\frac{I_1}{I_2}} = \sqrt{4} = 2$

21. **A-p, s; B-q; C-t; D-r, s, t**

For path difference $\lambda/4$, phase difference is $\pi/2$.

For path difference $\lambda/3$, phase difference is $2\pi/3$.

Here, $S_1P_0 - S_2P_0 = 0$

$\therefore \quad \delta(P_0) = 0$

The path difference for P_1 and P_2 will not be zero. The intensities at P_0 is maximum.

Intensity continuously decreases from P_0 towards P_2.

$\therefore \quad I(P_0) > I(P_1)$

(B) At P_1, path difference is zero. Hence P_1 is the brightest central fringe and $\delta P_1 = 0$.

$$\delta P_0 = \frac{\lambda}{4},\ \delta P_1 = 0,\ \delta P_2 = \frac{\lambda}{12}$$

(C) Here $\delta(P_0) = -\lambda/2;\ \delta(P_1) = -\lambda/4,\ \delta(P_2) = -\lambda/6$

$I(P_0) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos(-\pi)$

$= I_1 + I_2 - 2\sqrt{I_1}\sqrt{I_2} = I_0 + I_0 - 2I_0 = 0$

$I(P_1) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos(-\pi/2)$

$= I_1 + I_2 = I_0 + I_0 = 2I_0$

$I(P_2) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\left(-\frac{\pi}{3}\right)$

$= I_1 + I_2 + \sqrt{I_1}\sqrt{I_2} = I_0 + I_0 + I_0 = 3I_0$

$\therefore \quad I(P_2) > I(P_1) > I(P_0)$

(D) Here $\delta P_0 = 3\lambda/4;\ \delta P_1 = -\lambda/2;\ \delta P_2 = -5\lambda/12$

$I(P_0) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\left(\frac{-3\pi}{2}\right)$

$= I_1 + I_2 = I_0 + I_0 = 2I_0$

$I(P_1) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos(-\pi)$

$= I_1 + I_2 - 2\sqrt{I_1}\sqrt{I_2} = I_0 + I_0 - 2\sqrt{I_0}\sqrt{I_0} = 0$

$I(P_2) = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos[-5\pi/6]$

$= I_1 + I_2 - \sqrt{3}\sqrt{I_1}\sqrt{I_2} = \left(2-\sqrt{3}\right)I_0$

Clearly, $I(P_1) = 0$

$I(P_0) > I(P_1)$ and $I(P_2) > I(P_1)$

22. **(601.50)** Fringe width for nth fringe $y = n.\left(\frac{\lambda D}{d}\right)$

For 8^{th} fringe $y = 8\frac{\lambda D}{d}$

$y_{max} = 8\frac{\lambda D}{d_{min}}$ and $y_{min}\ 8\frac{\lambda D}{d_{max}}$

$$y_{max} - y_{min} = 8\lambda D\left[\frac{1}{d_{min}} - \frac{1}{d_{max}}\right]$$

Given D = 1m, $\lambda = 6000 \times 10^{-10m}$

$d_{max} = 0.34$ mm

$d_{min} = 0.76$ mm

$\therefore \quad y_{max} - y_{min}$

$= 8 \times 6000 \times 10^{-10} \times 1\left[\frac{1}{0.76 \times 10^{-3}} - \frac{1}{0.84 \times 10^{-3}}\right]$

$= 8 \times 6 \times 10^{-4} \times \left[\frac{0.08}{0.76 \times 0.84}\right] = 6.015 \times 10^{-4} m = 601.5 \mu m$

23. (24) Speed $v = \frac{dy}{dt} = -n.\frac{\lambda.d}{d^2}.\frac{d(d)}{dt}\left[\because y = n.\frac{\lambda D}{d}\right]$

$d = 0.8 + 0.04 \sin \omega t$ [given]

$\frac{d(d)}{dt} = 0.04\omega \cos \omega t$

For V_{max}; $\frac{d(d)}{dt} \longrightarrow max$

For $\frac{d(d)}{dt} \longrightarrow max.$

$\cos \omega t = 1 \Rightarrow \sin \omega t = 0$

$\Rightarrow \left(\frac{d(d)}{dt}\right)_{max} = 0.04$

$\Rightarrow d = 0.8\,mm$

$\therefore \quad V_{max} = \frac{8 \times 6000 \times 10^{-10} \times 1 \times 0.04 \times 0.08}{0.8 \times 0.8 \times 10^{-6} \times 10^{-3}} = 24 \mu m/s.$

