Wave Optics

Multiple Choice Questions

Choose and write the correct option(s) in the following questions.

1. **When a wave undergoes reflection at an interface from rarer to denser medium, adhoc change in its phase is** **[*CBSE 2020 (55/4/1)*]**

   (*a*) $\frac{\pi}{2}$ (*b*) 0 (*c*) π (*d*) $\frac{\pi}{4}$

2. **Two waves having the intensities in the ratio of 9 : 1 produce interference. The ratio of maximum to minimum intensity is**

   (*a*) 10 : 8 (*b*) 9 : 1 (*c*) 4 : 1 (*d*) 2 : 1

3. **Four independent waves are expressed as**

   (*i*) $y_1 = a_1 \sin \omega t$ **(*ii*) $y_2 = a_2 \sin 2\omega t$**

   (*iii*) $y_3 = a_3 \cos \omega t$ and **(*iv*) $y_4 = a_4 \sin (\omega t + \pi/3)$**

   The interference is possible between

   (*a*) (*i*) and (*iii*) (*b*) (*i*) and (*iv*)

   (*c*) (*iii*) and (*iv*) (*d*) not possible at all

4. **Consider sunlight incident on a slit of width 10^4 A. The image seen through the slit shall** [*NCERT Exemplar*]

(*a*) be a fine sharp slit white in colour at the center.

(*b*) a bright slit white at the center diffusing to zero intensities at the edges.

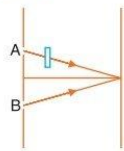
(*c*) a bright slit white at the center diffusing to regions of different colours.

(*d*) only be a diffused slit white in colour.

5. **In a Young's double-slit experiment the fringe width is found to be 0.4 mm. If the whole apparatus is dipped in water of refractive index 4/3, without disturbing the arrangement, the new fringe width will be**

(*a*) 0.30 mm (*b*) 0.40 mm (*c*) 0.53 mm (*d*) 0.2 mm

6 **In Young's experiment, monochromatic light is used to illuminate the slits *A* and *B*. Interference fringes are observed on a screen placed in front of the slits. Now if a thin glass plate is placed in the path of the beam coming from A, then**



(*a*) the fringes will disappear

(*b*) the fringe width will increase

(*c*) the fringe width will decrease

(*d*) there will be no change in the fringe width

7. **In Young's double slit experiment the separation *d* between the slits is 2 mm, the wavelength λ of the light used is 5896 Å and distance *D* between the screen and slits is 100 cm. It is found that the angular width of the fringes is 0.20°. To increase the fringe angular width to 0.21° (with same λ and *D*) the separation between the slits needs to be changed to**

(*a*) 1.8 mm

(*b*) 1.9 mm

(*c*) 2.1 mm

(*d*) 1.7 mm

8. **In a Young's double slit experiment, the source is white light. One of the holes is covered by a red filter and another by a blue filter. In this case** [*NCERT Exemplar*]

(*a*) there shall be alternate interference patterns of red and blue.

(*b*) there shall be an interference pattern for red distinct from that for blue.

(*c*) there shall be no interference fringes.

(*d*) there shall be an interference pattern for red mixing with one for blue.

9. **In a Young's double-slit experiment, the source *S* and two slits *A* and *B* are horizontal, with slit *A* above slit *B*. The fringes are observed on a vertical screen *K*. The optical path length from *S* to *B* is increased very slightly (by introducing a transparent material of higher refractive index) and optical path length from *S* to *A* is not changed. As a result, the fringe system on *K* moves**

(*a*) vertically downwards slightly

(*b*) vertically upwards slightly

(*c*) horizontally slightly to the left

(*d*) horizontally slightly to the right

10. **In Young's double-slit experiment, the distance between the slit sources and the screen is 1 m. If the distance between the slits is 2 mm and the wavelength of light used is 600 nm, the fringe width is**

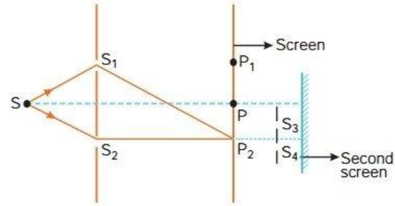
(*a*) 3 mm

(*b*) 0.3 mm

(*c*) 6 mm

(*d*) 0.6 mm

11. Figure shows a standard two slit arrangement with slits S_1, S_2. P_1, P_2 are the two minima points on either side of P. *[NCERT Exemplar]*



At P_2 on the screen, there is a hole and behind P_2 is a second 2- slit arrangement with slits S_3, S_4 and a second screen behind them.

(*a*) There would be no interference pattern on the second screen but it would be lighted.
(*b*) The second screen would be totally dark.
(*c*) There would be a single bright point on the second screen.
(*d*) There would be a regular two slit pattern on the second screen.

12. The Young's double-slit experiment is performed with blue and green lights of wavelengths 4360 Å and 5460 Å respectively. If x is the distance of 4th maxima from the central one, then

(*a*) $(x)_{blue} = (x)_{green}$
(*b*) $(x)_{blue} > (x)_{green}$
(*c*) $(x)_{blue} < (x)_{green}$
(*d*) $\frac{(x)_{blue}}{(x)_{green}} = \frac{5460}{4360}$

13. The intensity ratio of the maxima and minima in an interference pattern produced by two coherent sources of light is 9 : 1. The intensities of the used light sources are in ratio

(*a*) 3 : 1
(*b*) 4 : 1
(*c*) 9 : 1
(*d*) 10 : 1

14. In a double-slit experiment instead of slits of equal widths, one slit is made twice as wide as the other. Then in the interference pattern

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

15. In the wave picture of light, the intensity I of light is related to the amplitude A of the wave as *[CBSE 2023 (55/3/1)]*

(*a*) $I \propto \sqrt{A}$
(*b*) $I \propto A$
(*c*) $I \propto A^2$
(*d*) $I \propto \frac{1}{A^2}$

16. A double slit interference experiment is carried out in air and the entire arrangement is dipped in water. The fringe width

(*a*) increases
(*b*) decreasess
(*c*) remains unchanged
(*d*) fringe pattern disappears

17. An electromagnetic radiation of frequency n wavelength λ, travelling with velocity v in air enters a glass slab of refractive index μ. The frequency, wavelength and velocity of light in the glass slab will be respectively

(*a*) $n, 2\lambda$ and $\frac{v}{\mu}$
(*b*) $\frac{2n}{\mu}, \frac{\lambda}{\mu}$ and v
(*c*) $\frac{n}{\mu}, \frac{\lambda}{\mu}$ and $\frac{v}{\mu}$
(*d*) $n, \frac{\lambda}{\mu}$ and $\frac{v}{\mu}$

18. 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

(*a*) that the central maximum is narrower (*b*) more number of fringes

(*c*) less number of fringes (*d*) no diffraction pattern

19. Consider the diffraction pattern for a small pinhole. As the size of the hole is increased [*NCERT Exemplar*]

(*a*) the size decreases (*b*) the intensity increases

(*c*) the size increases (*d*) the intensity decreases

20. For light diverging from a point source [*NCERT Exemplar*]

(*a*) the wavefront is spherical.

(*b*) the intensity decreases in proportion to the distance squared.

(*c*) the wavefront is parabolic.

(*d*) the intensity at the wavefront does not depend on the distance.

21. In a single-slit diffraction experiment, the width of the slit is halved. The width of the central maximum, in the diffraction pattern, will become [*CBSE 2023 (55/3/1)*]

(*a*) half (*b*) twice (*c*) four times (*d*) one-fourth

22. In a Young's double slit experiment, the separation between the slits is 0.1 mm, the wavelength of light used is 600 nm and the interference pattern is observed on a screen 1 m away. Find the separation between bright fringes.

(*a*) 6.6 mm (*b*) 6.0 mm (*c*) 6 m (*d*) 60 cm

23. For light wave, λ is the wavelength, δ is the phase difference between two points on the wave separated by a distance of Δ. The relationship between λ, δ and Δ is

(*a*) $\Delta = \frac{2\pi}{\lambda}\delta$ (*b*) $\Delta = \frac{\lambda}{2\pi}\delta$ (*c*) $\delta = \frac{\Delta}{\lambda}$ (*d*) $\delta = \frac{\Delta\pi}{\lambda}$

24. The shape of the interference fringes in Young's double slit experiment when *D* (distance between slit and screen) is very large as compared to fringe width is nearly

(*a*) straight line (*b*) parabolic (*c*) circular (*d*) hyperbolic

Answers

1. (*c*)	**2.** (*c*)	**3.** (*d*)	**4.** (*a*)	**5.** (*a*)	**6.** (*d*)	**7.** (*b*)
8. (*c*)	**9.** (*a*)	**10.** (*b*)	**11.** (*d*)	**12.** (*c*)	**13.** (*b*)	**14.** (*a*)
15. (*c*)	**16.** (*b*)	**17.** (*d*)	**18.** (*d*)	**19.** (*a*), (*b*)	**20.** (*a*), (*b*)	**21.** (*b*)
22. (*b*)	**23.** (*b*)	**24.** (*a*)				

Assertion-Reason Questions

In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Choose the correct answer out of the following choices.

(a) *Both A and R are true and R is the correct explanation of A.*

(b) *Both A and R are true but R is not the correct explanation of A.*

(c) *A is true but R is false.*

(d) *A is false and R is also false.*

1. Assertion(*A*) : It is not possible to have interference between the waves produced by two violins.

Reason (*R*) : For interference of two waves the phase difference between the waves must remain constant. [*AIIMS 2012*]

2. **Assertion(A)** : The phase difference between any two points on a wavefront is zero.

Reason (R) : Corresponding to a beam of parallel rays of light, the wavefronts are planes parallel to one another.

3. **Assertion(A)** : For identical coherent waves, the maximum intensity is four times the intensity due to each wave.

Reason (R) : Intensity is proportional to the square of amplitude.

4. **Assertion(A)** : Corpuscular theory fails in explaining the velocities of light in air and water.

Reason (R) : According to corpuscular theory, light should travel faster in denser media than in rarer media. [*AIIMS 2012*]

5. **Assertion(A)** : In Young's double slit experiment all frings are of equal width.

Reason (R) : The fringe width depends upon wavelength of light (λ) used, distane of screen from plane of slits (D) and slits separation (d). [*CBSE 2023 (55/2/1)*]

6. **Assertion(A)** : Light added to light can produce darkness.

Reason (R) : When two coherent light waves interfere, there is darkness at position of destructive interference.

7. **Assertion(A)** : When the apparatus of Young's double-slit experiment is brought in a liquid from air, the fringe width decrease.

Reason (R) : The wavelength of light decreases in the liquid.

8. **Assertion(A)** : The phase difference between any two points on a wavefront is zero.

Reason (R) : All points on a wavefront are at the same distance from the source and thus oscillate in the same phase. [*CBSE 2023 (55/1/1)*]

9. **Assertion(A)** : Colours are seen in thin layers of oil on the surface of water.

Reason (R) : White light is composed of several colours. [*AIIMS 2018*]

10. **Assertion(A)** : Coloured spectrum is seen when we look through a muslin cloth.

Reason (R) : Coloured spectrum is due to diffraction of white light passing through fine slits made by fine threads in the muslin cloth.

