

WAVE OPTICS

CBSE CLASS XII PHYSICS

1 WAVEFRONT & HUYGENS PRINCIPLE

Wavefront: The locus of points in a medium which are in the same phase of vibration is called a wavefront.

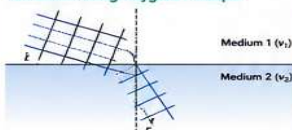
Types of Wavefronts

- **Plane Wavefront**
Direction of propagation
- **Spherical Wavefront**
Direction of propagation
- **Cylindrical Wavefront**
Direction of propagation

Huygens Principle

Every point on a wavefront acts as a source of secondary spherical wavelets which spread out in the medium with the same speed as the wave.

Refraction Using Huygens Principle



Relation between i and r

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \mu_{21}$$

where μ_{21} = Refractive index of medium 2
Refractive index of medium 1

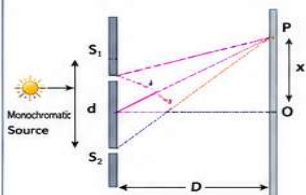
PYQ

Define wavefront. Draw different types of wavefronts. Derive Snell's law using Huygens principle.

2 INTERFERENCE & YOUNG'S DOUBLE SLIT EXPERIMENT

When two coherent light waves superpose, a stable interference pattern is produced.

Young's Double Slit Experiment (YDSE)



Fringe Width (β)

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

(Distance between two consecutive bright or dark fringes)

Position of n^{th} Bright Fringe

$$x_n = \frac{n\lambda D}{d} \quad (n = 0, \pm 1, \pm 2, \dots)$$

Path Difference

- For Bright fringes (Maxima): $\Delta x = n\lambda$
($n = 0, \pm 1, \pm 2, \dots$)
- For Dark fringes (Minima): $\Delta x = (2n+1)\frac{\lambda}{2}$
($n = 0, \pm 1, \pm 2, \dots$)

Intensity of Resultant Fringe

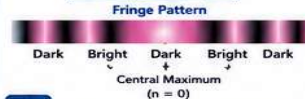
$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$$

Maximum Intensity (Bright Fringe)

$$I_{\text{max}} = (\sqrt{I_1} + \sqrt{I_2})^2$$

Minimum Intensity (Dark Fringe)

$$I_{\text{min}} = (\sqrt{I_1} - \sqrt{I_2})^2$$



PYQ

Derive the expression for fringe width in YDSE. What are the conditions for maxima and minima?

3 COHERENT SOURCES & SUSTAINED INTERFERENCE

Conditions for Two Sources to be Coherent

- ✓ Same frequency (monochromatic)
- ✓ Constant phase difference
- ✓ Same state of polarization
- ✓ Same amplitude (or nearly same)

Coherent Sources

Sources which satisfy the above conditions are called coherent sources.

Sustained Interference

When two coherent sources of same frequency superpose, the resultant interference pattern is stable and constant in time. This is called sustained interference.

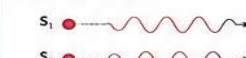
Coherent vs Incoherent Sources

Coherent Sources



- Same frequency
- Constant phase difference
- Resultant pattern is stable (sustained interference)

Incoherent Sources



- Same or different frequency
- Random phase difference
- Resultant pattern is unstable (no sustained interference)

PYQ

Focus the conditions for two sources to be coherent. What is sustained interference?



Coherent sources are:
"Same Frequency,
Constant Phase,
Same Polarization."

PYQ TIPS

- ✓ Derivations are important:
 - Snell's law using Huygens principle
 - Fringe width in YDSE
 - Condition for minima in diffraction
- ✓ Learn diagrams neatly.
- ✓ Write conditions for maxima/minima clearly.
- ✓ Understand the difference between interference and diffraction.
- ✓ Numericals are mostly formula based.

PYQ

Focus on NCERT end-of-chapter questions and previous 10 years board questions.

BOARD EXAM TIPS

- ✓ Learn definitions word-for-word.
- ✓ Know all formulas with symbols.
- ✓ Practice derivations regularly.
- ✓ Draw neat, labelled diagrams.
- ✓ Write logical steps in derivations.
- ✓ Use correct units.
- ✓ Attempt NCERT in-text, examples and exercise thoroughly.
- ✓ Revise PYQs before the exam.

Concept Clear + Diagrams Neat
Formulas Perfect + Score High!

4 SINGLE SLIT DIFFRACTION

When monochromatic light passes through a single narrow slit, the light spreads out and a diffraction pattern is obtained on the screen.

Theory

Minima (dark bands) occur when path difference from the edges of the slit is an integral multiple of wavelength.

Condition for Minima

$$a \sin \theta = n\lambda$$

($n = \pm 1, \pm 2, \pm 3, \dots$)

where, a = width of slit

Angular Width of Central Maximum

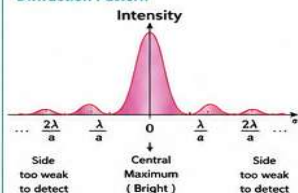
$$\theta_{\text{angular}} = \frac{2\lambda}{a} \quad (\text{radians})$$

Linear Width of Central Maximum

$$\beta = \frac{2\lambda D}{a}$$

(where D = distance of screen)

Diffraction Pattern



PYQ

Derive the expression for angular width of the central maximum in single slit diffraction.

QUICK REVISION

- ✓ Wavefront: Locus of same phase points.
- ✓ Huygens Principle: Each point on the wavefront acts as a source of secondary wavelets.
- ✓ YDSE: Interference of two coherent sources gives alternate bright and dark fringes.
- ✓ Fringe width: $\beta = \frac{\lambda D}{d}$
- ✓ Bright: $\Delta x = n\lambda$ Dark: $\Delta x = (2n+1)\frac{\lambda}{2}$
- ✓ Coherent sources $\rightarrow$ Sustained interference.
- ✓ Diffraction: Bending/spreading of light around edges; pattern of maxima & minima.

FORMULA SUMMARY

- Final relation (Huygens/Snell): $\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \mu_{21}$
- Fringe width: $\beta = \frac{\lambda D}{d}$
- Position of n^{th} bright fringe: $x_n = \frac{n\lambda D}{d}$
- Path difference (bright): $\Delta x = n\lambda$
- Path difference (dark): $\Delta x = (2n+1)\frac{\lambda}{2}$
- Intensity: $I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$
- Max intensity: $I_{\text{max}} = (\sqrt{I_1} + \sqrt{I_2})^2$
- Min intensity: $I_{\text{min}} = (\sqrt{I_1} - \sqrt{I_2})^2$
- Diffraction minima: $a \sin \theta = n\lambda$
- Angular width: $\theta = \frac{2\lambda}{a}$
- Linear width: $\beta = \frac{2\lambda D}{a}$
- Wavelength in medium: $\lambda_{\text{medium}} = \frac{\lambda}{\mu}$

COMMON MISTAKES

- ✗ Confusing interference with diffraction.
- ✗ Using $\beta = \frac{\lambda D}{d}$ in single slit diffraction.
- ✗ Forgetting $(2n+1)\frac{\lambda}{2}$ - condition for dark fringes.
- ✗ Not distinguishing coherent and incoherent sources.
- ✗ Wrong units in formula application.
- ✗ Not drawing proper labelled diagrams.