24. Let the m^{th} maxima of 500 nm wavelength coincides with n^{th} maxima of 700 nm wavelength.

So, $y_n = y_m$

$\Rightarrow \frac{n\lambda_1 D}{d} = \frac{m\lambda_2 D}{d}$

$\Rightarrow n\lambda_1 = m\lambda_2$

$\Rightarrow \quad n \times 700 = m \times 500$

$\Rightarrow \quad 7n = 5m$

So, we get n = 5 and m = 7

So, minimum distance $= y_n = \frac{n\lambda_1 D}{d} = 5 \times 700 \times 10^{-9} \times 10^3$

$= 3.5$ mm

25. (a) Let the central maxima is obtained at a distance x below O.

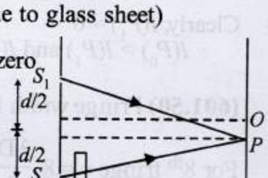
$\therefore \quad \Delta x_1 = S_1P - S_2P = \frac{xd}{D}$

and $\Delta x_2 = \left(\frac{\mu_g}{\mu_m} - 1\right)$ + (Due to glass sheet)

Here, net path difference is zero

$\therefore \quad \Delta x_1 = \Delta x_2$

$\therefore \quad \frac{xd}{D} = \left(\frac{\mu_g}{\mu_m} - 1\right)t$



$\Rightarrow x = \left(\frac{\mu_g}{\mu_m} - 1\right)t \times \frac{D}{d}$

$= \left(\frac{1.5}{4/3} - 1\right) \times \frac{(10.4 \times 10^{-6})(1.5)}{0.45 \times 10^{-3}} = 4.33 \times 10^{-3}$ m

(b) **For O,** path difference $= \left(\frac{\mu_g}{\mu_m} - 1\right)t \quad (\because \Delta x_1 = 0)$

$\therefore$ Phase difference

$\phi = \frac{2\pi}{\lambda}\Delta x = \frac{2\pi}{\lambda}\left(\frac{\mu_g}{\mu_m} - 1\right)t$

$= \frac{2 \times 3.14}{6 \times 10^{-7}}\left(\frac{1.5}{4/3} - 1\right)(10.4 \times 10^{-6}) = 6.8$ rad

$\because \quad I = I_0 \cos^2 \frac{\phi}{2} \quad \therefore \frac{I}{I_0} = \cos^2(6.8) = 0.75$

or, $I = \frac{3}{4} I_0$

(c) **For maximum intensity at O**

Again path difference $= \left(\frac{\mu_g}{\mu_m} - 1\right)t$

For maxima, path difference $= n\lambda$

$\therefore \quad n\lambda = \left(\frac{\mu_g}{\mu_m} - 1\right)t$

$\Rightarrow \lambda = \left(\frac{\mu_g}{\mu_m} - 1\right)\frac{t}{n} = \left(\frac{1.5}{4/3} - 1\right)\frac{10.4 \times 10^{-6}}{n}$

$= \frac{1.3 \times 10^{-6} m}{n} = \frac{1300}{n} nm$

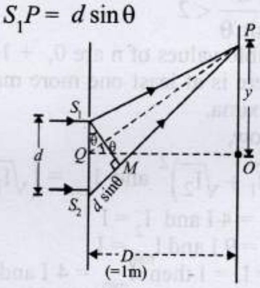
Putting n = 1, 2, 3 ..... to find the wavelength in the range of 0.4×10^{-6} m to 0.7×10^{-6} m we get

$\lambda = 6.5 \times 10^{-7}$ m and 4.33×10^{-7} m

26. (a) If the incident beam falls normally,

Path difference (Δx) from the ray starting from S_1 and S_2 and reaching a point P

$\Delta x = S_2P - S_1P = d \sin\theta$



And path difference for minimum intensity $= (2n - 1)\frac{\lambda}{2}$

where n = 1, 2, 3...