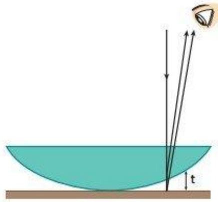
Answers

1. (*a*) **2.** (*b*) **3.** (*b*) **4.** (*a*) **5.** (*a*) **6.** (*a*) **7.** (*a*)
8. (*a*) **9.** (*b*) **10.** (*a*)

Case-based/Passage-based Questions

Read the paragraph given below and answer the questions that follow:

1. **Newton's Rings:** The figure shows convex surface of a lens in contact with a plane glass plate. A thin film of air is formed between the two surfaces. When you view the setup with monochromatic light, you see circular interference fringes. These were studied by Newton and are called Newton's rings. When you view the setup by reflected light, the center of the pattern is black. Can you see why this should be expected?



We can use interference fringes to compare the surfaces of two optical parts by placing the two in contact and observing the interference fringes. The figure shows a photograph made during the grinding of a telescope objective lens. The lower, larger diameter, thicker disk is the correctly shaped master, and the smaller, upper disk is the lens under test. The "Contour lines" are Newton's interference fringes; each one indicates an additional distance between the specimen and the master of one half wavelength. At 10 lines from the center spot the distance between the two surfaces is 5 wavelengths, or about 0.003 mm. This isn't very good, high quality lenses are routinely ground with a precision of less than one wavelength. The surface of the primary mirror of the Hubble Space Telescope was ground to a precision of better than $\frac{1}{50}$ wavelength. Unfortunately, it was ground to incorrect specifications, creating one of the most precise errors in the history of optical technology.

(*i*) What principle is responsible for light spreading as it passes through a narrow slit?

(*a*) Interference (*b*) Diffraction

(*c*) Polarisation (*d*) Refraction

(*ii*) When viewed with white light, Newton's ring appear as

(*a*) alternating bright and dark rings

(*b*) a series of concentric rings

(*c*) a concentric ring pattern of rainbow colors

(*d*) a dark ring centred at the point of contact

(*iii*) Newton's rings is a natural phenomenon that involves

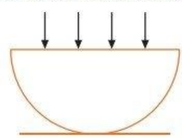
(*a*) an interference pattern due to reflection of light between two surfaces

(*b*) an interference pattern due to refraction of light between two surfaces

(*c*) a diffraction pattern due to reflection of light between two surfaces

(*d*) a diffraction pattern due to refraction of light between two surfaces

(*iv*) A thin slice is cut out of a glass cylinder along a line parallel to its axis. The slice is placed on a flat glass plate as shown. The observed interference fringes from this combination will be



(*a*) straight

(*b*) circular

(*c*) equally spaced

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

OR

Two light sources are said to be coherent if they

(*a*) are of the same frequency, and maintain a constant phase difference

(*b*) are of the same amplitude, and maintain a constant phase difference

(*c*) are of the same frequency and amplitude

(*d*) are of the same frequency

2. **Diffraction:** Diffraction of light is bending of light around the corners of an object whose size is comparable with the wavelength of light. Diffration actually defines the limits of ray optics. This limit for optical instruments is set by the wavelength of light. An experimental arrangement is set up to observe the diffraction pattern due to a single slit. [*CBSE 2023 (55/3/1), Modified*]

(*i*) The penetration of light into the region of geometrical shadow is called

(*a*) polarisation (*b*) interference
(*c*) diffraction (*d*) refraction

(*ii*) To observe diffraction, the size of an obstacle

(*a*) should be of the same order as wavelength
(*b*) should be much larger than the wavelength
(*c*) have no relation to wavelength
(*d*) should be exactly $\frac{l}{2}$

(*iii*) Both, light and sound waves produce diffraction. It is more difficult to observe diffraction with light waves because

(*a*) light waves do not require medium (*b*) wavelength of light waves is too small
(*c*) light waves are transverse in nature (*d*) speed of light is far greater

(*iv*) Angular width of central maximum of a diffraction pattern of a single slit does not depend upon

(*a*) distance between slit and source (*b*) wavelength of light used
(*c*) width of the slit (*d*) frequency of light used

OR

The diffraction effect can be observed in

(*a*) only sound waves (*b*) only light waves
(*c*) only ultrasonic waves (*d*) sound as well as light waves

Explanations

1. (*i*) (*b*) The phenomenon of bending of light around the sharp corners and the spreading of light within the geometrical shadow of the opaque obstacles is called diffraction of light.

(*ii*) (*c*) When viewed with white light, it forms a concentric ring pattern of rainbow colors, because the different wavelengths of light interfere at different thickness of the air layer between the surface.

(*iii*) (*a*) Newton's rings is a phenomenon in which an interference pattern is created by the reflection of light between two surfaces; a spherical surface and an adjacent touching flat surface.

(*iv*) (*b*) The fringes are locus of equal thickness which are circular. These are called Newton's rings.

OR

(*d*) The two waves are perfectly coherent, if their frequency and wave form are identical and their phase difference is constant.

2. (*i*) (*c*) The bending of light around the corners is known as diffraction of light. So, the light penetrates into the region of geometrical shadow.

(*ii*) (*a*) To observe diffraction, the size of obstacle should be of the same order as that of the wavelength.

(*iii*) (*b*) It is more difficult to observe diffraction with light waves because wavelength of light waves is far too smaller compared to that of sound waves.

(*iv*) (*a*) Angular width, $\theta = \frac{\lambda}{d} = \frac{c}{\nu d}$

Hence, angular width depend upon wavelength of light used, width of slit and frequency of light used.

OR

(*d*) The diffraction effect can be observed in sound as well as in light waves.

CONCEPTUAL QUESTIONS

Q. 1. Why are coherent soruces required to create interference of light? [*CBSE (F) 2009*]

Ans. Coherent sources are required for sustained interference. If sources are incoherent, the intensity at a point will go on changing with time.

Q. 2. Name any two factors on which the fringe width in a Young's double-slit experiment depends. [*CBSE 2023 (55/1/1)*]

Ans. As we know, Fringe width, $\beta = \frac{\lambda D}{d}$.

Factors which affect β, are:

(*a*) Wavelength of light (λ)

(*b*) Width of slit (*d*)

Q. 3. Write the conditions on path difference under which (*i*) constructive (*ii*) destructive interference occur in Young's double slit experiment. [*CBSE 2020 (55/5/1)*]

Ans. (*i*) for constructive interference path difference, $\Delta p = n\lambda, n = 0, 1, 2, 3...$ ½

(*ii*) for destructive interference path difference, $\Delta p = (2n + 1)\frac{\lambda}{2}, n = 0, 1, 2, 3...$ ½

[*CBSE Marking Scheme 2020 (55/5/1)*]

Q. 4. How does the fringe width of interference fringes change, when the whole apparatus of Young's experiment is kept in water (refractive index 4/3)? [*CBSE Delhi 2011*] [*HOTS*]

Ans. Fringe width, $\beta = \frac{D\lambda}{d} \Rightarrow \beta \propto \lambda$ for same D and d. When the whole apparatus is immersed in a transparent liquid of refractive index $n = 4/3$, the wavelength decreases to $\lambda' = \frac{\lambda}{n} = \frac{\lambda}{4/3}$. So, fringe width decreases to $\frac{3}{4}$ times.

Q. 5. In what way is the diffraction from each slit related to interference pattern in double slit experiment? [*CBSE Bhubaneshwar 2015*]

Ans. The intensity of interference fringes in a double slit arrangement is modulated by the diffraction pattern of each slit. Alternatively, in double slit experiment the interference pattern on the screen is actually superposition of single slit diffraction for each slit.

Q. 6. What is the shape of the wavefront on earth for sunlight? [*NCERT Exemplar*]

Ans. Spherical with huge radius as compared to the earth's radius so that it is almost a plane.

Q. 7. Why is the interference pattern not detected, when two coherent sources are far apart? [*HOTS*]

Ans. Fringe width of interference fringes, is given by $\beta = \frac{D\lambda}{d} \propto \frac{1}{d}$. If the sources are far apart; d is large; so fringe width (β) will be so small that the fringes are not resolved and they do not appear separate. That is why the interference pattern is not detected for large separation of coherent sources.

Q. 8. No interference pattern is detected when two coherent sources are infinitely close to each other. Why? [*HOTS*]

Ans. Fringe width of interference fringes is given by $\beta = \frac{D\lambda}{d} \propto \frac{1}{d}$. When d is infinitely small, fringe width β will be too large. In such a case even a single fringe may occupy the whole field of view. Hence, the interference pattern cannot be detected.

Q. 9. Consider a point at the focal point of a convergent lens. Another convergent lens of short focal length is placed on the other side. What is the nature of the wavefronts emerging from the final image? [*HOTS*] [*NCERT Exemplar*]

Ans. The focal point of a convergent lens is the position of real image formed by this lens, when object is at infinity. When another convergent lens of short focal length is placed on the other side, the combination will form a real point image at the combined focus of the two lenses. The wavefronts emerging from the final image will be spherical.

Q. 10. Why are coherent sources necessary to produce a sustained interference pattern? [*CBSE Delhi 2012*]

Ans. This is because coherent sources are needed to ensure that the positions of maxima and minima do not change with time.

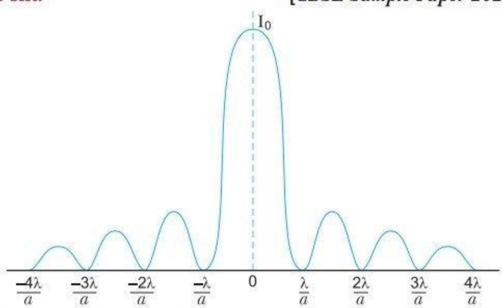
If the phase difference between wave, reaching at a point change with time intensity will change and sustained interference will not be obtained.

Very Short Answer Questions

Each of the following questions are of 2 marks.

Q. 1. Draw the graph showing intensity distribution of fringes with phase angle due to diffraction through single slit. [*CBSE Sample Paper 2021, CBSE 2023 (55/4/1)*]

Ans.



Intensity distribution of diffraction pattern.

Q. 2. State Huygens principle. How did Huygens explain the absence of the backwave? [*CBSE 2023 (55/3/1)*]

Ans. According to Huygens' principle, each point on a wave front is a source of secondary waves, which add up to give wave front at any later time which vibrating in same phase in all directions.

The absence of the back wave can be shown mathematically as we know that the amplitude of secondary wavelets is proportional to $(1 + \cos\theta)$, where θ is angle between the ray at the point of consideration and the direction of secondary wavelets. For a backward wavefront at $\theta = \pi$ so that $(1 + \cos\theta = 0)$. Thus the resultant amplitude of all the secondary wavelets at any point on the backward wavefront is zero. Hence, a backward wave point cannot exist.