REMEMBER THIS

Bright fringes are wider in YDSE as we move away from the center only in case of unequal intensities of sources.

INTERFERENCE vs DIFFRACTION

INTERFERENCE (YDSE)	BASIS	DIFFRACTION (Single Slit)
Superposition of waves from two coherent sources	Cause	Bending of waves around edges of a slit
Two coherent sources	Sources	Single slit (one source)
Bright and dark fringes of nearly equal intensity	Pattern	Central maximum is bright and broad; side maxima are weak
All fringes have same width ($\beta = \frac{\lambda D}{d}$)	Fringe Width	Central maximum is widest ($\beta = \frac{2\lambda D}{a}$)
Maxima: $n\lambda$ Minima: $(2n+1)\frac{\lambda}{2}$	Conditions	Minima: $n\lambda$ (where $a \sin \theta = n\lambda$)
Depends on d, D, λ	Dependence	Depends on a, D, λ
Almost uniform in all fringes	Energy Distribution	Most energy in central maximum

WAVELENGTH IN MEDIUM

$$\lambda_{\text{medium}} = \frac{\lambda}{\mu}$$

Where, λ = wavelength in vacuum (air)
 μ = Refractive index of medium

KEY TAKEAWAY

Wave optics explains the behaviour of light as a wave — through wavefronts, interference and diffraction — using superposition principle.



MULTIPLE CHOICE QUESTIONS(1-20)

1. In Young's double slit experiment, the two slits act as coherent sources of equal amplitude 'a' and of wavelength λ . In other experiment with the same set up, the two slits are sources of equal amplitude 'a' and wavelength λ , but are incoherent. The ratio of intensity of light at the mid point of the screen in the first case to that in the second case is

- (a) 2:1 (b) 1:2 (c) 3:4 (d) 4:3

2. The maximum number of possible interference maxima for slit separation equal to twice the wavelength in Young's double slit experiment is

- (a) infinite (b) five (c) three (d) zero

3. Young's double slit experiment is first performed in air and then in a medium other than air. It is found that 8th bright fringe in the medium lies where 5th dark fringe lies in air. The refractive index of the medium is nearly.

- (a) 1.25 (b) 1.59 (c) 1.69 (d) 1.78

4. 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,

- (a) there shall be 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

5. Huygen's concept of secondary waves

- (a) is used to explain absorption of light by a medium
(b) is a geometrical method to find the position of a new wavefront
(c) is used to determine the velocity of light
(d) is used to explain rectilinear propagation of light

6. Diffraction pattern is observed using green light. When green light is replaced by red light

- (a) no change is observed
(b) bands become narrower and crowded
(c) bands become broader and well separated
(d) bands disappear

7. A wavefront is defined as a surface where all points have:

- (a) Different frequencies (b) The same phase
(c) Different amplitude (d) Zero displacement

8. Two independent sodium lamps do not produce an interference pattern because:

- (a) They have different intensities. (b) Their phase difference changes randomly
(c) They are too far apart (d) Sodium emits white light

9. A single slit of width 0.1 mm is illuminated by light of wavelength 600 nm. The screen is 2 m away. The width of the central maximum is:

- (a) 12 mm (b) 24 mm (c) 6 mm (d) 3 mm

10. Light of wavelength $6328 \text{ \AA}$ is incident on a single slit of width 0.2 mm. The angular width of the central maximum on a screen kept at a distance 9 m from the slit is

- (a) $1.5 \times 10^{-3} \text{ rad}$ (b) $3.142 \times 10^{-3} \text{ rad}$ (c) $6.328 \times 10^{-3} \text{ rad}$ (d) $14.3 \times 10^{-3} \text{ rad}$

11. The resultant amplitude of a vibrating particle by the superposition of the two waves

$$y_1 = a \sin(\omega t + \pi/3) \quad \text{and} \quad y_2 = a \sin \omega t \text{ is :-}$$

- (a) a (b) $\sqrt{2} a$ (c) 2a (d) $\sqrt{3} a$

12. Which of following is a true statement, if in Young's experiment, separation between the slits is gradually increased :

- (a) fringe width increases and fringes disappear (b) fringe width decreases and fringes disappear
(c) fringes become blurred. (d) fringe width remains constant and fringes are more bright

13. In an interference of yellow light derived from two slit apertures, if at some point on the screen, yellow light has a path difference of $3\lambda/2$, then the fringe at that point will be :

- (a) yellow in colour (b) white in colour (c) dark (d) bright

14. Two beams of light having intensities I and 4I interfere to produce a fringe pattern on a screen. The phase difference between the beam is $\pi/2$ at point A and 2π at point B. Then find out the difference between the resultant intensities at A and B.

- (a) 2I (b) 5I (c) I (d) 4I

15. In an interference pattern of two waves fringe width is β . If the frequency of source is doubled then fringe width will become :

- (a) $(1/2) \beta$ (b) β (c) 2β (d) $(3/2) \beta$

16. In Young's double-slit experiment, distance between slits is kept 1mm and a screen is kept 1m apart from slits. If wavelength of light used is 500nm, then fringe spacing is

- (a) 0.5mm (b) 0.5cm (c) 0.25mm (d) 0.25cm

17. A light source of $5000\text{\AA}$ wave length produces a single slit diffraction. The first minima in diffraction pattern is seen, at a distance of 5mm from central maxima. The distance between screen and slit is 2 metre. The width of slit in mm will be :

- (a) 0.1 (b) 0.4 (c) 0.2 (d) 2

18. Find the half angular width of the central bright maximum in the Fraunhofer diffraction pattern of a slit of width $12 \times 10^{-5} \text{ cm}$ when the slit is illuminated by monochromatic light of wavelength $6000 \text{ \AA}$.

- (a) 40° (b) 45° (c) 30° (d) 60°

19. What happens if one of the slits, say S_1 in Young's double, slit experiment-is covered with a glass plate which absorbs half the intensity of light from it?

- (a) The bright fringes become less-bright and the dark fringes have a finite light intensity
(b) The bright fringes become brighter and the dark fringes become darker
(c) The fringe width decreases
(d) No fringes will be observed

20. 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

- (a) the intensities of both the maxima and the minima increase
(b) the intensities of the maxima increases and 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.