$\therefore \quad d \sin\theta = (2n - 1)\frac{\lambda}{2}$

$\Rightarrow \quad \sin\theta = \frac{(2n-1)\lambda}{2d} = \frac{(2n-1)0.5}{2 \times 1.0} = \frac{2n-1}{4}$

Also $-1 \le \sin\theta \le 1 \therefore$ possible values of m are $\pm 1, \pm 2, 0$

From ΔPOQ position of minima

$y = D\tan\theta = \frac{D\sin\theta}{\sqrt{1-\sin^2\theta}} = \frac{\sin\theta}{\sqrt{1-\sin^2\theta}} \quad (\because D = 1m)$

Therefore the y-coordinates of all the interference minima on the screen as follows

For $m = +1$, $\sin\theta = \frac{1}{4}$ and $y = 0.26$

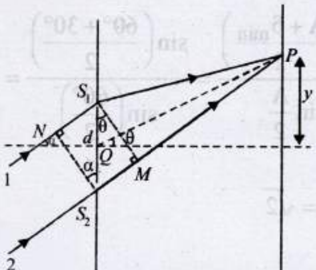
$m = -1$, $\sin\theta = -\frac{3}{4}$ and $y = -1.13$ m

$m=+2,\ \sin\theta=\frac{3}{4}\ \therefore y=+1.13\text{ m}$

$m=0,\ \sin\theta=-\frac{1}{4}\ \therefore y=-0.26\text{ m}$

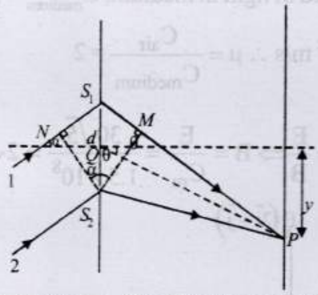
(b) If the incident beam makes anangle of 30° with x-axis Path difference between ray 1 and 2 reaching $P=S_2M-NS_1$

$\therefore\quad \Delta x_1 = d\sin\theta - d\sin\alpha$



Path difference between ray 1 and 2 reaching $P=NS_1+S_1M$

$\Delta x_2 = d\sin\alpha + d\sin\theta$



For central maxima, path difference should be zero.

$\therefore\quad \Delta x_1 = 0 \text{ or } \Delta x_2 = 0$

$\therefore\quad d\sin\alpha = d\sin\theta$

$\therefore\quad \alpha=\theta=30°$

$\because\quad y=\frac{\sin\theta}{\sqrt{1-\sin^2\theta}}=0.58\text{ m}$

For first minima; $d\sin\theta - d\sin\alpha = \frac{\lambda}{2}$

$\Rightarrow\quad d\sin\theta = \frac{\lambda}{2}+d\sin\alpha$

$\therefore\quad \sin\theta=\frac{\lambda}{2d}+\sin\alpha=\frac{0.5}{2\times 1}+\sin 30°=\frac{1}{4}+\frac{1}{2}=\frac{3}{4}$

$\therefore\quad y=\frac{\sin\theta}{\sqrt{1-\sin^2\theta}}=1.13\text{ m}$

For first minima on the other side

$d\sin\theta=\frac{\lambda}{2}$ or

$\sin\theta=\frac{\lambda}{2d}$ or, $\sin\theta=\frac{0.5}{2\times 0.1}=\frac{1}{4}$

$\therefore\quad y=\frac{\sin\theta}{\sqrt{1-\sin^2\theta}}=0.26\text{ m}$

Hence y-coordinates of the first minima on either side of the central maximum are 0.26 m and 1.13 m.

27. The phase difference $\phi=\frac{2\pi}{\lambda}\Delta x=\frac{2\pi}{\lambda}(5\lambda+\Delta)$

Where $\Delta < \lambda/2$

We know that $I(\phi)=I_{max}\cos^2\left(\frac{\phi}{2}\right)$

Intensity of $P=\frac{3}{4}I_{max}$

$\frac{3}{4}I_{max}=I_{max}\cos^2\frac{\phi}{2}\Rightarrow\frac{\phi}{2}=30°=\frac{\pi}{6}$

$\Rightarrow\quad \frac{2\pi}{6}=\frac{2\pi}{\lambda}(5\lambda+\Delta)\Rightarrow \Delta x\, 5\lambda+\frac{\lambda}{6}=0.3\,t$

$\therefore\quad t=9.3\times10^{-6}\text{ m}$

28. (i) ${}^{a}_{m}\mu=\frac{\lambda_a}{\lambda_m}\Rightarrow\lambda_m=\frac{\lambda_a}{{}^{a}_{m}\mu}$

(Wave length of light in the given liquid)

$\therefore\quad$ Fringe width $B=\frac{D}{d}\lambda$

$=\frac{\lambda_a D}{{}^{a}_{m}\mu d}=\frac{6300\times10^{-10}\times1.33}{1.33\times10^{-3}}=6.3\times10^{-4}\text{m}$