Q. 3. Find the intensity at a point on a screen in Young's double slit experiment where the interfering waves of equal intensity have a path difference of (*i*) $\frac{\lambda}{4}$, and (*ii*) $\frac{\lambda}{3}$. [*CBSE (F) 2017*]

Ans. As we know, $I = 4\, I_0 \cos^2\frac{\phi}{2}$

(*i*) If path difference $= \dfrac{\lambda}{4}$

$$\Rightarrow \qquad \phi = \frac{2\pi}{\lambda} \times \Delta = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2}$$

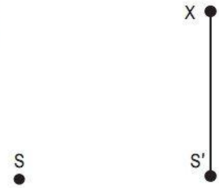
$$\text{Also,} \qquad I = 4I_0 \cos^2 \frac{\phi}{2} = 4I_0 \cos^2 \frac{\pi}{4} = \mathbf{2I_0}$$

(*ii*) If $\Delta = \dfrac{\lambda}{3}$

$$\Rightarrow \qquad \phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{3} = \frac{2\pi}{3}$$

$$\therefore \qquad I = 4I_0 \cos^2 \frac{\phi}{2} = 4I_0 \cos^2 \left(\frac{2\pi}{3 \times 2} \right) = \mathbf{I_0}$$

Q. 4. Two waves from two coherent sources *S* and *S'* superimpose at *X* as shown in the figure. If *X* is a point on the second minima and *SX*– *S'X* is 4.5 cm. Calculate the wavelength of the waves. **[*CBSE Sample Paper, 2021*]**



Ans. For 2nd minima, $n = 2$

Path difference $= \Delta x = (2n-1)\dfrac{\lambda}{2} = \dfrac{3\lambda}{2}$

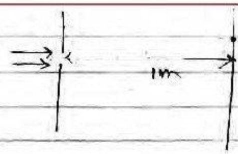
From the figure, Path Difference = SX – S'X = 4.5 cm (given)

Hence, $\qquad \Delta x = SX - S'X \quad \Rightarrow \quad \dfrac{3\lambda}{2} = 4.5$

$$\therefore \qquad \lambda = \mathbf{3\ cm}$$

Q. 5. A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting diffraction pattern is obtained on a screen 1 m away. If the first minimum is formed at a distance of 2.5 mm from the centre of the screen, find the (*i*) width of the slit, and (*ii*) distance of first secondary maximum from the centre of the screen. **[*CBSE 2020 (55/2/1)*]**

Ans.



We know for first minimum

$a \sin\theta = \lambda$.

$\Rightarrow \sin\theta = \lambda/a \Rightarrow \theta = \lambda/a$ [∵ θ is very small]

[a = width of slit,
λ = wavelength].

∴ linear distance = Dθ = Dλ/a.

[D is distance between slit and screen].

Here, $D\lambda/a = 2.5$ mm

$\Rightarrow \dfrac{1 \times 500 \times 10^{-9}}{a} = 2.5 \times 10^{-3}$

$\Rightarrow a = \dfrac{500 \times 10^{-9}}{2.5 \times 10^{-3}} = 200 \times 10^{-6}$ m $\Rightarrow 2 \times 10^{-4}$ m $= 0.2$ mm

∴ slit width = 0.2 mm (Ans i)

Now, angular distance ~~from se~~ for first secondary maximum

~~θ~~ $a \sin\theta = 3\lambda/2 \Rightarrow \theta = 3\lambda/2a$.

∴ linear distance = $\dfrac{3\lambda D}{2a}$.

∴ linear distance = $\dfrac{3}{2} \dfrac{\lambda D}{a} = \dfrac{3}{2} \times 2.5$ mm

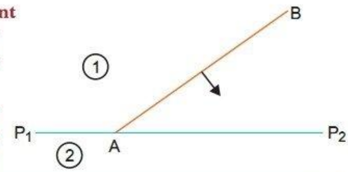
= 3.75

∴ distance = 3.75 mm (Ans ii)

[*Topper's Answer 2020*]

Q. 6. Define the term 'wave front of light'. A plane wave front AB propagating from denser medium (1) into a rarer medium (2) is incident on the surface P_1P_2 separating the two media as shown in fig.

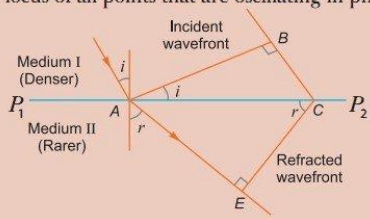
Using Huygen's principle, draw the secondary wavelets and obtain the refracted wave front in the diagram. [*CBSE 2020 (55/5/1)*]



Ans. The wave front is a surface of constant phase. **1**

Alternatively

The wave front is the locus of all points that are oscillating in phase.



1

[*CBSE Marking Scheme 2020 (55/5/1)*]

Q. 7. Two slits are made 1 mm apart and the screen is placed 1 m away. What should be the width of each slit to obtain 10 maxima of the double slit pattern within the central maximum of the single slit pattern? [*CBSE Guwahati 2015*]

Ans. If a is the size of single slit for diffraction pattern then, for first maxima

$$\theta = \frac{\lambda}{a} \quad (n = 1)$$

and angular separation of central maxima in the diffraction pattern

$$\theta' = 2\theta = \frac{2\lambda}{a}$$

The angular size of the fringe in the interference pattern

$$\alpha = \frac{\beta}{D} = \frac{\lambda}{d}$$

If there are 10 maxima within the central maxima of the diffraction pattern, then

$$10\,\alpha = \theta'$$

$$10\left(\frac{\lambda}{d}\right) = \frac{2\lambda}{a} \quad \Rightarrow \quad a = \frac{d}{5}$$

The distance between two slits is 1 mm.

$\therefore$ Size of the single slit $a = \frac{1}{5}\text{mm} = \mathbf{0.2\ mm}$

Q. 8. Two coherent monochromatic light beams of intensities I and $4I$ superpose each other. Find the ratio of maximum and minimum intensities in the resulting beam. [*CBSE 2023 (55/1/1)*]

Ans. As we know,

$$\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \frac{(\sqrt{I} + 2\sqrt{I})^2}{(\sqrt{I} - 2\sqrt{I})^2} \qquad (\because a_1^2 = I, a_1 = \sqrt{I} \qquad a_2^2 = 4I, a_2 = 2\sqrt{I})$$

$$\therefore \qquad \frac{I_{max}}{I_{min}} = \frac{[\sqrt{I}(1+2)]^2}{[\sqrt{I}(1-2)]^2} = \frac{\mathbf{9}}{\mathbf{1}}$$

Q. 9. (*i*) In diffraction due to a single slit, the phase difference between light waves reaching a point on the screen is 5π. Explain whether a bright or a dark fringe will be formed at the point.

(*ii*) What should the width (a) of each slit be to obtain eight maxima of two double-slit patterns (slit separation d) within the central maximum of the single slit pattern? [*CBSE 2023(55/4/1)*]

Ans. (*i*) As from the relation,

$$\frac{\Delta x}{\lambda} = \frac{\theta}{2\pi}$$

$$\therefore \qquad \Delta x = \left(\frac{5\pi}{2\pi}\right)\lambda = \frac{5}{2}\lambda = \left(2 + \frac{1}{2}\right)\lambda$$

For maxima in single-slit diffraction,

Path difference, $\Delta x = \left(n + \frac{1}{2}\right)\lambda$, $n = 0, 1, 2,$

As compare from above results, we get, $n = 2$

So, the bright fringe will formed.

(*ii*) In *YDSE*,

Fringe width, $\beta_1 = 8\beta_0 = \frac{8\lambda D}{d}$ (given)

also, angular width, $\theta_1 = \frac{\beta_1}{D} = \frac{8\lambda}{d}$

For single-slit diffraction pattern,

For central maxima, $\theta_2 = \frac{2\lambda}{a}$

Now, $\theta_1 = \theta_2$

$$\frac{8\lambda}{d} = \frac{2\lambda}{a}$$

$$\therefore \qquad a = \frac{d}{4}$$

Thus, width of each shit will be $\frac{1}{4}$th of slit separation.

Q. 10. In Young's double-slit experiment, the two slits are separated by a distance equal to 100 times the wavelength of light that passes through the slits. Calculate:

(*a*) the angular separation in radians between the central maximum and the adjacent maximum.

(*b*) the distance between these two maxima on a screen 50 cm from the slits. [*CBSE 2023 (55/1/1)*]

Ans. Here, $d = 100\,\lambda$ (given), $D = 50$ cm.

(*a*) Angular width, $\theta = \frac{\lambda}{d} = \frac{\lambda}{100\lambda} = \mathbf{0.01\ rad}$.

(*b*) Fringe width, $\beta = \frac{\lambda D}{d} = \frac{\lambda}{100\lambda} \times 50 = \frac{50}{100} = \mathbf{0.5\ cm}$.

Short Answer Questions

Each of the following questions are of 3 marks.

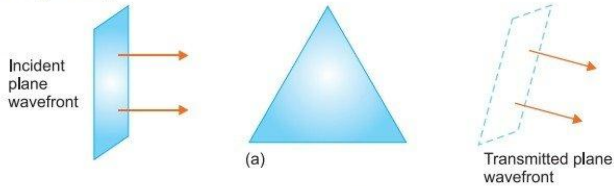
Q. 1. Draw the diagrams to show the behaviour of plane wavefronts as they (*a*) pass through a thin prism, and (*b*) pass through a thin convex lens and (*c*) reflect by a concave mirror.

[*CBSE Bhubaneshwar 2015, CBSE Sample Paper 2021*]

OR

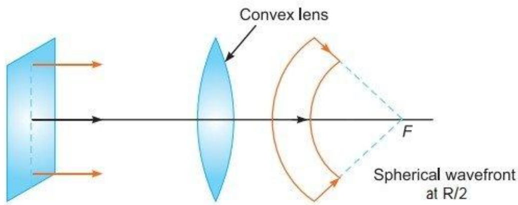
Use Huygens principle to show reflection/refraction of a plane wave by (*i*) concave mirror, and (*ii*) a convex lens. [*CBSE 2023 (55/3/1)*]

Ans. The behaviour of a thin prism, a thin convex lens and a concave mirror are shown in fig. (*a*), (*b*) and (*c*) respectively.



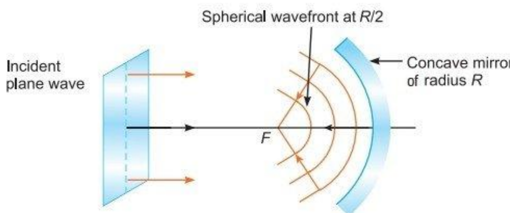
(a)

A plane wavefront after refraction through prism is plane.



(b)

A plane wavefront emerging after refraction through convex lens is spherical and converges to focus F.



(c)

A plane wavefront emerging after reflection through concave mirror is spherical and converges to focus F.

Q. 2. What is the shape of the wavefront in each of the following cases: [*CBSE Delhi 2009*]

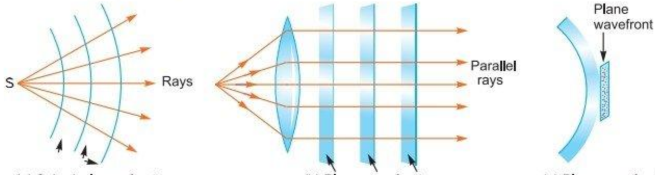
(*a*) light diverging from a point source.

(*b*) light emerging out of a convex lens when a point source is placed at its focus.

(*c*) the portion of a wavefront of light from a distant star intercepted by the earth.

Ans. (*a*) The wavefront will be **spherical** of increasing radius, fig. (*a*).