ANSWERS (1-20)

1.	If I_0 is intension of light from each slit then $I_c = 4 I_0$. $I_{in} = 2I_0$, $I_c/I_{in}=2$	a
2.	Maximum possible maxima $\sin \theta = 1 \Rightarrow n = 2$. No. of maxima $N = (2n + 1) = (2 \times 2 + 1) = 5$	b
3.	$X_5 \text{ dark} = X_8 \text{ bright}$. Equating we get $\mu = 1.78$	d
4.	In this case there shall be no interference fringes.	c
5.	is a geometrical method to find the position of a new wavefront	b
6.	This occurs because red light has a longer wavelength than green light, and diffraction fringe width is directly proportional to the wavelength.	c
7.	A wavefront is a locus of all particles vibrating in the same phase. It is a surface of constant phase.	b

8.	Independent sources undergo abrupt phase changes every $\sim 10^{-10}$ s (temporal incoherence). The pattern averages out, producing uniform illumination.	b
9.	Linear width $= 2\lambda D/a = 2 \times 600 \times 10^{-9} \times 2 / (0.1 \times 10^{-3}) = 2.4 \times 10^{-2}$ m = 24 mm.	b
10.	$2\theta = 2\lambda/a = 6.328 \times 10^{-3}$ rad	c
11.	use the formula $A^2 = A_1^2 + A_2^2 + 2A_1A_2\cos\phi$	d
12.	Use formula, $\beta = \lambda D/d$, As the fringes become narrower, they become harder to distinguish, and eventually, they will disappear	b
13.	path difference, $3\lambda/2$ as $(1 + \frac{1}{2})\lambda$ -condition for dark fringe	c
14.	Use the formula $I = I_1 + I_2 + 2\sqrt{I_1I_2}\cos\phi$	d
15.	use the formula $\beta = \frac{\lambda D}{d} = \frac{cD}{vd}$	a
16.	use the formula $\beta = \frac{\lambda D}{d}$	a
17.	use the formula $y = \frac{\lambda D}{a}$	c
18.	condition for the first minimum is $a \sin\theta = \lambda$	c
19.	The bright fringes become less-bright and the dark fringes have a finite light intensity	a
20.	because the increased light through the wider slit prevents perfect cancellation at the minima while adding total energy to the maxima.	a

EXERCISE QUESTIONS

- Two coherent light beams of intensity I and $4I$ are superposed. The maximum and minimum possible intensities in the resulting beam are:
 (a) $5I$ and $3I$ (b) $5I$ and I (c) $9I$ and $3I$ (d) $9I$ and I
- In an interference experiment, third bright fringe is obtained at a point on the screen with a light of 700 nm. What should be the wavelength of the light in order to obtain 5th bright fringe at the same point?
 (a) 500 nm (b) 630 nm (c) 750 nm (d) 420 nm
- In Young's double slit experiment, the two slits act as coherent sources of equal amplitude A and 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 mid-point of the screen in the first case to that in the second case is
 (a) 4 : 1 (b) 2 : 1 (c) 1 : 1 (d) 1 : 2
- In Young's double slit experiment maximum intensity of each source is I . At angular position θ the intensity becomes $4I$ where $\sin\theta$ is:
 (a) λ/d (b) $\lambda/2d$ (c) $\lambda/3d$ (d) $\lambda/4d$

5. Which of following is a true statement, if in Young's experiment, separation between the slits and screen is gradually decreased :

(a) fringe width increases and fringes disappear. (b) fringe width decreases and fringes disappear. (c) fringes become blurred (d) fringe width remains constant and fringes are more bright

ANSWERS- 1. d 2. d 3. b 4. a 5. b

ASSERTION-REASON QUESTION

For these Questions two statements are given one labelled **Assertion (A)** and other labelled **Reason (R)**. Select the correct answer to these questions from the options as given below

- (a) If both Assertion and Reason are true and Reason is correct explanation of Assertion.
- (b) If both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
- (c) If Assertion is true but Reason is false.
- (d) If both Assertion and Reason are false.

1. Assertion (A): The fringe width in Young's experiment decreases when the experiment is performed in a medium with refractive index greater than 1.

Reason (R): The effective wavelength of light in a medium becomes λ/μ , where μ is the refractive index.

2. Assertion (A): Two equal wavelengths meet at point when coming from opposite direction may give brightest spot at the point of meeting.

Reason(R) : Two waves moving in opposite directions meet in opposite phase.

3.Assertion (A): The two slits in YDSE are illuminated by two different sodium lamps emitting light of same wavelength. No interference pattern will be observed.

Reason (R): Two independent light sources (except LASER) cannot be coherent.

4. Assertion (A): In calculating the disturbance produced by a pair of superimposed incoherent wave trains, you can add their intensities.

Reason (R): $I = I_1 + I_2 + 2(I_1 I_2)^{1/2} \cos \Theta$. The average value of $\cos \Theta = 0$, for incoherent waves.

5. Assertion (A): Thin films such as soap bubble or thin layer of oil spread on water show beautiful colors when illuminated by white light.

Reason (R): It is due to interference of Sun's light reflected from upper and lower surfaces of the film.

6. Assertion (A): In YDSE central fringe may not be a bright fringe.

Reason (R): If path difference at central fringe is zero then it will be a bright fringe.

7. Assertion (A): Fringe width in single slit experiment depends upon refractive index of the medium.

Reason (R): Refractive index changes optical path of ray of light forming fringe pattern also changes.

8. Assertion (A): Diffraction of light is more pronounced through a narrower slit.

Reason (R): The amount of diffraction is inversely proportional to the slit width relative to the wavelength.

9. Assertion (A): We cannot get diffraction pattern from a wide slit illuminated by monochromatic light.

Reason (R): In diffraction pattern, all the bright bands are not of the same intensity.

10. Assertion (A): In Young's experiment, the fringe width for dark fringes is different from that for white fringes.

Reason (R): In Young's double slit experiment the fringes are performed with a source of white light then only black and bright fringes are observed.

ANSWERS

1. a. 2. c. 3. a. 4. a 5. a 6. b 7. a 8. a 9. b 10. d

EXERCISE QUESTIONS

1. Assertion (A): In Young's double slit experiment if intensity of each source is I_0 than minimum and maximum intensities will be zero and $4I_0$ respectively.

Reason (R): In Young's double slit experiment energy conservation is not followed.

2. Assertion (A): Two monochromatic sources of light originated from same source with intensities I and $4I$ are placed in front of two slits in interference pattern in front of both the slits intensity of fringes shall be different.

Reason (R): Central band of interference pattern shall be the brightest.

3. Assertion (A): The angular fringe width in YDSE is independent of the distance D of the screen.

Reason (R): Angular fringe width $\theta = \beta/D = \lambda/d$; it depends only on λ and d .

4. Assertion (A): Wavefronts are always perpendicular to rays of light.

Reason (R): A ray is defined as the direction of energy propagation and is always perpendicular to the wavefront.

5. Assertion (A): Interference obeys the law of conservation of energy.

Reason (R): The energy is redistributed in case of interference

SHORT ANSWER TYPE -I

1. How does the fringe width in Young's double-slit experiment change when the distance of separation between the slits and screen is doubled?
2. When white light is used in YDSE we say Central band is white surrounded by colored bands with inner edge as violet and outer edge as red. justify it, as well as explain pattern of width of fringes obtained.
3. In a Young's double-slit experimental set-up with slit separation 0.6 mm a beam of light consisting of two wavelengths 440 nm and 660 nm is used to obtain interference pattern

on a screen kept 1.5 m in front of the slits. Find the least distance of the point from the central maximum where the bright fringes due to both the wavelengths coincide.