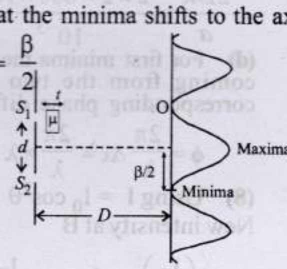
(ii) Let 't' be the thickness of glass hect which covers one of the slits. The shift of fringes when one slit is covered with thin glass sheet

$=\frac{Dt}{d}\left[\frac{{}_g\mu}{{}_m\mu}-1\right]$

The shift has to be such that the minima shifts to the axis

i.e., shifting of the fringes $=\frac{\beta}{2}$

$\therefore\quad \frac{Dt}{d}\left[\frac{{}_g\mu-{}_m\mu}{{}_m\mu}\right]=\frac{\beta}{2}$



$\Rightarrow\quad t=\frac{\beta d_m\mu}{2({}_g\mu-{}_m\mu)\times D}$

$=\frac{6.3\times10^{-4}\times10^{-3}\times1.33}{2(1.53-1.33)\times1.33}$

$=15.75\times10^{-7}\text{ m}=1.575\times10^{-6}\text{ m}$

29. Here power transmitted by A

$P_1=10\%\text{ of }I(\pi r_A^2)$

$=\left[10\%\text{ of}\left(\frac{10}{\pi}\right)\right]\times\pi(0.001)^2=10^{-6}\text{ W}$

Similarly, power transmitted by B

$P_2=\left[10\%\text{ of}\left(\frac{10}{\pi}\right)\right]\times\pi\times(0.002)^2=4\times10^{-6}\text{ W}$

Let $\Delta\phi$ be the phase difference introduced by film

$\therefore\quad \Delta\phi=\frac{2\pi}{\lambda}$ (path difference introduced by the film)

$=\frac{2\pi}{\lambda}\times(\mu-1)t=\frac{2\pi}{6000\times10^{-10}}[1.5-1]\times2000\times10^{-10}=\frac{\pi}{3}$

$\therefore\quad$ Power received at focal spot, F

$P=P_1+P_2+2\sqrt{P_1P_2}\cos\Delta\phi$

$=10^{-6}+4\times10^{-6}+2\sqrt{10^{-6}\times4\times10^{-6}}\cos\frac{\pi}{3}=7\times10^{-6}\text{ W}.$

30. (i) As we know, distance of the nth bright fringe from the central maxima

$y_n=\frac{n\lambda D}{d}$, For 3rd bright fringe $n=3$

$\therefore\ y_3 = \dfrac{3\times 6500\times 10^{-10}\times 120\times 10^{-2}}{2\times 10^{-3}} = 1.17\times 10^{-3}$ m

(ii) Let nth bright fringe of wavelength 6500 Å coincide with mth bright fringe of wavelength 5200Å. Here distance will be same from the central bright.

$\dfrac{n\lambda_1 D}{d} = \dfrac{m\lambda_2 D}{d}\quad \therefore\ \dfrac{n}{m} = \dfrac{5200}{6500} = \dfrac{4}{5}$

The least distance from the central maximum thus corresponds to 4th bright fringe of λ_1 = 6500 Å of 5th bright fringe of λ_2 = 5200 Å. Its distance from the central maxima

$y_n = \dfrac{4\times 6500\times 10^{-10}\times 120\times 10^{-2}}{2\times 10^3} = 1.56\times 10^{-3}$ m

Topic-3: Diffraction, Polarisation of Light and Resolving Power

1. **(d)** For diffraction pattern to be observed, the width of slit should be comparable to the wave length of light used. The wavelength of X-rays (1 – 100 Å) << slit width 0.6 mm.
2. **(c)** At the angular position of the first diffraction minimum, the phase difference (θ) between the wavelets from the opposite edges of the slit = 2π radian.
3. **(d)** The distance between the first dark fringe on either side of the central maximum = width of central maximum. Hence distance between two dark fringes on either side

$= \dfrac{2D\lambda}{a} = \dfrac{2\times 2\times 600\times 10^{-9}}{10^{-3}} = 2.4\times 10^{-3}\text{ m} = 2.4\text{ mm}$

4. **(d)** For first minima the path difference between the rays coming from the two edges should be λ therefore corresponding phase difference

$\phi = \dfrac{2\pi}{\lambda}\Delta x = \dfrac{2\pi}{\lambda}\times\lambda = 2\pi.$