(*b*) The rays coming out of the convex lens, when point source is at focus, are parallel, so wavefront is **plane,** fig. (*b*).



(a) Spherical wavefront (b) Plane wavefront (c) Plane wavefront (*c*) The wavefront starting from star is spherical. As star is very far from the earth, so the wavefront intercepted by earth is a very small portion of a sphere of large radius; which is **plane** (*i.e.*, wavefront intercepted by earth is plane), fig. (*c*).

Q. 3. Explain the following, giving reasons:

(*i*) When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency.

(*ii*) When light travels from a rarer to a denser medium, the speed decreases. Does this decrease in speed imply a reduction in the energy carried by the wave?

(*iii*) In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of light? [*CBSE Central 2016*]

Ans. (*i*) Reflection and refraction arise through interaction of incident light with atomic constituents of matter which vibrate with the same frequency as that of the incident light. Hence frequency remains unchanged.

(*ii*) No; when light travels from a rarer to a denser media, its frequency remains unchanged. According to quantum theory of light, the energy of light photon depends on frequency and not on speed.

(*iii*) For a given frequency, intensity of light in the photon picture is determined by the number of photon incident normally on a crossing an unit area per unit time.

Q. 4. (*a*) Write the necessary conditions to obtain sustained interference fringes. Also write the expression for the fringe width.

(*b*) In Young's double slit experiment, plot a graph showing the variation of fringe width versus the distance of the screen from the plane of the slits keeping other parameters same. What information can one obtain from the slope of the curve?

(*c*) What is the effect on the fringe width if the distance between the slits is reduced keeping other parameters same? [*CBSE Patna 2015*]

Ans. (*a*) **Conditions for sustained interference:**

(*i*) The interfering sources must be coherent *i.e.*, sources must have same frequency and constant initial phase.

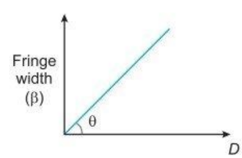
(*ii*) Interfering waves must have same or nearly same amplitude, so that there may be contrast between maxima and minima.

Fringe width, $\beta = \dfrac{D\lambda}{d}$

where D = distance between slits and screen.

d = separation between slits.

λ = wavelength of light used.



(*b*) **Information from the slope:**

Wavelength, $\lambda = \text{Slope} \times d = d.\tan\theta$

(*c*) **Effect:** From relation, $\beta = \dfrac{\lambda D}{d}$

Fringe width, $\beta \propto \dfrac{1}{d}$

If distance d between the slits is reduced, the size of fringe width will increase.

Q. 5. For a single slit of width "*a*", the first minimum of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of $\dfrac{\lambda}{a}$. At the same angle of $\dfrac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance "*a*". Explain. [*CBSE Delhi 2014*]

Ans. Case I: The overlapping of the contributions of the wavelets from two halves of a single slit produces a minimum because corresponding wavelets from two halves have a path difference of λ/2.

Case II: The overlapping of the wavefronts from the two slits produces first maximum because these wavefronts have the path difference of λ.

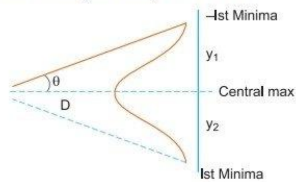
Q. 6. In the experiment on diffraction due to a single slit, show that

(*i*) the intensity of diffraction fringes decreases as the order (n) increases.

(*ii*) angular width of the central maximum is twice that of the first order secondary maximum. [*CBSE (F) 2011*]

Ans. (*i*) The reason is that the intensity of central maximum is due to constructive interference of wavelets from all parts of slit, the first secondary maximum is due to contribution of wavelets from one third part of slit (wavelets from remaining two parts interfere destructively) the second secondary maximum is due to contribution of wavelets from one fifth part only and so on.

(*ii*) For first minima $a\sin\theta = \lambda$ or $a\theta = \lambda$ $\quad \tan\theta = \frac{y_1}{D}$



$\Rightarrow \quad \theta = \frac{y_1}{D}$ (for θ is small, $\sin\theta \approx \theta$ and $\tan\theta \approx \theta$)

$\Rightarrow \quad \frac{ay_1}{D} = \lambda \qquad y_1 = \frac{\lambda D}{a} = y_2$

Hence the angular width of central maximum $= 2\theta = \frac{2\lambda}{a}$

Width of secondary maximum = Separation between nth and $(n+1)$th minima

For minima $\theta_n = \frac{n\lambda}{a} \qquad \theta_{n+1} = (n+1)\frac{\lambda}{a}$

Angular width of secondary maximum $= (n+1)\frac{\lambda}{a} - \frac{n\lambda}{a} = \frac{\lambda}{a}$

Hence β = Angular width $\times D = \frac{\lambda D}{a}$

Thus central maximum has twice the angular width of secondary maximum.

Q. 7. What is the effect on the interference fringes in Young's double slit experiment due to each of the following operations? Justify your answers.

(*a*) The screen is moved away from the plane of the slits.

(*b*) The separation between slits is increased.

(*c*) The source slit is moved closer to the plane of double slit. [*CBSE 2020 (55/5/1)*]

Ans. (*a*) Fringe width increases, $\beta = \frac{\lambda D}{d} \Rightarrow \beta \propto D$

(*b*) Fringe width decreases $\left(\beta \propto \frac{1}{d}\right)$

(*c*) Since condition $\frac{s}{S} < \frac{\lambda}{d}$ is not satisfied, no interference will be obtained and frenges disappear.

Q. 8. Two coherent light waves of intensity 5×10^{-2} Wm^{-2} each super-impose and produce the interference pattern on a screen. At a point where the path difference between the waves is $\lambda/6$, λ being wavelength of the wave, find the

(*a*) phase difference between the waves

(*b*) resultant intensity at the point

(*c*) resultant intensity in terms of the intensity at the maximum [*CBSE 2020 (55/4/1)*]

Ans. (*a*) Phase difference $= \frac{2\pi}{\lambda}$(path difference Δ)

$$\Delta = \frac{\lambda}{6} \text{ (Given)} \qquad \text{then, } \phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{6} = \frac{\pi}{3}$$

(*b*) $I = 2I_0(1+\cos\phi) = 2I_0\left(1+\cos\frac{\pi}{3}\right) = 2I_0\left(1+\frac{1}{2}\right) = 3I_0$

$$= 3 \times 5 \times 10^{-2}\ \text{Wm}^{-2}$$

$$= \mathbf{15 \times 10^{-2}\ Wm^{-2}}$$

(*c*) Maximum intensity $= 4I_0$

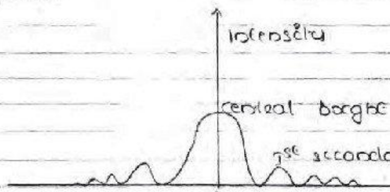
$$I_m = 4I_0,\ I = 3I_0$$

$$\frac{I}{I_m} = \frac{3}{4} \quad \Rightarrow \quad I = \frac{3}{4} I_m$$

Q. 9. Draw the intensity pattern for single slit diffraction and double slit interference for (*i*) the fringes produced in interference, and (*ii*) the Hence, state two difference between interference and diffraction. **[*CBSE AI 2017*]**

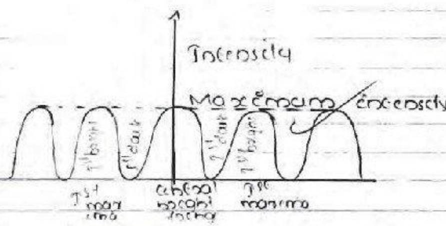
Ans. Intensity pattern of single slit diffraction

The central bright fringe has the maximum intensity and the intensity decreases as we move on to the either sides of the central maximum.



Intensity pattern for double slit interference:

All the bright fringes possess the same intensity



Interference	Diffraction
All the bright fringes are of equal intensity	The principal maxima possess the highest intensity and the intensity decreases as we move on to either sides from the principal maxima
All bright fringes are of equal width	The width of fringes also increases from principal maxima to either sides.
Maxima occurs at $\theta_n = \frac{n\lambda}{d}$	Minima occurs at $\theta_n = \frac{n\lambda}{d}$
Good contrast between bright and dark fringes	Poor contrast between bright and dark fringes

[*Topper's Answer 2017*]

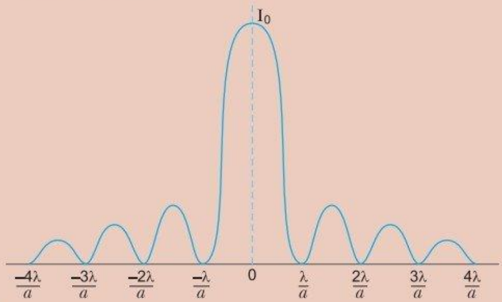
Q. 10. A plane wavefront of light of wavelength 'λ' is incident normally on a narrow slit of width 'a' and a diffraction pattern is observed on a screen at a distance 'D' from the slit.

(i) Depict the intensity distribution in the pattern observed.

(ii) Obtain the expression for the first maximum from the central maximum.

[*CBSE 2022 (55/2/1), Term-2*]

Ans. (i) Intensity distribution curve 1½



(ii) For maximum,

$$a \sin\theta = (n + \frac{1}{2})\lambda$$ ½

For first Maximum; $n = 1$ ½

For small θ; $a\theta = \frac{3\lambda}{2} \Rightarrow \theta = \frac{3\lambda}{2a}$

$$\Rightarrow \frac{x}{D} = \frac{3}{2}\frac{\lambda}{a}$$

$$\therefore \quad x = \frac{3}{2}\frac{\lambda D}{a}$$ ½

[*CBSE Marking Scheme 2022 (55/2/1), Term-2*]

Q. 11. A beam of light consisting of two wavelengths 600 nm and 500 nm is used in a Young's double slit experiment. The slit separation is 1.0 mm and the screen is kept 0.60 m away from the plane of the slits. Calculate :

(i) the distance of the second bright fringe from the central maximum for wavelength 500 nm, and

(ii) the least distance from the central maximum where the bright fringes due to both the wavelengths coincide. **[*CBSE 2022 (55/3/3), Term-2*]**

Ans.