4. Answer the following questions:

- (i) In what way is diffraction from each slit related to the interference pattern in a double slit experiment?
 - (ii) When a tiny circular obstacle is placed in the path of light from a distance source, a bright spot is seen at the center of the shadow of the obstacle. Explain, why.
5. (a) The ratio of the widths of two slits in Young's double slit experiment is 4: 1. Evaluate the ratio of intensities at maxima and minima in the interference pattern.
(b) Does the appearance of bright and dark fringes in the interference pattern violate, in any way, conservation of energy?
6. Two plane monochromatic waves propagating in the same direction with amplitudes A and $2A$ and differing in phase by $\pi/3$ superimpose. Calculate the amplitude of resulting wave.
7. (a) Write the conditions under which light sources can be said to be coherent.
(b) Why is it necessary to have coherent sources in order to produce an interference pattern?
8. Draw the shape of the wavefront coming out of a concave mirror and a convex lens when a plane wave is incident on it.
9. How will the interference pattern in Young's double slit experiment gets affected when
(i) distance between the slits S_1 and S_2 is reduced and
(ii) the entire set up is immersed in water. Justify your answer in each case.
10. How will the angular separation and visibility of fringes in Young's double slit experiment change when (i) screen is moved away from the plane of slits, and (ii) width of source slit is increased?

SOLUTIONS/HINTS

- 1. The fringe width is $\beta = \lambda D/d$, D (distance between slits and screen) is doubled, then fringe width will be doubled.
- 2. Since white light is a combination of all visible colors, the superposition of all colors at the central maximum results in a bright white band. Also the position of bright fringe is directly proportional to the wavelength of light. Thus, the first order bright fringe will be a spectrum with violet light at the inner edge and red light at the outer edge.
- 3. $n=2$, $y=n \lambda_2 D/d$, $y=3.3$ mm
- 4. (i) The observed double-slit interference pattern is actually the interference pattern modulated by the single-slit diffraction pattern.
(ii) Due to the symmetry of the circular obstacle, the diffracted wavelets from all points along the circumference of the obstacle's edge travel the *same optical path length* to the exact center of the shadow. Because they travel the same path length, they arrive in phase at the center of the shadow. This in-phase superposition leads to constructive interference at the exact center of the shadow, resulting in a bright spot.
- 5. (a) $Intensity \propto width\ of\ slit$ and use the correct formula Ans. 9:1

(b) No, the appearance of bright and dark fringes does not violate the law of conservation of energy.

6. Use the formula $A^2 = A_1^2 + A_2^2 + 2A_1A_2 \cos \phi$ Ans $A\sqrt{7}$

7. (a) Conditions for Coherent Sources: Same Frequency/Wavelength: The light sources must emit light of the same frequency or monochromatic light. Constant Phase Difference: The phase difference between the waves must remain constant with time. Same Amplitude (Optional but preferred): For high-contrast interference, amplitudes should be nearly equal. Origin: They should be derived from a single source to maintain phase consistency.

(b) Necessity of Coherent Sources: Coherent sources are necessary to produce a sustained (stable) interference pattern. If the phase relationship changes randomly (incoherent), the bright and dark fringes will shift positions constantly, averaging out to uniform illumination, and no interference pattern will be observable

8. Concave Mirror: When a plane wavefront is incident normally, the reflected wavefront converges at the focus. Therefore, it is a converging spherical wavefront.

Convex Lens: When a plane wavefront passes through a convex lens, it converges towards the focal point. The refracted wavefront is a converging spherical wavefront.

9. : (i) fringe width increases As $\beta = \lambda D/d$

(ii) fringe width decreases

10. $\beta = \frac{\lambda D}{a}$ Angular separation $\theta = \frac{\lambda}{a}$ (i) unchanged (ii) the interference pattern becomes less and less sharp. When the source slit becomes so wide that the condition $s/S < \lambda/D$ is not satisfied, the interference pattern disappears, but the angular width remains unchanged.

EXERCISE QUESTIONS

1. In YDSE with $D = 1\text{m}$, $d = 1\text{mm}$, light of wavelength 500 nm is incident at an angle of 0.57° w.r.t. the axis of symmetry of the two slits in the experimental set up. If centre of symmetry of screen is O .

(Competitive Corner)

(i) find the position of central maxima

(ii) Intensity at point O in terms of intensity of central maxima I_0 .

2. In Young's double slit experiment using mono-chromatic light of wavelength λ , the intensity of light at a point on the screen where path difference is λ , is K units. Find out the intensity of light at a point where path difference is $2\lambda/3$.

3. In young's double slit experiment how is the fringe width change when

(a) Light of smaller frequency is used

(b) Distance between the slits is decreased?

4. What type of wavefront will emerge from a (i) point source (ii) distant light source (iii) A spherical wave front after reflection from a plane mirror. (iv) A spherical wave front after reflection from a concave mirror.

5. Two wavelengths of light 600 nm and 610 nm are used in turn, to study the diffraction at a single slit of size 2 mm. The distance between the slits and screen is 2 m. Calculate the separation between the positions of the second order maximum of the diffraction pattern obtained in the two cases.

ANSWERS

1. (i) 9.949 mm (ii) $0.90I_0$ 2. $K/4$ 3. (a) increase (b) increase
4. (i) spherical wavefronts (ii) plane wavefronts (iii) spherical wavefronts (diverging) (iv) is spherical (either converging or diverging) or plane wavefronts, depending on the source's position 5. 0.025 mm.

SHORT ANSWER TYPE- II

1. (a) What is the effect on the interference fringes if the monochromatic source is replaced by a source of polychromatic light.
(b) In Young's double slit experiment, the two slits 0.15 mm apart are illuminated by monochromatic light of wavelength 450 nm. The screen is 1.0 m away from the slits. Find the distance of the second (i) bright fringe, (ii) dark fringe from the central Maximum.
2. How will the interference pattern in Young's double slit experiment gets affected when
(i) distance between the slits S_1 and S_2 is reduced and
(ii) the entire set up is immersed in water. Justify your answer in each case.
3. A parallel beam of monochromatic light falls normally on a narrow slit of width 'a' to produce a diffraction pattern on the screen placed parallel to the plane of the slit. Use Huygens' principle to explain that
(i) the central bright maxima is twice as wide as the other maxima.
(ii) the intensity falls as we move to successive maxima away from the centre on either side.
4. (a) Why are coherent sources necessary to produce a sustained interference pattern?
(b) In Young's double slit experiment using mono-chromatic light of wavelength λ , the intensity of light at a point on the screen where path difference is λ , is K units. Find out the intensity of light at a point where path difference is 2λ .
5. (a) Define the term wave front.
(b) State Huygen's principle.
(c) Consider a plane wave front incident on a thin convex lens. Draw a proper diagram to show how the incident wave front traverses through the lens and after refraction focuses on the focal point of the lens, giving the shape of the emergent wave front.
6. (a) Draw a graph showing the variation of intensity of light with the position on the screen in Young's double-slit experiment.
(b) Find the intensity of light at a point on the screen when two interfering waves of the same intensity (I_0) have a path difference of (i) $\lambda/4$ and (ii) $\lambda/3$.