5. **(8)** Using $I = I_0\cos^2\theta$

New intensity at B

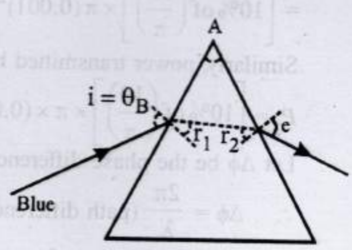
$I'_B = \left(\dfrac{I_B}{2}\right)\cos^2 45° = \dfrac{I_B}{4}$

New value of $r = \dfrac{I_A}{I_B} = \dfrac{4I_A}{I_B}$

$= 4\times 2 = 8$

6. **(a, c, d)**

Since for blue light ray, there is no reflection from the surface of the prism, so



$\tan\theta_B = \mu_B = \sqrt{3}$

Angle of incidence

$i = \theta_B = 60°$

From snell's law

$1\sin 60° = \sqrt{3}\sin r_1 \Rightarrow 1\times\dfrac{\sqrt{3}}{2} = \sqrt{3}\sin r_1$

$\therefore r_1 = 30°$

$\because r_1 + r_2 = A$

$\delta = (i + e) - A$

$\therefore 60° = 60° + e - A \Rightarrow e = A$

Again, $\sqrt{3}\sin r_2 = 1\sin e$

$\Rightarrow \sqrt{3}\sin(A - 30°) = \sin A \Rightarrow \sqrt{3}\sin 30° = \sin A$

$\therefore \sqrt{3}/2 = \sin A$

$\therefore A = 60°$

So, $e = 60°$

For red light

$\mu = \dfrac{\sin\left(\dfrac{A+\delta_{min}}{2}\right)}{\sin\dfrac{A}{2}} = \dfrac{\sin\left(\dfrac{60°+30°}{2}\right)}{\sin\left(\dfrac{60°}{2}\right)} = \dfrac{\sin 45°}{\sin 30°}$

$= \dfrac{(1/\sqrt{2})}{\dfrac{1}{2}} = \sqrt{2}$

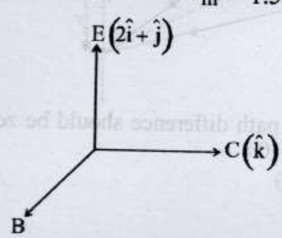
Therefore options (a, c, d) are correct.

7. **(a, d)** Speed of light in medium, $C_{medium} = \dfrac{\omega}{K} = \dfrac{5\times 10^{14}}{10^7/3}$

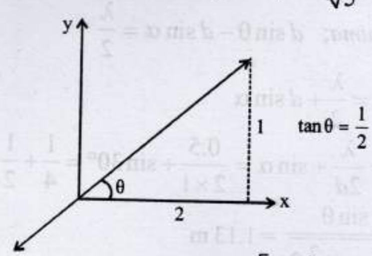
$= 1.5\times 10^8$ m/s $\therefore \mu = \dfrac{C_{air}}{C_{medium}} = 2$

Also,

$C_{medium} = \dfrac{E}{B} \Rightarrow B = \dfrac{E}{C_m} = \dfrac{30\sqrt{5}}{1.5\times 10^8} = 2\sqrt{5}\times 10^{-7}$



$B_{direction} = \vec{V}\times\vec{E} \equiv \hat{k}\times(2\hat{i}+\hat{j}) = \dfrac{2\hat{j}-\hat{i}}{\sqrt{5}}$



$\therefore B_x = 2\times 10^{-7}\left(-\hat{i}+2\hat{j}\right)\sin\left[27\left(5\times 10^{17}t - \dfrac{10^7}{3}z\right)\right]$

Topic-4: Miscellaneous (Mixed Concepts) Problems

1. $I \propto \dfrac{1}{r^2}$ and $I \propto A^2$

$\therefore A \propto \dfrac{1}{r}$ or, $\dfrac{A_1}{A_2} = \dfrac{r_2}{r_1} = \dfrac{25}{9}$

2. **(A) → (p); (B) → (r); (C) → (r); (D) → (p), (q), (r)**

(A) More the radius of aperture more is the amount of light entering the telescope.

(B) Angular magnification, $M = \dfrac{f_0}{f_e}$

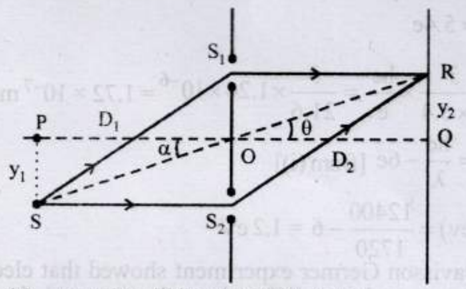
(C) Length of telescope, $L = f_0 + f_e$
Sharpness of image depends on dispersion of lens, spherical aberration and radius of aperture.