Fringe width of any wavelength in Young's ~~dobl~~ double slit experiment is given by (β)

$$\boxed{\beta = \frac{D\lambda}{d}}$$

$D \to$ distance between slits and screen

$\lambda \to$ wavelength of light

$d \to$ distance between the slits

Hence,

• Fringe width of 600nm ⇒ $\beta_{600} = \frac{D\lambda}{d} = \frac{0.60 \times 600 \times 10^{-9}}{1.0 \times 10^{-3}}$

$= 3.6 \times 10^{-4}$ m

$\boxed{\beta_{600} = 0.36 \text{ mm}}$

Fringe width of 500nm ⇒ $\beta_{500} = \frac{D\lambda}{d} = \frac{0.6 \times 500 \times 10^{-9}}{1.0 \times 10^{-3}}$

$\boxed{\beta_{500} = 0.30 \text{ mm}}$

(i) Position of second bright fringe of 500nm ⇒ $y_2 = 2\beta_{500}$
Position of central maximum ⇒ $y_1 = 0$

⇒ Distance between second bright fringe and central maximum for $\lambda = 500$nm $= y_2 - y_1 = 2\beta_{500}$

$= \boxed{0.6 \text{ mm}}$
$= \boxed{6 \times 10^{-4} \text{ m}}$

Ans: Thus, the distance is 0.60mm (or 6×10^{-4} m)

(ii) Position of m^{th} bright fringe from central maxima for $\lambda = 500$ nm $= m\beta_{500}$

Position of n^{th} bright fringe from central maxima for $\lambda = 600$ nm $= n\beta_{600}$

If this position is same for both

$m\beta_{500} = n\beta_{600}$ ⇒ $m \times 0.30 = n \times 0.36$

$\boxed{5m = 6n}$ [where m, n are integers]

$\frac{m}{n} = \frac{6}{5}$

⇒ For smallest distance $m = 6$, $n = 5$

⇒ distance $= m\beta_{500} = n\beta_{600} = 6 \times 0.3$ mm

$= 5 \times 0.36$ mm

$= \boxed{1.8 \text{ mm}}$

Ans: Thus the least distance is 1.8mm (or 1.8×10^{-3} m)

[*Topper's Answer 2022*]

Q. 12. In the diffraction due to a single slit experiment, the aperture of the slit is 3 mm. If monochromatic light of wavelength 620 nm is incident normally on the slit, calculate the separation between the first order minima and the 3rd order maxima on one side of the screen. The distance between the slit and the screen is 1.5 m. ***[CBSE 2019 (55/1/1)]***

Ans. Condition for minima

$$a \sin\theta = n\lambda \quad ...(i)$$

and condition for secondary maxima

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

The first order minima $[n = 1]$

$$a \sin\theta = \lambda, \quad \tan\theta = \frac{y_1}{D}$$

$$\sin\theta = \frac{\lambda}{a} \Rightarrow \theta = \frac{\lambda}{a}, \quad \theta = \frac{y_1}{D} \quad [\because \text{for } \theta \text{ is small, } \sin\theta \simeq \theta \text{ and } \tan\theta \simeq \theta]$$

$$\therefore \quad \frac{y_1}{D} = \frac{\lambda}{a} \Rightarrow y_1 = \frac{\lambda D}{a}$$

Also 3rd order maxima

$$a \sin\theta = \left(3 + \frac{1}{2}\right)\lambda \Rightarrow a \sin\theta = \frac{7}{2}\lambda$$

$$\frac{y_3}{D} = \frac{7}{2}\frac{\lambda}{a} \Rightarrow y_3 = \frac{7}{2}\frac{\lambda D}{a}$$

Distance between first order minima from centre of the central maxima

$$y_1 = \frac{\lambda D}{a}$$

Distance of third order maxima from centre of the central maxima

$$y_3 = \frac{7\lambda D}{2a}$$

Distance between first order minima and third order maxima,

$$y_3 - y_1 = \frac{7}{2}\frac{\lambda D}{a} - \frac{\lambda D}{a} = \frac{\lambda D}{a}\left[\frac{7}{2} - 1\right] = \frac{\lambda D}{a} \times \frac{5}{2}$$

$$= \frac{620 \times 10^{-9} \times 1.5}{3 \times 10^{-3}} \times \frac{5}{2} = \mathbf{7.75 \times 10^{-4}\ m}$$

Q. 13. A parallel beam of light of wavelength 600 nm is incident normally on a slit of width 0.2 mm. If the resulting diffraction pattern is observed on a screen 1 m away, find the distance of

(*i*) first minimum, and

(*ii*) second maximum, from the central maximum ***[CBSE 2022 (55/1/1),Term-2]***

Ans. (*i*) $y = \frac{\lambda D}{a}, \quad [n = 1]$ ½

$$= \frac{600 \times 10^{-9} \times 1}{0.2 \times 10^{-3}}$$ ½

$$= 3 \times 10^{-3}\ \text{m} = 3\ \text{mm}$$ ½

(*ii*) $y = \left(n + \frac{1}{2}\right)\frac{\lambda D}{a}, \quad [n = 2]$ ½

$$\Rightarrow y = \left(2 + \frac{1}{2}\right)\frac{\lambda D}{a}$$ ½

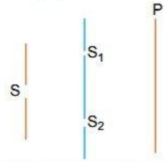
$$\therefore y = \frac{5}{2} \times \frac{600 \times 10^{-9} \times 1}{0.2 \times 10^{-3}}$$

$$= 7.5 \times 10^{-3} = 7.5\ \text{mm}$$ ½

[CBSE Marking Scheme 2022 (55/1/1), Term-2]

Q. 14. **(*i*) In a Young's double-slit experiment $SS_2 - SS_1 = \frac{\lambda}{4}$, where S_1 and S_2 are the two slits as shown in the figure.**

Find the path difference ($S_2P - S_1P$) for constructive and destructive interference at P.



(*ii*) What is the effect on the interference fringes in a Young's double-slit experiment, if the monochromatic source S is replaced by a source of white light? **[*CBSE 2023 (55/4/1)*]**

Ans. (*i*) Net path difference between two waves reaching on the screen through two slits is given as

$$SS_2P - SS_1P = (SS_2 - SS_1) + (S_2P - S_1P)$$

$$\Delta x = \frac{\lambda}{4} + (S_2P - S_1P)$$

For constructive interference $\Delta x = n\lambda$

$$\therefore \quad (S_2P - S_1P) = n\lambda - \frac{\lambda}{4} = \lambda\left(n - \frac{1}{4}\right) \text{ where, } n = 0, 1, 2, ...$$

For destructive interference,

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

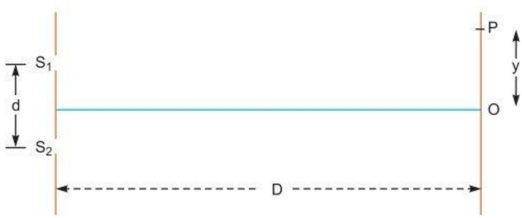
also, $$\Delta x = \frac{\lambda}{4} + (S_2P - S_1P)$$

$$\therefore \quad (S_2P - S_1P) = (2n-1)\frac{\lambda}{2} - \frac{\lambda}{4}$$

$$= \frac{\lambda}{4}[4n - 3], \text{ where } n = 1, 2, 3....$$

(*ii*) If monochromatic light source is replaced by a source of white light, the interference patterns due to different components of colours of white light will overlap. The central bright fringes for all colours are at same point, hence the central fringes is white, but all other fringes are coloured.

Q. 15. **The intensity at the central maxima (O) in a Young's double slit experiment is I_0. If the distance OP equals one-third of the fringe width of the pattern, show that the intensity at point P would be $\frac{I_0}{4}$.** **[*CBSE (F) 2011, 2012*]**



Ans. Fringe width $(\beta) = \frac{\lambda D}{d}$

$$y = \frac{\beta}{3} = \frac{\lambda D}{3d}$$

Path diff $(\Delta P) = \dfrac{yd}{D} \Rightarrow \Delta P = \dfrac{\lambda D}{3d} \cdot \dfrac{d}{D} = \dfrac{\lambda}{3}$

$\therefore \quad \Delta\phi = \dfrac{2\pi}{\lambda} . \Delta P = \dfrac{2\pi}{\lambda} \cdot \dfrac{\lambda}{3} = \dfrac{2\pi}{3}$

Intensity at central maxima, $I_0 = 4I$, where I = Intensity due to one slit.

Intensity at point P, $I_P = 4I\cos^2\left(\dfrac{\Delta\phi}{2}\right) = I_0 \cos^2 \dfrac{\Delta\phi}{2}$

$$= I_0\left[\cos\frac{2\pi}{3\times 2}\right]^2 = I_0\left(\frac{1}{2}\right)^2 = \frac{I_0}{4}$$

Q. 16. In a diffraction pattern due to a single slit, how will the angular width of central maximum change, if

(*i*) Orange light is used in place of green light,

(*ii*) the screen is moved closer to the slit,

(*iii*) the slit width is decreased ? Justify your answer in each case. **[*CBSE 2022 (55/3/3), Term-2*]**

Ans.

Angular width of the central maximum in single slit $(\theta) = \dfrac{2\lambda}{a}$

$\lambda \rightarrow$ wavelength of light

$a \rightarrow$ width of slit

Orange light has greater wavelength than green light. As the angular width of the central maxima is directly proportial to wavelength of light, ~~the~~ its value will increase is orange light is used in place of green light.

$\theta \propto \lambda$

$\lambda_{orange} > \lambda_{green}$

$\Rightarrow \boxed{\theta_{orange} > \theta_{green}}$

Ans: Increase in angular width.

The distance between the slit and screen is decreased when the screen is moved ~~cros~~ closer to slit. As the angular width is independent of the distance between the slit and screen its value will not change

$\theta \propto D^0$

$\boxed{\theta_i = \theta_f}$

Ans: No change in angular width

As the angular width is inversely proportional to slit width, it value will increase on decreasing width.

$$\therefore \quad \theta \propto \frac{1}{a}$$

$$a_i > a_f$$

$$\therefore \boxed{\theta_f > \theta_i}$$

Ans: Increase in angular width.

[*Topper's Answer*, 2022]

Q. 17. A beam of light consisting of two wavelength 650 nm and 520 nm, is used to obtain interference fringes in a Young's double slit experiment on a screen 1.2 m away. The separation between the slits is 2 mm.

(*a*) Find the distance of the third bright fringe on the screen from the central maximum for wavelength 650 nm.

(*b*) What is the least distance from the central maximum when the bright fringes due to both the wavelength coincide? **[*NCERT*]**

Ans. Given, $\lambda_1 = 650 \text{ nm} = 650 \times 10^{-9} \text{ m}$,

$$\lambda_2 = 520 \text{ nm} = 520 \times 10^{-9} \text{ m}$$

(*a*) For bright fringes,

$$y_n = \frac{nD\lambda_1}{d} \qquad [n = 3]$$

$$\Rightarrow \qquad y_3 = \frac{3 \times 1.2 \times 650 \times 10^{-9}}{2 \times 10^{-3}} = 1.17 \times 10^{-3} \text{m} = \mathbf{1.17 \ mm}$$

(*b*) For least distance of coincidence of fringes, there must be a difference of 1 in order of λ_1 and λ_2.

$$\Rightarrow \qquad n_1\beta_1 = n_2\beta_2 \text{ (given)} \quad \Rightarrow \quad \frac{n_1 D\lambda_1}{d} = \frac{n_2 D\lambda_2}{d} \quad \Rightarrow \quad n_1\lambda_1 = n_2\lambda_2$$

As $\lambda_1 > \lambda_2$, $n_1 < n_2$

If bright fringe will coincide at a least distance y, $n_1 = n, n_2 = n + 1$

$$\therefore \qquad (y_n)\lambda_1 = (y_{n+1})\lambda_2$$

$$\Rightarrow \qquad \frac{nD\lambda_1}{d} = \frac{(n+1)D\lambda_2}{d}$$

$$\Rightarrow \qquad n\lambda_1 = (n + 1)\lambda_2$$

$$\Rightarrow \qquad n = \frac{\lambda_2}{\lambda_1 - \lambda_2} = \frac{520 \text{ nm}}{(650 - 520) \text{ nm}} = \frac{520}{130} = 4$$

$$\therefore \text{ Least distance,} \quad y_{\min} = \frac{nD\lambda_1}{d} = \frac{4 \times 1.2 \times 650 \times 10^{-9}}{2 \times 10^{-3}}$$

$$= 1.56 \times 10^{-3} \text{ m}$$

$$= \mathbf{1.56 \ mm}$$

Long Answer Questions

Each of the following questions are of 5 marks.