7. Which of the following statements does not correctly comply with Huygens' Principle of constructing a secondary wavefront from a primary wavefront? Justify each case?
- (a) After some time interval, the new position of the wave front is the forward envelope to the secondary wavelets.
- (b) Secondary wavelets propagate outward through a medium with speed characteristic of waves in that medium.
- (c) A secondary wavefront is always a plane wavefront irrespective of whether the primary wavefront is planar or spherical.
8. (a) In a Young's double slit experiment, the two slits are illuminated by two different lamps having same wavelength of light. Explain with reason, whether interference pattern will be observed on the screen or not.
- (b) Light waves of intensities I_0 each from two coherent sources arrive at two points on a screen with path differences of $5\lambda/2$ and 5λ . Find the intensities at the points.
9. Two monochromatic sources of light originated from same source with intensities I and $4I$ are placed in front of two slits in YDSE. Prove that in interference pattern in front of both the slits intensity of fringes shall be same irrespective of the fact that sources are coherent or not. Justify?
10. Why we need coherent sources to get sustained interference of light? Someone says that two identical independent light sources can be coherent for a very short time period. It is called temporal coherency. Explain the statement.

SOLUTIONS/HINTS

1. (a) fringes will become coloured near to edge of central band lower wavelength will be seen.
- (b) (i) Distance of second bright fringe is $= \frac{2\lambda D}{d} = 6\text{mm}$
- (ii) Distance of second dark from central maxima, $= 3\frac{\lambda D}{2d} = 4.5\text{mm}$
2. i) fringe width increases As $\beta = \lambda D/d$
- ii) fringe width decreases $\beta \propto \lambda$
3. i) Describe single slit exp using wave theory ii) This is because the waves diffracting from different parts of the slit interfere with each other, and the interference pattern creates both bright and dark fringes (minima). The central bright fringe is the brightest and widest, and the intensity of the secondary maxima (bright fringes) decreases as you move further away from the center.
4. (a) if sources are not coherent then phase difference will be time varying.
- (b) phase difference $= \phi = 2\pi/\lambda \times 2\lambda = 4\pi$ intensity $I = I_0 \cos^2(\frac{\phi}{2})$, $I_0 = K$. so $I = K$
5. (a) Wavefront is the continuous locus of all points (such as wave crests or troughs) that oscillate in phase, meaning they are at the same distance from the source.
- (b) Correct principle (c) proper diagram with explanation

ANSWERS/HINTS

1. $\frac{1950D}{d} \text{ nm} , \frac{2600D}{d} \text{ nm}$

2. 0.15 degrees

3. 0.008

4. Definition ,500 nm

5.(i)Correct difference (ii)Verification using Huygens principle

LONG ANSWER TYPE QUESTIONS

1. (a) State the essential condition for diffraction of light to take place.
(b) Use Huygen's principle to explain diffraction of light due to a narrow single slit and the formation of a pattern of fringes obtained on the screen.
(c) Sketch the pattern of fringes formed due to diffraction at a single slit showing variation of intensity with angle θ .
2. Red colour of light of wavelength λ is passed from two narrow slits which are distance d apart and interference pattern is obtained on the screen distance D apart from the plane of two slits. Then find the answer to following parts assuming that slit widths are equal to produce intensity I_0 from each slit.
(a) Intensity at a point on the screen, situated at a distance $1/4$ th of fringe separation from centre.
(b) Intensity in the screen, if the sources become incoherent by using two different lamps behind lamps S_1 and S_2 .
(c) Angular position of 10th maxima, and the angular width of that fringe.
(d) Find the distance between 5th maxima and 3rd minima, at same side of central maxima.
3. (a) In a diffraction experiment, the slit is illuminated by light of wavelength 600 nm. The first minimum of the pattern falls at $\theta = 30^\circ$. Calculate the width of the slit.
(b) Show that the angular width of the first diffraction fringe is half of that of the central fringe.
(c) If a monochromatic source of light is replaced by white light, what change would you observe in the diffraction pattern?
4. (a) In Young's double slit experiment, derive the condition for (i) constructive interference and (ii) destructive interference at a point on the screen.
(b) 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.
5. Explain Huygen's principle. Name the types of wavefronts that corresponds to a beam of light
(a) coming from a convex lens when point source placed at focus.
(b) coming from very far off source.

(c) coming from a convex lens (μ for lens = 1.1) when point source placed at its focus inside water $\mu = 1.33$.

(d) wave front from a distant source fall perpendicular to an equilateral hollow prism placed in side water.

6. (a) Prove the laws of reflection by using a basic principle in wave optics. Name the principle.

(b) Laser light of wavelength 640 nm incident on a pair of slits produces an interference pattern in which the bright fringes are separated by 7.2 mm. Calculate the wavelength of another source of light which produces interference fringes separated by 8.1 mm using same arrangement. Also find the minimum value of the order 'n' of bright fringe of shorter wavelength which coincides with that of the longer wavelength

7. (a) In a single slit diffraction pattern, how is the angular width of central maximum affected when (i) slit width is increased (ii) the distance between the slit and the screen is increased.

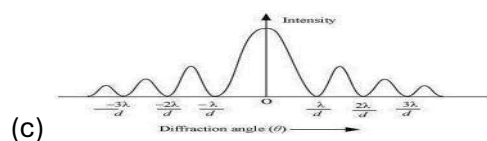
(iii) light of smaller wavelength is used. Justify your answer.

(b) A slit of width d is illuminated by light of wavelength 700 nm. Find the value of d for which the first minimum falls at an angle of 30°

SOLUTIONS/HINTS

1. (a) Essential condition for diffraction: the size of the obstacle or aperture (slit) must be comparable to the wavelength of the light being used.

(b) Correct explanation



2. (a) $\Delta x = \frac{y_d}{D} = \frac{\lambda}{4}$; $\Phi = \frac{\pi}{2}$; $I = 4I_0 \cos^2 \frac{\Phi}{2} = 2I_0$

(b) No interference pattern observed, $I_{total} = 2I_0$

(c) $d \sin \theta = 10\lambda$, find θ using this formula ; Angular width, $\Delta\theta = \frac{\lambda}{d}$

(d) distance = $|y_5 - y_3|$ Ans - $\frac{5\lambda D}{2d}$

3. a) Condition for minima; $a \sin \theta = n\lambda$ use this formula to find $a = 1.2 \mu\text{m}$

b) Condition for first minimum, $a\theta = \lambda$; $\theta_1 = \frac{\lambda}{a}$ $\theta_2 = -\frac{\lambda}{a}$

Angular width = $2\theta_1 = \frac{2\lambda}{a}$

c) The central maximum will remain white, secondary maxima will become colored fringes and the overlapping of different colored secondary maxima will increase.

4. a) correct derivation for (i) constructive interference and (ii) destructive interference at a point on the screen.

b) Here $y_1 = y_2$ to find the order of the bright fringes. Then calculate the position of this coinciding fringe using both pair of values. Ans: 12 mm

5. The principle is based on two primary postulates:

Secondary Sources: Every point on a given wavefront acts as a source of new secondary spherical wavelets.

Forward Propagation: The new position of the wavefront at any later time is the forward envelope (the common tangent surface) of all these secondary wavelets

a) plane wavefronts b) plane wavefronts c) Using lens maker's formula, we will find that lens will behave diverging. So we get diverging wavefront d) Plane wavefront

6. (a) Correct prove and name of principle

(b) Distance between two bright fringes = Fringe width

$$\beta = \frac{\lambda D}{d} \text{ using } \beta_1 / \beta_2 = \lambda_1 / \lambda_2$$

$\lambda_2 = 720 \text{ nm}$, minimum order $n=9$

7. (a) (i) decrease, $\theta = \frac{\lambda}{d}$, justification

(ii) independent

(iii) decrease, $\theta = \frac{\lambda}{d}$

(b) $d \sin \theta = \lambda$, $d = 1.4 \mu\text{m}$

EXERCISE QUESTIONS

1. (a) In a YDSE, two light waves, each of intensity I_0 , interfere at a point, having a path difference $\frac{\lambda}{8}$ on the screen. Find the intensity at this point.