3. (a) For plane wavefronts, the beam of light is parallel. Hence light travels as a parallel beam in each medium.

4. (c) Since points c and d are on the same wavefront,
$\therefore\ \phi_d = \phi_c$
Similarly, $\phi_e = \phi_f \ \therefore \phi_d - \phi_f = \phi_c - \phi_e$

5. (b) From figure, the gap between consecutive wavefronts in medium 2 is less than that in medium 1. Hence, wavelength of light in medium 2 is less than that in medium 1. Therefore, speed of light ($v = f\lambda$) in medium 1 greater than in medium 2.

6.

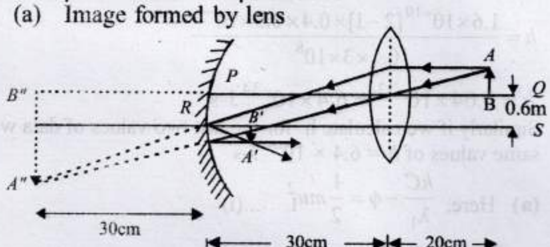


(a) Δx at R will be zero if $\Delta x_1 = \Delta x_2$
$\Rightarrow$ d sin α = d sin θ
$\Rightarrow \alpha = \theta \Rightarrow \tan\alpha = \tan\theta$

$$\Rightarrow \frac{y_1}{D_1} = \frac{y_2}{D_2} \Rightarrow y_2 = \frac{y_1}{D_1} \times D_2 = \left(\frac{10}{200} \times 40\right) \text{cm} = 2\text{cm}$$

(b) The central bright fringe will be observed at Point Q. If the path difference created by liquid slab of thickness t = 10 cm or 100 mm is equal to Δx. So net path difference at Q becomes zero, then
$t(\mu - 1) = \Delta x_1$
$\Rightarrow 100(\mu - 1) = 0.16$
$\Rightarrow \mu - 1 = 0.0016 \Rightarrow \mu = 1.0016$

7. (a) Image formed by lens



Applying lens formula

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_\ell} \Rightarrow \frac{1}{v} - \frac{1}{-20} = \frac{1}{15}$$

$$\Rightarrow \frac{1}{v} = \frac{1}{15} - \frac{1}{20} = \frac{1}{60} \Rightarrow v = 60 \text{ cm}$$

Magnification, $m = \frac{v}{u} = \frac{60}{-20} = -3$

The image formed by lens is real inverted and magnified
$A'B'$ size 3×1.2 cm = 3.6 cm
For the mirror, applying mirror formula,

$$\frac{1}{v'} + \frac{1}{u'} = \frac{1}{f_m} \Rightarrow \frac{1}{v'} = \frac{1}{-30} - \frac{1}{30} = -\frac{2}{30}$$

$\therefore\ v' = -15$ cm

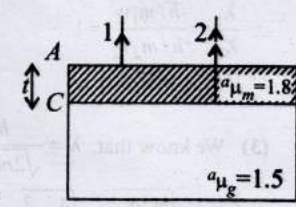
Magnification, $m = -\frac{v'}{u'} = -\frac{-15}{30} = \frac{1}{2}$

Size of image = $\frac{1}{2} \times 3.6 = 1.8$ cm.

i.e., The final image $A''B''$ is inverted w.r.t. the original image AB and its position will be 0.3 cm above RS and 1.5 cm below RS. The position of the image is 15 cm to the right of the mirror.

(b) The path difference between the two rays ray-1 reflected from the upper surface AB and ray-2 reflected from lower surface CD

$$\Delta x = {}^a\mu_m \times 2t + \frac{\lambda}{2}$$



Here $\frac{\lambda}{2}$ is the path difference as the ray 1 suffer reflection from a denser medium on surface AB

For constructive interference
Path difference = $n\lambda$ where n is 1, 2,....

$$\therefore\ {}^a\mu_m \times 2t + \frac{\lambda}{2} = n\lambda \Rightarrow 2\,{}^a\mu_m t = \left(n - \frac{1}{2}\right)\lambda$$

For least value of thickness t, $n = 1$

$$\therefore\ t = \frac{\lambda}{4^a \mu_m} = \frac{648}{4 \times 1.8} = 90 \text{ nm.}$$