Q. 1. Using Huygens' principle, draw a diagram to show propagation of a wavefront originating from a monochromatic point source. Explain briefly.

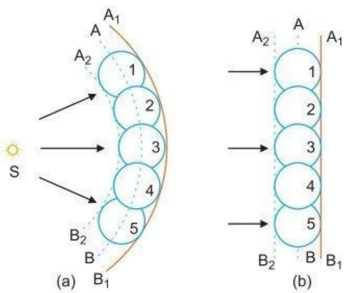
Ans. Propagation of Wavefront from a Point Source:

This principle is useful for determining the position of a given wavefront at any time in the future if we know its present position. The principle may be stated in three parts as follows:

(*i*) Every point on a given wavefront may be regarded as a source of new disturbance.

(*ii*) The new disturbances from each point spread out in all directions with the velocity of light and are called the ***secondary wavelets.***

(*iii*) The surface of tangency to the secondary wavelets in forward direction at any instant gives the new position of the wavefront at that time.



Let us illustrate this principle by the following example:

Let AB shown in the fig. be the section of a wavefront in a homogeneous isotropic medium at $t = 0$. We have to find the position of the wavefront at time t using Huygens' principle. Let v be the velocity of light in the given medium.

(*a*) Take the number of points 1, 2, 3, ... on the wavefront AB. These points are the sources of secondary wavelets.

(*b*) At time t the radius of these secondary wavelets is vt. Taking each point as centre, draw circles of radius vt.

(*c*) Draw a tangent A_1B_1 common to all these circles in the forward direction.

This gives the position of new wavefront at the required time t.

The Huygens' construction gives a backward wavefront also shown by dotted line A_2B_2 which is contrary to observation. The difficulty is removed by assuming that the intensity of the spherical wavelets is not uniform in all directions; but varies continuously from a maximum in the forward direction to a minimum of zero in the backward direction.

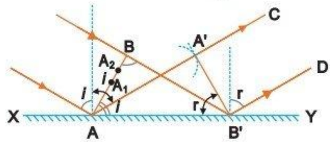
The directions which are normal to the wavefront are called rays, *i.e.*, a ray is the direction in which the disturbance is propagated.

Q. 2. Define the term wavefront. Using Huygen's wave theory, verify the law of reflection.

[*CBSE (55/1/1) 2019, 2020 (55/2/1), 2023 (55/5/1)*]

Ans. **Wavefront:** A wavefront is a locus of particles of medium all vibrating in the same phase.

Law of Reflection: Let XY be a reflecting surface at which a wavefront is being incident obliquely. Let v be the speed of the wavefront and at time $t = 0$, the wavefront touches the surface XY at A. After time t, the point B of wavefront reaches the point B' of the surface.



According to Huygen's principle each point of wavefront acts as a source of secondary waves. When the point A of wavefront strikes the reflecting surface, then due to presence of reflecting surface, it cannot advance further; but the secondary wavelet originating from point A begins to spread in all directions in the first medium with speed v. As the wavefront AB advances further, its points A_1, A_2, A_3 ... etc. strike the reflecting surface successively and send spherical secondary wavelets in the first medium.

First of all the secondary wavelet starts from point A and traverses distance $AA' (= vt)$ in first medium in time t. In the same time t, the point B of wavefront, after travelling a distance BB', reaches point B' (of the surface), from where the secondary wavelet now starts. Now taking A as centre we draw a spherical arc of radius $AA' (= vt)$ and draw tangent $A'B'$ on this arc from point B'. As the incident wavefront AB advances, the secondary wavelets starting from points between A and B', one after the other and will touch $A'B'$ simultaneously. According to Huygen's principle wavefront $A'B'$ represents the new position of AB, *i.e.*, $A'B'$ is the reflected wavefront corresponding to incident wavefront AB.

Now in right-angled triangles ABB' and $AA'B'$

$\angle ABB' = \angle AA'B'$ (both are equal to 90°)

side BB' = side AA' (both are equal to vt)

and side AB' is common.

i.e., both triangles are congruent.

$\therefore \quad \angle BAB' = \angle AB'A'$

i.e., incident wavefront AB and reflected wavefront $A'B'$ make equal angles with the reflecting surface XY. As the rays are always normal to the wavefront, therefore the incident and the reflected rays make equal angles with the normal drawn on the surface XY, *i.e.*,

Angle of incidence (i) = Angle of reflection (r)

This is the second law of reflection.

Since AB, $A'B'$ and XY are all in the plane of paper, therefore the perpendiculars dropped on them will also be in the same plane. Therefore we conclude that ***the incident ray, reflected ray and the normal at the point of incidence, all lie in the same plane.*** This is the first law of reflection. Thus Huygen's principle explains both the laws of reflection.

Q. 3. **(*a*) How is a wavefront defined? Using Huygen's constructions draw a figure showing the propagation of a plane wave refracting at a plane surface separating two media. Hence verify Snell's law of refraction.** **[*CBSE 2023 (55/1/1)*]**

When a light wave travels from rarer to denser medium, the speed decreases. Does it imply reduction its energy? Explain. **[*CBSE Delhi 2008, 2013, (F) 2011, 2012*]**

(*b*) When monochromatic light travels from a rarer to a denser medium, explain the following, giving reasons:

(*i*) **Is the frequency of reflected and refracted light same as the frequency of incident light?**

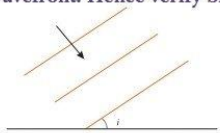
(*ii*) **Does the decrease in speed imply a reduction in the energy carried by light wave?**

[*CBSE Delhi 2013*]

OR

A plane wavefront propagating in a medium of refractive index 'n_1' is incident on a plane surface making the angle of incidence '*i*' as shown in the figure. It enters into a medium of refractive index 'n_2' ($n_2 > n_1$). Use Huygens' construction of secondary wavelets to trace the propagation of the refracted wavefront. Hence verify Snell's law of refraction.

[*CBSE (F) 2015, 2023 (55/5/1)*]



Ans. (*a*) **Wavefront:** A wavefront is a locus of all particles of medium vibrating in the same phase.

Huygen's Principle: Refer point 1 of Points to remember.

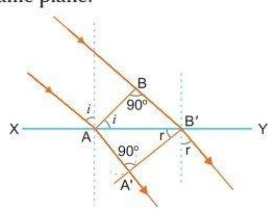
Proof of Snell's law of Refraction using Huygen's wave theory: When a wave starting from one homogeneous medium enters the another homogeneous medium, it is deviated from its path. This phenomenon is called **refraction**. In transversing from first medium to another medium, the frequency of wave remains unchanged but its speed and the wavelength both are changed. Let *XY* be a surface separating the two media '1' and '2'. Let v_1 and v_2 be the speeds of waves in these media.

Suppose a plane wavefront *AB* in first medium is incident obliquely on the boundary surface *XY* and its end *A* touches the surface at *A* at time $t = 0$ while the other end *B* reaches the surface at point B' after time-interval *t*. Clearly $BB' = v_1t$. As the wavefront *AB* advances, it strikes the points between *A* and B' of boundary surface. According to Huygen's principle, secondary spherical wavelets originate from these points, which travel with speed v_1 in the first medium and speed v_2 in the second medium.

First of all secondary wavelet starts from *A*, which traverses a distance $AA' (= v_2t)$ in second medium in time *t*. In the same time-interval *t*, the point of wavefront traverses a distance $BB' (= v_1t)$ in first medium and reaches B', from, where the secondary wavelet now starts. Clearly $BB' = v_1t$ and $AA' = v_2t$.

Assuming *A* as centre, we draw a spherical arc of radius $AA' (= v_2t)$ and draw tangent $B'A'$ on this arc from B'. As the incident wavefront *AB* advances, the secondary wavelets start from points between *A* and B', one after the other and will touch $A'B'$ simultaneously. According to Huygen's principle $A'B'$ is the new position of wavefront *AB* in the second medium. ***Hence A'B' will be the refracted wavefront.***

First law: As *AB*, $A'B'$ and surface *XY* are in the plane of paper, therefore the perpendicular drawn on them will be in the same plane. As the lines drawn normal to wavefront denote the rays, therefore we may say that the incident ray, refracted ray and the normal at the point of incidence all lie in the same plane.



This is the first law of refraction.

Second law: Let the incident wavefront AB and refracted wavefront $A'B'$ make angles i and r respectively with refracting surface XY.

In right-angled triangle $AB'B$, $\angle ABB' = 90°$

$$\therefore \qquad \sin i = \sin \angle BAB' = \frac{BB'}{AB'} = \frac{v_1 t}{AB'} \qquad ...(i)$$

Similarly in right-angled triangle $AA'B'$, $\angle AA'B' = 90°$

$$\therefore \qquad \sin r = \sin \angle AB'A' = \frac{AA'}{AB'} = \frac{v_2 t}{AB'} \qquad ...(ii)$$

Dividing equation (*i*) by (*ii*), we get

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \text{constant} \qquad ...(iii)$$

As the rays are always normal to the wavefront, therefore the incident and refracted rays make angles i and r with the normal drawn on the surface XY *i.e.* i and r are the angle of incidence and angle of refraction respectively. According to equation (*iii*):

The ratio of sine of angle of incidence and the sine of angle of refraction for a given pair of media is a constant and is equal to the ratio of velocities of waves in the two media. This is the second law of refraction, and is called the Snell's law.

(*b*) (*i*) If the radiation of certain frequency interact with the atoms/molecules of the matter, they start to vibrate with the same frequency under forced oscillations.

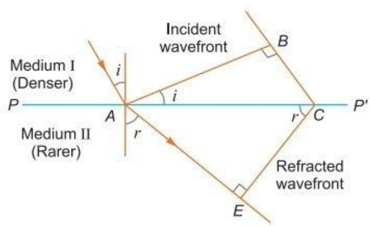
Thus, the frequency of the scattered light (Under reflection and refraction) equals to the frequency of incident radiation.

(*ii*) No, energy carried by the wave depends on the frequency of the wave, but not on the speed of the wave.

Q. 4. Use Huygens' principle to show how a plane wavefront propagates from a denser to rarer medium. Hence, verify Snell's law of refraction.

[CBSE Allahabad 2015, Sample Paper 2016, 2021; 2019(55/1/1), 2020(55/1/1), 2023(55/1/1)]

Ans. We assume a plane wavefront AB propagating in denser medium incident on the interface PP' at angle i as shown in Fig. Let t be the time taken by the wave front to travel a distance BC. If v_1 is the speed of the light in medium I.



So, $\qquad BC = v_1 t$

In order to find the shape of the refracted wavefront, we draw a sphere of radius $AE = v_2 t$, where v_2 is the speed of light in medium II (rarer medium). The tangent plane CE represents the refracted wavefront.