(b) In a double-slit experiment, 6th dark fringe is observed at a certain point of the screen. A transparent sheet of thickness t and refractive index n is now introduced in the path of one of the two interfering waves to increase its phase by $\frac{2\pi(n-1)t}{\lambda}$. The pattern is shifted and 8th bright fringe is observed at the same point. Find the relation for thickness t in terms of n and λ .

(Competitive Corner)

2. (a) Draw the variation of intensity with angle of diffraction in single slit diffraction pattern. Write the expression for value of angle corresponding to zero intensity locations.

(b) In what way diffraction of light waves differs from diffraction of sound waves?

(c) A parallel beam of light of wavelength 650 nm passes through a slit of width 0.6 mm. The diffraction pattern is obtained on a screen kept 60 cm away from the slit. Find the distance between first order minima on both sides of the central maximum.

3. A physics teacher wants to demonstrate interference with the help of double slit experiment using a laser beam of 633 nm wavelength. Since the hall is large enough, interference pattern is formed on the wall 5 m from the slits. For clear and comfortable view by all the students they want the fringe width 5 mm.

(a) Find the slit separation for obtaining the desired interference pattern.

(b) How far will the first minimum be from the central maximum?

(c) Light waves from two pinholes illuminated by two sodium lamps do not produce

interference patterns. Give reason

4. A double slit set-up was initially placed in a tank filled with water and the interference pattern was obtained using a laser light. When water is replaced by a transparent liquid of refractive index $n > n_{\text{water}}$, what will be the effect on the following:

- (a) Speed, frequency, and wavelength of the light of laser beam
- (b) The fringe width, shape of interference fringes and shift in the position of central maximum.

5. Using Huygen's principle draw a ray diagram showing the propagation of a plane wave refracting at a plane surface separating two media. Also verify Snell's law of refraction.

ANSWERS

- 1. (a) $3.414 I_0$ (b) $\frac{5\lambda}{2(n-1)}$
- 2. (a) Correct graph (b) light waves have low wavelength. (c) 1.3 mm
- 3. (a) $633\mu\text{m}$ (b) 2.5 mm (c) they are **not coherent**, meaning they do not maintain a constant phase relationship
- 4. (a) speed of light and wavelength will decrease and frequency remains unaffected.
(b) Fringe width decreases, shapes and position of central maxima will not change
- 5. (a) Correct ray diagram and correct derivation.

CASE STUDY/PASSAGE-BASED QUESTIONS

(C.S.-1). In a Young's double-slit experiment, the two slits behave as coherent sources. When coherent light waves superpose over each other they create an interference pattern of successive bright and dark regions due to constructive and destructive interference. Two slits 2 mm apart are illuminated by a source of monochromatic light and the interference pattern is observed on a screen 5.0 m away from the slits as shown in the figure.

(i) What property of light does this interference experiment demonstrate ?

- (A) Wave nature of light (B) Particle nature of light (C) Transverse nature of light

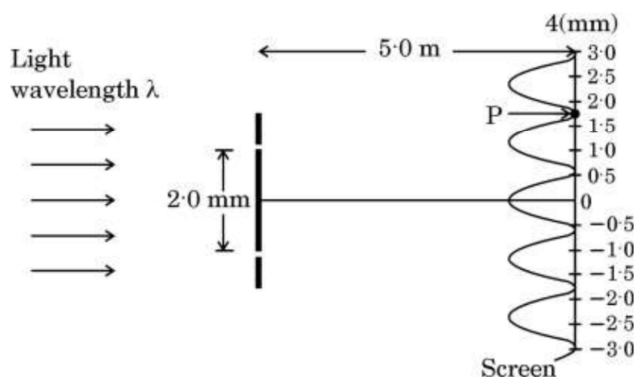
(D) Both wave nature and transverse nature of light

(ii) The wavelength of light used in this experiment is :

- (A) 720 nm (B) 590 nm (C) 480 nm (D) 364 nm

(iii) The fringe width in the interference pattern formed on the screen is : (A) 1.2 mm. (B) 0.2 mm. (C) 4.2 mm. (D) 6.8 mm

(iv) The path difference between the two waves meeting at point P,



where there is a minimum in the interference pattern is :

- (A) $8.1 \times 10^{-7} \text{ m}$ (B) $7.2 \times 10^{-7} \text{ m}$ (C) $6.5 \times 10^{-7} \text{ m}$ (D) $6.0 \times 10^{-7} \text{ m}$

(v) When the experiment is performed in a liquid of refractive index greater than 1, then fringe pattern will :

- (A) disappear. (B) become blurred. (C) be widened. (D) be compressed

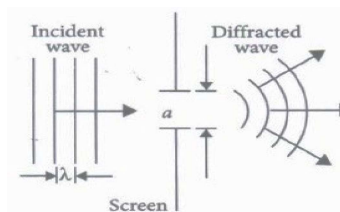
Answer (C.S.-1).

- (i) (A) wave nature of light (ii) (C) 480 nm (iii) (A) 1.2 mm.

- (iv) (B) $7.2 \times 10^{-7} \text{ m}$. (v) (D) be compressed

(C.S.-2).

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. The light thus deviates from its linear path. The deviation becomes much more pronounced, when the dimensions of the aperture or the obstacle are comparable to the wavelength of light.



(i) Light seems to propagate in rectilinear path because

- (A) its spread is very large. (B) its wavelength is very small
(C) reflected from the upper surface of atmosphere (D) it is not absorbed by atmosphere

(ii) In diffraction from a single slit the angular width of the central maxima does not depends on (A) λ of light used. (B) width of slit (C) distance of slits from the screen
(D) ratio of λ and slit width

(iii) For a diffraction from a single slit, the intensity of the central point is

- (A) infinite. (B) finite and same magnitude as the surrounding maxima
(C) finite but much larger than the surrounding maxima
(D) finite and substantially smaller than the surrounding maxima

(iv) In a single diffraction pattern observed on a screen placed at D metre distance from the slit of width d metre, the ratio of the width of the central maxima to the width of other secondary maxima is (approx.)

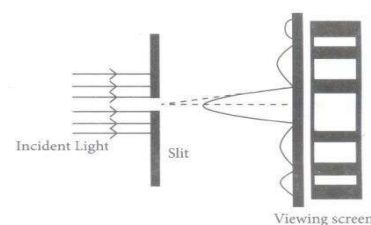
- (A) 2: 1 (B) 1: 2 (C) 1: 1 (D) 3: 1

Answer (C.S.-2).

- (i) B (ii) C (iii) C (iv) A

(C.S.-3)

When light from a monochromatic source is incident on a single narrow slit, it gets diffracted and a pattern of alternate bright and dark fringes is obtained on screen, called "Diffraction Pattern" of single slit. In diffraction pattern of single slit, it is found that



- (I) Central bright fringe is of maximum intensity and the intensity of any secondary bright fringe decreases with increase in its order.
- (II) Central bright fringe is twice as wide as any other secondary bright or dark fringe .