In ΔABC, $\qquad \sin i = \dfrac{BC}{AC} = \dfrac{v_1 t}{AC}$

and in ΔACE, $\sin r = \frac{AE}{AC} = \frac{v_2 t}{AC}$

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{v_1 t}{v_2 t} = \frac{v_1}{v_2} \quad \text{...(i)}$$

Let c be the speed of light in vacuum

So, $$n_1 = \frac{c}{v_1} \text{ and } n_2 = \frac{c}{v_2}$$

$$\frac{n_2}{n_1} = \frac{v_1}{v_2} \quad \text{...(ii)}$$

From equations (*i*) and (*ii*), we have

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$$

$$n_1 \sin i = n_2 \sin r$$

It is known as Snell's law.

Q. 5. (*a*) In Young's double slit experiment, discuss the conditions for (*i*) constructive, and (*ii*) destructive interference at a point on the screen. Draw a graph showing variation of the resultant intensity in the interference pattern against position '*X*' on the screen.

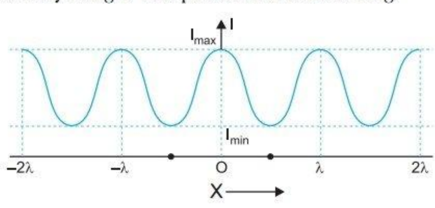
[*CBSE Delhi 2016, (AI) 2012*]

(*b*) Compare and contrast the pattern which is seen with two coherently illuminated narrow slits in Young's experiment with that seen for a coherently illuminated single slit producing diffraction.

Ans. (*a*) **Conditions of Constructive and Destructive Interference:**

When two waves of same frequency and constant initial phase difference travel in the same direction along a straight line simultaneously, they superpose in such a way that the intensity of the resultant wave is maximum at certain points and minimum at certain other points. The phenomenon of redistribution of intensity due to superposition of two waves of same frequency and constant initial phase difference is called the interference. The waves of same frequency and constant initial phase difference are called **coherent waves**. At points of medium where the waves arrive in the same phase, the resultant intensity is maximum and the interference at these points is said to be **constructive**. On the other hand, at points of medium where the waves arrive in opposite phase, the resultant intensity is minimum and the interference at these points is said to be **destructive**. The positions of maximum intensity are called **maxima** while those of minimum intensity are called **minima**. The interference takes place in sound and light both.

Variation of Intensity of light with position x is shown in fig.



(*b*) **Comparison of two Slit Young's Interference pattern and Single slit diffraction pattern**

Both patterns are the result of wave nature of light; both patterns contain maxima and minima. Interference pattern is the result of superposing two coherent wave while the diffraction pattern is the superposition of large number of waves originating from each point on a single slit.

Differences: (*i*) In Young's two slit experiment; all maxima are of same intensity while in diffraction at a single slit, the intensity of central maximum is maximum and it falls rapidly for first, second order secondary maxima on either side of it.

(*ii*) In Young's interference the fringes are of equal width while in diffraction at a single slit, the central maximum is twice as wide as other maxima. The intensity falls as we go to successive maxima away from the centre on either side.

(*iii*) In a single slit diffraction pattern of width a, the first minimum occurs at λ/a; while in two slit interference pattern of slit separation a, we get maximum at the same angle $\frac{\lambda}{a}$.

Q. 6. Two harmonic waves of monochromatic light

$$y_1 = a \cos \omega t \text{ and } y_2 = a \cos(\omega t + \phi)$$

are superimposed on each other. Show that maximum intensity in interference pattern is four times the intensity due to each slit. Hence write the conditions for constructive and destructive interference in terms of the phase angle ϕ. [*CBSE South 2016*]

Ans. The resultant displacement will be given by

$$y = y_1 + y_2$$

$$= a \cos \omega t + a \cos(\omega t + \phi)$$

$$= a[\cos \omega t + \cos(\omega t + \phi)]$$

$$= 2a \cos(\phi/2) \cos(\omega t + \phi/2)$$

The amplitude of the resultant displacement is $2a \cos(\phi/2)$

The intensity of light is directly proportional to the square of amplitude of the wave. The resultant intensity will be given by

$$I = 4a^2 \cos^2 \frac{\phi}{2}$$

$\therefore$ Intensity $= 4I_0 \cos^2\left(\frac{\phi}{2}\right)$, where $I_0 = a^2$ is the intensity of each harmonic wave

At the maxima, $\phi = \pm 2n\pi$

$$\therefore \quad \cos^2 \frac{\phi}{2} = 1$$

At the maxima, $I = 4I_0 = 4 \times$ intensity due to one slit

$$I = 4I_0 \cos^2\left(\frac{\phi}{2}\right)$$

For constructive interference, I is maximum.

It is possible when $\cos^2\left(\frac{\phi}{2}\right) = 1; \frac{\phi}{2} = n\pi; \phi = 2n\pi$

For destructive interference, I is minimum, *i.e.*, $I = 0$

It is possible when $\cos^2\left(\frac{\phi}{2}\right) = 0; \frac{\phi}{2} = \frac{(2n-1)\pi}{2}; \phi = (2n \pm 1)\frac{\pi}{2}$

Q. 7. What is interference of light? Write two essential conditions for sustained interference pattern to be produced on the screen.

Draw a graph showing the variation of intensity versus the position on the screen in Young's experiment when (*a*) both the slits are opened and (*b*) one of the slits is closed.

What is the effect on the interference pattern in Young's double slit experiment when:

(*i*) screen is moved closer to the plane of slits?

(*ii*) separation between two slits is increased?

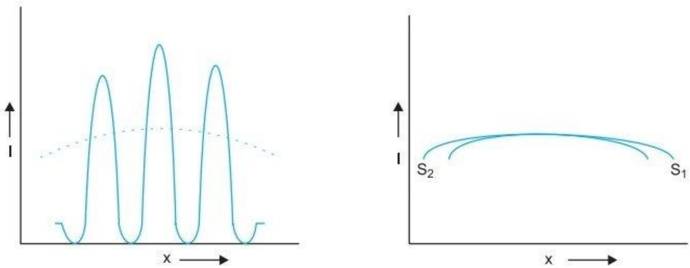
Explain your answer in each case.

Ans. **Interference of light:** When two waves of same frequency and constant initial phase difference travel in the same direction along a straight line simultaneously, they superpose in such a way that the intensity of the resultant wave is maximum at certain points and minimum at certain other points. This phenomenon of redistribution of energy due to superposition of two waves of same frequency and constant initial phase difference is called interference.

Conditions for Sustained Interference of Light Waves

To obtain sustained (well-defined and observable) interference pattern, the intensity must be maximum and zero at points corresponding to constructive and destructive interference. For the purpose following conditions must be fulfilled:

- *The two interfering sources must be coherent and of same frequency, i.e., the sources should emit light of the same wavelength or frequency and their initial phase should remain constant*. If this condition is not satisfied the phase difference between the interfering waves will vary continuously. As a result the resultant intensity at any point will vary with time being alternately maximum and minimum, just like the phenomenon of beats in sound.
- *The interfering waves must have equal amplitudes*. Otherwise the minimum intensity will not be zero and there will be general illumination.



(*a*) When both the slits are opened. The dashed curve is the single slit intensity for comparison

(*b*) When one of the slits is closed.

The variation of intensity I versus the position x on the screen in Young's experiment.

Fringe width, $\beta = \frac{D\lambda}{d}$.

(*i*) $\beta \propto D$, therefore with the decrease of separation between the plane of slits and screen, the fringe width decreases.

(*ii*) On increasing the separation between two slits (d), the fringe separation decreases as β is inversely proportional to $d \left(i.e., \beta \propto \frac{1}{d} \right)$.

Q. 8. **What is diffraction of light? Draw a graph showing the variation of intensity with angle in a single slit diffraction experiment. Write one feature which distinguishes the observed pattern from the double slit interference pattern.** **[*CBSE (F) 2013*]**

How would the diffraction pattern of a single slit be affected when:

(*i*) the width of the slit is decreased?

(*ii*) the monochromatic source of light is replaced by a source of white light?

Ans. **Diffraction of Light:** When light is incident on a narrow opening or an obstacle in its path, it is bent at the sharp edges of the obstacle or opening. This phenomenon is called diffraction of light.

For graph refer point 5 of Points to remember.

In an interference pattern all the maxima have the same intensity while in diffraction pattern the maxima are of different intensities. For example in Young's double slit experiment all maxima are of the same intensity and in diffraction at a single slit, the central maximum have the maximum intensity and it falls rapidly for first, second orders secondary maxima on either side of it.

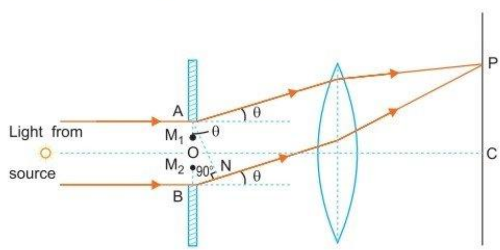
(*i*) **When the width of the slit is decreased:** From the relation $\sin\theta = \frac{\lambda}{a}$, we find that if the width of the slit (a) is decreased, then for a given wavelength, $\sin\theta$ is large and hence θ is large. Hence diffraction maxima and minima are quite distant on either side of θ.

(*ii*) With monochromatic light, the diffraction pattern consists of alternate bright and dark bands. If white light is used central maximum is white and on either side, the diffraction bands are coloured.

Q. 9. Describe diffraction of light due to a single slit. Explain formation of a pattern of fringes obtained on the screen and plot showing variation of intensity with angle θ in single slit diffraction. [*CBSE Delhi 2010, (F) 2013, (AI) 2014*]

Ans. **Diffraction of light at a single slit:** When monochromatic light is made incident on a single slit, we get diffraction pattern on a screen placed behind the slit. The diffraction pattern contains bright and dark bands, the intensity of central band is maximum and goes on decreasing on both sides.

Explanation: Let AB be a slit of width 'a' and a parallel beam of monochromatic light is incident on it. According to Fresnel the diffraction pattern is the result of superposition of a large number of waves, starting from different points of illuminated slit.



Let θ be the angle of diffraction for waves reaching at point P of screen and AN the perpendicular dropped from A on wave diffracted from B.

The path difference between rays diffracted at points A and B,

$$\Delta = BP - AP = BN$$

In ΔANB, $\angle ANB = 90°$ and $\angle BAN = \theta$

$$\therefore \quad \sin\theta = \frac{BN}{AB} \text{ or } BN = AB\sin\theta$$

As AB = width of slit = a

$\therefore$ Path difference, $\quad \Delta = a\sin\theta \qquad$ ...(*i*)

To find the effect of all coherent waves at P, we have to sum up their contribution, each with a different phase. This was done by Fresnel by rigorous calculations, but the main features may be explained by simple arguments given below:

At the central point C of the screen, the angle θ is zero. Hence the waves starting from all points of slit arrive in the same phase. This gives maximum intensity at the central point C.