Read the following case/passage and answer the following questions:

- (i) A single slit of width 0.1 mm is illuminated by a parallel beam of light of wavelength 6000 Å and diffraction bands are observed on a screen 0.5 m from the slit. The distance of the third dark band from the first dark band of opposite side is
(A) 6 mm (B) 15 mm (C) 9 mm (D) 12 mm
- (ii) In Fraunhofer diffraction pattern, slit width is 0.2 mm and screen is at 2 m away from the lens. If wavelength of light used is 5000 Å then the distance between the first minimum on either side the central maximum is
(A) 10^{-1} m (B) 10^{-2} m (C) 2×10^{-2} m (D) 2×10^{-1} m
- (iii) Light of wavelength 600 nm is incident normally on a slit of width 0.2 mm. The angular width of central maxima in the diffraction pattern is
(A) 6×10^{-3} rad (B) 4×10^{-3} rad (C) 2.4×10^{-3} rad (D) 4.5×10^{-3} rad
- (iv) A diffraction pattern is obtained by using a beam of red light. What will happen, if the red light is replaced by the blue light?
- (v) To observe diffraction, the size of the obstacle
(A) should be $\lambda/2$, where λ is the wavelength.
(B) should be of the order of wavelength.
(C) has no relation to wavelength.
(d) should be much larger than the wavelength.

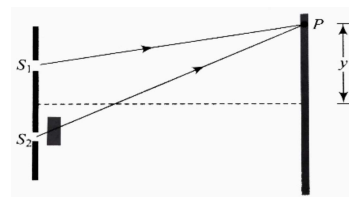
Answer (C.S.-3).

- (i) D (ii) B (iii) A (iv) Explanation (v) B

EXERCISE QUESTIONS

(EQ-1)

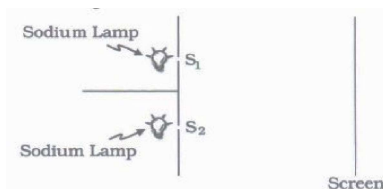
Interference of light:- If double slit apparatus is immersed in a liquid of refractive index μ , the wavelength of light reduces to λ/μ and fringe width also reduces to $\beta' = \beta/\mu$. The given figure shows a double-slit experiment in which coherent monochromatic light of wavelength λ from a distant source



is incident upon the two slits, each of width w ($w \gg \lambda$) and the interference pattern is viewed on a distant screen. A thin piece of glass of thickness t and refractive index n is placed between one of the slit and the screen, perpendicular to the light path.

- (i) In Young's double slit interference pattern, the angular fringe width
- (A) can be changed only by changing the wavelength of incident light
 - (B) can be changed only by changing the separation between the two slits
 - (C) can be changed either by changing the wavelength or by changing the separation between two slits
 - (D) is a universal constant and hence cannot be changed
- (ii) If the width w of one of the slits is increased to $2w$, the wave amplitude emerging from the slit will change from a to:
- (A) $1.5a$
 - (B) $2a$
 - (C) $\sqrt{2}a$
 - (D) no change
- (iii) In YDSE, let A and B be two slits. Films of thicknesses t_A and t_B and refractive indices μ_A and μ_B are placed in front of A and B, respectively. If $\mu_A t_A = \mu_B t_B$ then the central maxima will
- (A) not shift
 - (B) shift towards A
 - (C) shift towards B
 - (D) shift towards A if $t_B > t_A$ and shift towards B if $t_B < t_A$
- (iv) In Young's double slit experiment, a third slit is made in between the double slits. Then
- (A) fringes of unequal width are formed.
 - (B) contrast between bright and dark fringes is reduced
 - (C) intensity of fringes totally disappears
 - (D) only bright light is observed on the screen
- (v) In Young's double slit experiment, if one of the slits is covered with a microscope cover slip, then
- (A) fringe pattern disappears
 - (B) the screen just gets illuminated
 - (C) in the fringe pattern, the brightness of the bright fringes will decrease and the dark fringes will become more dark
 - (D) bright fringes will be more bright and dark fringes will become more dark.

(EQ-2) Interference is based on the superposition principle of waves from coherent sources. According to this principle, at a particular point in the medium, the resultant displacement produced by a number of waves is the vector sum of the displacements produced by each of the waves. If two isolated sodium lamps illuminate two pin holes S_1 and S_2 . The intensities will add up and no interference fringes will be observed on the screen. Here the source undergoes abrupt phase change in times of the order of 10^{-10} seconds called temporal coherency.



The intensities will add up and no interference fringes will be observed on the screen. Here the source undergoes abrupt phase change in times of the order of 10^{-10} seconds called temporal coherency.

- (i) Two coherent sources of intensity 100 W/m^2 and 25 W/m^2 interfere to form fringes. Find

the ratio of maximum intensity to minimum intensity

- (a) 5:3 (b) 9:1 (c) 4:1 (d) None of the all

(ii) Which of the following does not show interference?

- (a) Soap bubble (b) Excessively thin film of oil
(c) A thick film of oil (d) Wedge shaped film

(iii) In a Young's double-slit experiment, the slit separation is doubled. To maintain the same fringe spacing on the screen, the screen-to-slit distance D must be changed by

- (a) $2D$ (b) $4D$ (c) $D/2$ (d) D

(iv) The maximum number of possible interference maxima for slit separation equal to twice the wavelength in Young's double-slit experiment, is

- (a) Infinite (b) Five (c) Three (d) zero

(v) The resultant amplitude of a vibrating particle by the superposition of the two waves are

$$y_1 = a \sin [\omega t + \pi/3] \text{ and } y_2 = a \sin \omega t \text{ is}$$

- (a) a (b) $\sqrt{2}a$ (c) $2a$ (d) $\sqrt{3}a$

(EQ-3)

Diffraction and interference are closely related phenomena that occur together.

Diffraction is the phenomenon of bending of light around the edges of the obstacle, while interference is the combination of waves that results in a new wave pattern. In order to get interference, there must be at least two waves that are diffracting. So while diffraction can occur without interference, interference cannot occur without diffraction. Two slits of width $2 \mu\text{m}$ each in an opaque material are separated by a distance of $6 \mu\text{m}$.

Monochromatic light of wavelength 450 nm is incident normally on the slits. One finds a combined interference and diffraction pattern on the screen.

(i). The number of peaks of the interference fringes formed without the central peak of the envelope of the diffraction pattern will be

- (a) 2 (b) 3 (c) 4 (d) 6

(ii). The number of peaks of the interference formed if the slit width is doubled while keeping the distance between the slits same will be

- (a) 1 (b) 2 (c) 3 (d) 4

(iii). If instead of 450 nm light, another light of wavelength 680 nm is used, number of peaks of the interference formed in the central peak of the envelope of the diffraction pattern will be

- (a) 2 (b) 4 (c) 6 (d) 9

(iv). The number of bright fringes formed due to interference on 1 m of screen placed at $4/3 \text{ m}$ away from the slits is

- (a) 2 (b) 3 (c) 6 (d) 10

FORMULA SHEET

CBSE CLASS XII PHYSICS • WAVE OPTICS

PREMIUM SMART-STUDY REVISION POSTER & FORMULA SHEET

NEP 2020 Aligned — Highly Visual — Short Tricks & PYQ Tips — Quick Revision

1. WAVEFRONT & HUYGENS PRINCIPLE

Wavefront: The continuous locus of all adjacent particles of a medium vibrating in the same phase.

- **Plane Wavefront:** Originates from a source at infinity (parallel rays).
- **Spherical Wavefront:** Originates from a point source at finite distance.
- **Cylindrical Wavefront:** Originates from a linear source (e.g., narrow slit).

Huygens Principle: 1. Every point on a wavefront acts as a fresh source of secondary wavelets moving with the speed of light.
2. The forward envelope (tangential surface) of these secondary wavelets at any instant gives the new wavefront.



2. REFLECTION & REFRACTION VIA WAVE THEORY

Key Concept: Rays are always perpendicular to the wavefront (Ray $\perp$ Wavefront). Time taken by light along any ray path from one wavefront to another is identical.

- **Law of Reflection:** Proved by showing triangles formed by incident and reflected wavefronts are congruent $\Rightarrow \angle i = \angle r$.
- **Law of Refraction (Snell's Law):**

$$\mu = \frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$$

- **CRITICAL NOTE:** When light travels from a rarer to a denser medium, speed (v) and wavelength (λ) decrease:

$$\lambda_{\text{medium}} = \frac{\lambda_{\text{vacuum}}}{\mu}$$

But **Frequency (ν) remains absolutely constant** (depends only on the source).

3. COHERENT SOURCES & SUPERPOSITION

Coherent Sources: Two sources emitting light waves of the same frequency/wavelength with a constant phase difference.

Note: Two independent light bulbs can never be coherent because atoms emit light bursts with random phase changes every $\sim 10^{-10}$ s.

Resultant Intensity Formula: For two interfering waves of intensities I_1, I_2 and phase difference ϕ :

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos \phi$$

Phase Diff (ϕ) vs Path Diff (Δx):

$$\phi = \frac{2\pi}{\lambda} \cdot \Delta x$$

Intensity Extrema:

- **Maximum Intensity (Constructive):** $\cos \phi = 1 \Rightarrow I_{\text{max}} = (\sqrt{I_1} + \sqrt{I_2})^2$
- **Minimum Intensity (Destructive):** $\cos \phi = -1 \Rightarrow I_{\text{min}} = (\sqrt{I_1} - \sqrt{I_2})^2$

Identical Slits ($I_1 = I_2 = I_0$):

$$I = 4I_0 \cos^2 \left(\frac{\phi}{2} \right) \Rightarrow I_{\text{max}} = 4I_0, \quad I_{\text{min}} = 0$$

Slit Width & Amplitude Relations:

$$\frac{w_1}{w_2} = \frac{I_1}{I_2} = \frac{A_1^2}{A_2^2} \Rightarrow \frac{I_{\text{max}}}{I_{\text{min}}} = \left(\frac{A_1 + A_2}{A_1 - A_2} \right)^2 = \left(\frac{\sqrt{w_1} + \sqrt{w_2}}{\sqrt{w_1} - \sqrt{w_2}} \right)^2$$

4. YOUNG'S DOUBLE SLIT EXPERIMENT (YDSE)

Setup: Slit separation = d , Slit-to-Screen distance = D .
Path Difference at point P on screen at distance y from center:

$$\Delta x = S_2P - S_1P \approx d \sin \theta \approx \frac{y \cdot d}{D}$$

1. **Bright Fringes (Constructive Interference):**

- Path difference: $\Delta x = n\lambda$ ($n = 0, 1, 2, \dots$)
- Position from central max: $y_n = \frac{n\lambda D}{d}$

2. **Dark Fringes (Destructive Interference):**

- Path difference: $\Delta x = (2n+1)\frac{\lambda}{2}$ ($n = 0, 1, 2, \dots$)
- Position from central max: $y_n = \frac{(2n+1)\lambda D}{2d}$

Fringe Width (β): Distance between two successive bright or dark fringes:

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

- **Angular Fringe Width:** $\theta_0 = \frac{\beta}{D} = \frac{\lambda}{d}$ (Independent of screen distance D).
- **Immersion in Medium:** Entire setup immersed in liquid of ref. index $\mu \Rightarrow \beta_{\text{medium}} = \frac{\beta_{\text{air}}}{\mu}$ (Fringes shrink).

5. DIFFRACTION DUE TO SINGLE SLIT

Bending of light around corners of an obstacle/aperture of size comparable to λ . Slit width = a .

Condition for Minima (Dark Fringes):

$$a \sin \theta = n\lambda \Rightarrow y_n = \frac{n\lambda D}{a} \quad (n = \pm 1, \pm 2, \dots)$$

Warning: $n = 0$ corresponds to the central maximum, not a minimum!

Condition for Secondary Maxima (Bright Fringes):

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

Central Maximum Dimensions:

- **Angular Width:** $2\theta = \frac{2\lambda}{a}$
- **Linear Width:** $W_0 = \frac{2\lambda D}{a} = 2\beta_{\text{diff}}$

Key Takeaway: The central maximum in single-slit diffraction is **twice as wide** as any secondary maximum, and holds most of the total intensity.

6. INTERFERENCE VS DIFFRACTION

Feature	Interference (YDSE)	Diffraction (Single Slit)
Origin	Superposition of waves from two distinct coherent slits.	Superposition of wavelets from different parts of same slit.
Fringe Width	All fringes have equal width ($\beta = \lambda D/d$).	Central maximum is double the width of secondary maxima.
Intensity	All bright fringes have uniform maximum intensity.	Intensity falls off rapidly for higher-order secondary maxima.

7. QUICK RECALL & PYQ TIPS (MANDATORY)

- **Optical Path:** Distance light travels in vacuum in the same time it travels distance x in medium: $x_{\text{optical}} = \mu x$.
- **Insertion of Thin Plate:** Placing a glass slab of thickness t and ref. index μ in front of one slit introduces path diff $\Delta x = (\mu - 1)t$.
- **Fringe Shift:** Pattern shifts towards covered slit by:

$$\Delta y = \frac{D}{d} (\mu - 1)t = \frac{\beta}{\lambda} (\mu - 1)t$$

- **Sustained Interference:** Coherent, monochromatic, narrow slits, small separation d , large screen distance D .
- **White Light Source:** Central fringe is **white**. Closest side fringe is **violet** (λ min), outermost is **red**.

8. TRICKS & COMMON MISTAKES

COMMON MISTAKE ALERT:

- **Formula Reversal:** In YDSE, $n\lambda$ gives **BRIGHT** fringes. In Single Slit Diffraction, $n\lambda$ gives **DARK** minima. Never mix them up!
- **Intensity Ratio Error:** Remember intensity $I \propto A^2$, so finding $I_{\text{max}}/I_{\text{min}}$ requires taking square roots of individual intensities first.

Symbols: λ : Wavelength (m), β : Fringe width (m), D : Distance to screen (m), d, a : Slit sizes (m), μ : Refractive index.