Minima: Now we divide the slit into two equal halves AO and OB, each of width $\frac{a}{2}$. Now for every point, M_1 in AO, there is a corresponding point M_2 in OB, such that $M_1 M_2 = \frac{a}{2}$; then path difference between waves arriving at P and starting from M_1 and M_2 will be $\frac{a}{2}\sin\theta = \frac{\lambda}{2}$. This means that the contributions from the two halves of slit AO and OB are opposite in phase and so cancel each other. Thus above equation gives the angle of diffraction at which intensity falls to zero. Similarly it may be shown that the intensity is zero for $\sin\theta = \frac{n\lambda}{a}$, with n as integer. Thus the general condition of **minima** is

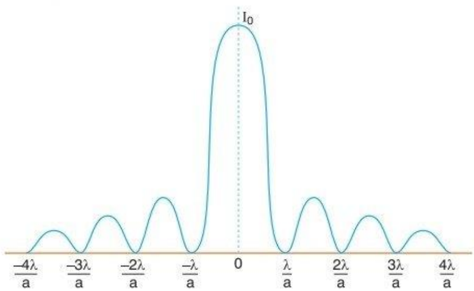
$$a \sin\theta = n\lambda \qquad ...(ii)$$

Secondary Maxima: Let us now consider angle θ such that

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

which is midway between two dark bands given by

$$\sin\theta = \theta = \frac{\lambda}{a} \text{ and } \sin\theta = \theta = \frac{2\lambda}{a}$$



Let us now divide the slit into three parts. If we take the first two parts of slit, the path difference between rays diffracted from the extreme ends of the first two parts

$$\frac{2}{3}a\sin\theta = \frac{2}{3}a \times \frac{3\lambda}{2a} = \lambda$$

Then the first two parts will have a path difference of $\frac{\lambda}{2}$ and cancel the effect of each other. The remaining third part will contribute to the intensity at a point between two minima. Clearly there will be a maxima between first two minima, but this maxima will be of much weaker intensity than central maximum. This is called *first secondary maxima*. In a similar manner we can show that there are secondary maxima between any two consecutive minima; and the intensity of maxima will go on decreasing with increase of order of maxima. In general the position of nth maxima will be given by

$$a\sin\theta = \left(n + \frac{1}{2}\right)\lambda, \qquad [n = 1,2,3,4,....]$$

The intensity of secondary maxima decreases with increase of order n because with increasing n, the contribution of slit decreases.

For $n = 2$, it is one-fifth, for $n = 3$, it is one-seventh and so on.

Questions for Practice

1. Choose and write the correct option in the following questions.

(*i*) In a Young's double-slit experiment, the fringe width is found to be β. If the entire apparatus is immersed in a liquid of refractive index μ, the new fringe width will be [*CBSE 2023 (55/4/1)*]

(*a*) β (*b*) μβ (*c*) $\frac{\beta}{\mu}$ (*d*) $\frac{\beta}{\mu^2}$

(*ii*) Angular width of interference fringe depends on

(*a*) distance between slit and screen (*b*) wavelength of light

(*c*) ratio of the wavelength and slit width (*d*) width of slit

(*iii*) A linear aperture whose width is 0.02 cm is placed immediately in front of a lens of focal length 60 cm. The aperture is illuminated normally by a parallel beam of wavelength 5×10^{-5} cm. The distance of the first dark band of the differaction pattern from the centre of the screen is

(*a*) 0.10 cm (*b*) 0.25 cm (*c*) 0.20 cm (*d*) 0.15 cm

(*iv*) The shape of the interference fringes in Young's double slit experiment when *D* (distance between slit and screen) is very large as compared to fringe width is nearly

(*a*) straight line (*b*) parabolic (*c*) circular (*d*) hyperbolic

(*v*) A plane wavefront is incident on a concave mirror of radius of curvature *R*. The radius of the refracted wave front will be [*CBSE 2023 (55/4/1)*]

(*a*) 2*R* (*b*) *R* (*c*) $\frac{R}{2}$ (*d*) $\frac{R}{4}$

2. ***In the following questions, a statement of Assertion (A) is followed by a statement of Reason (R). Choose the correct answer out of the following choices.***

(a) ***Both A and R are true and R is the correct explanation of A.***

(b) ***Both A and R are true but R is not the correct explanation of A.***

(c) ***A is true but R is false.***

(d) ***A is false and R is also false.***

(*i*) Assertion (*A*) : No interference pattern is detected when two coherent sources are infinitely close to each other.

Reason (*R*) : Fringe width is inversely proportional to separation between the slit.

(*ii*) Assertion (*A*) : To observe diffraction of light, the size of obstacle/aperture should be of the order of 10^{-7} m.

Reason (*R*) : 10^{-7} m is the order of wavelength of visible light. [*AIIMS 2012*]

3. Define a wavefront. [*CBSE Sample Paper 2021*]

4. State the reason, why two independent sources of light cannot be considered as coherent sources.

5. How does the fringe width, in Young's double-slit experiment, change when the distance of separation between the slits and screen is doubled?

6. When monochromatic light travels from one medium to another, its wavelength changes but frequency remains the same. Explain. [*CBSE Delhi 2011*]

7. Light of wavelength 5000 Å propagating in air gets partly reflected from the surface of water. How will the wavelengths and frequencies of the reflected and refracted light be affected? [*CBSE Delhi 2015*]

8. What will be the effect on interference fringes if red light is replaced by blue light? [*CBSE Delhi 2013*]

9. How does the angular separation between fringes in single-slit diffraction experiment change when the distance of separation between the slit and screen is doubled? [*CBSE (AI) 2012*]

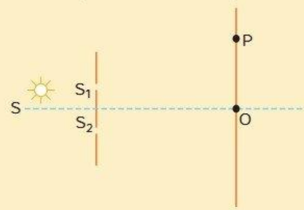
10. In a single-slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band? [*CBSE (AI) 2012*]

11. Find the intensity at a point on a screen in Young's double slit experiment where the interfering waves of equal intensity have a path difference of (*i*) $\frac{\lambda}{4}$, and (*ii*) $\frac{\lambda}{3}$.

12. What should be the width of each slit to obtain n maxima of double slit pattern within the central maxima of single slit pattern? [*CBSE Sample Paper 2021*]

13. Monochromatic light of wavelength 588 nm is incident from air to water interface. Find the wavelength and speed of the refracted light. The refractive index of water is $\frac{4}{3}$. [*CBSE 2020 (55/3/1)*]

14. The figure shows a modified Young's double slit experimental set-up. Here $SS_2 - SS_1 = \lambda/4$.



(*a*) Write the condition for constructive interference.

(*b*) Obtain an expression for the fringe width.

15. (*a*) The refractive index of glass is 1.5. What is the speed of light in glass? (Speed of light in vacuum is 3.0×10^8 ms^{-1}).

(*b*) Is the speed of light in glass independent of the colour of light? If not, which of the two colours, red and violet, travels slower in the glass prism? [*NCERT*]

16. In Young's double slit experiment the slits are separated by 0.28 mm and the screen is placed 1.4 m away. The distance between the central bright fringe and the fourth fringe is measured to be 1.2 cm. Determine the wavelength of light used in this experiment. [*NCERT*]

17. In Young's double slit experiment using monochromatic light of wavelength λ the intensity at a point on the screen where path difference is λ is *K* units. What is the intensity of light at a point where path difference is $\frac{\lambda}{3}$? [*NCERT*] [*CBSE Delhi 2012*]

18. (*a*) If one of two identical slits producing interference in Young's experiment is covered with glass, so that the light intensity passing through it is reduced to 50%, find the ratio of the maximum and minimum intensity of the fringe in the interference pattern.

(*b*) What kind of fringes do you expect to observe if white light is used instead of monochromatic light?

19. In a Young's double slit experiment using light of wavelength 600 nm, the slit separation is 0.8 mm and the screen is kept 1.6 m from the plane of the slits. Calculate

(*i*) the fringe width

(*ii*) the distance of (*a*) third minimum and (*b*) fifth maximum, from the central maximum.

[*CBSE 2022 (55/3/1), Term-2*]

20. In a single slit diffraction experiment, light of wavelength λ illuminates the slit of width '*a*' and the diffraction pattern is observed on a screen.

(*a*) Show the intensity distribution in the pattern with the angular position θ.

(*b*) How are the intensity and angular width of central maxima affected when

(*i*) width of slit is increased, and

(*ii*) separation between slit and screen is decreased? **[*CBSE 2020 (55/1/2)*]**

21. Answer the following questions:

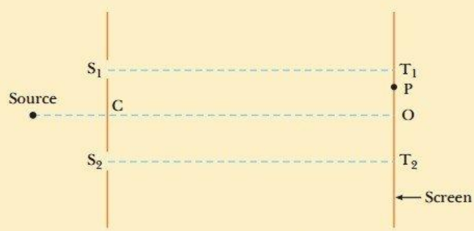
(*a*) In a single slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band?

(*b*) How is the width of the central maximum changed when red light is replaced by blue?

(*c*) In what way is diffraction from each slit related to the interference pattern in a double slit experiment? **[*CBSE 2019 (55/5/3)*]**

22. Monochromatic light of wavelength 589 nm is incident from air on a water surface. What is the wavelength, frequency and speed of (*a*) reflected and (*b*) refracted light? Refractive index of water is 1.33. **[*NCERT*]**

23. Consider a two slit interference arrangements such that the distance of the screen from the slits is half the distance between the slits.



OP = x
CO = D
$S_1C - CS_2$ = D

Obtain the value of D in terms of λ such that the first minima on the screen fall at a distance D from the centre O. **[*CBSE Sample Paper 2017*]**

24. Use Huygen's principle to explain the formation of diffraction pattern due to a single slit illuminated by a monochromatic source of light.

When the width of slit is made double the original width, how this affect the size and intensity of the central diffraction band? **[*CBSE Delhi 2012*]**

25. A beam of light consisting of two wavelengths, 800 nm and 600 nm is used to obtain the interference fringes in a Young's double slit experiment on a screen placed 1.4 m away. If the two slits are separated by 0.28 mm, calculate the least distance from the central bright maximum where the bright fringes of the two wavelengths coincide. **[*CBSE (AI) 2012*]**

26. Two wavelengths of sodium light 590 nm and 596 nm are used, in turn, to study the diffraction taking place at a single slit of aperture 2×10^{-4} m. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases. **[*CBSE Delhi 2013*]**

27. (*a*) In Young's double slit experiment, two slits are 1 mm apart and the screen is placed 1 m away from the slits. Calculate the fringe width when light of wavelength 500 nm is used.

(*b*) What should be the width of each slit in order to obtain 10 maxima of the double slits pattern within the central maximum of the single slit pattern? [*CBSE East 2016*]

Answers

1. (*i*) (*c*) (*ii*) (*c*) (*iii*) (*d*) (*iv*) (*a*) (*v*) (*c*)

2. (*i*) (*b*) (*ii*) (*a*)

11. (*i*) $2I_0$ (*ii*) I_0

13. 441 nm, 2.25×10^{-8} m/s

15. 2×10^8 ms^{-1}

16. 600 nm

17. $\frac{1}{4}K$

18. (*a*) 34 : 1

19. (*i*) 1.2 mm (*ii*) (*a*) 3 mm (*b*) 6 mm

22. (*a*) 589 nm, 3×10^8 ms^{-1}, 5.1×10^{14} Hz (*b*) 44 nm, 2.26×10^8 ms^{-1}, 5.1×10^{14} Hz

23. $\dfrac{\lambda}{2(\sqrt{5}-1)}$ **25.** 12×10^{-3} m

26. 0.065 mm **27.** (*a*) 5×10^{-4} m (*b*) 2×10^{-4} m