CHAPTER

10 Wave Optics

Syllabus

Wave optics: Wave front and Huygen's principle, reflection and refraction of plane wave at a plane surface using wave fronts. Proof of laws of reflection and refraction using Huygen's principle. Interference, Young's double slit experiment and expression for fringe width, coherent sources and sustained interference of light, diffraction due to a single slit, width of central maximum

CASE STUDY / PASSAGE BASED QUESTIONS

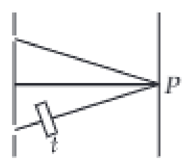
Questions 1-10 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

1

Intensity of Interference

If double slit apparatus is immersed in a liquid of refractive index, μ the wavelength of light reduces to λ' and fringe width also reduces to $\beta' = \frac{\beta}{\mu}$.

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 $w(w >> \lambda)$ 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 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 sources

(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 become the amplitude due to slit

(a) $1.5a$ (b) $a/2$ (c) $2a$ (d) no change

(iii) In *YDSE*, let A and B be two slits. Films of thicknesses t_A and t_B and refractive indices m_A and m_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 decreases and the dark fringes will become more dark
(d) bright fringes will be more bright and dark fringes will become more dark.

2

Fringe Width

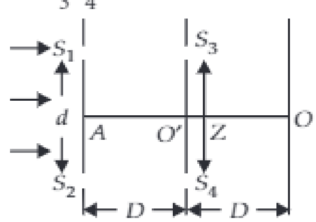
Distance between two successive bright or dark fringes is called fringe width.

$$\beta = Y_{n+1} - Y_n = \frac{(n+1)\lambda D}{d} - \frac{n\lambda D}{d} = \frac{\lambda D}{d}$$

Fringe width is independent of the order of the maxima. If whole apparatus is immersed in liquid of refractive index μ then $\beta = \frac{\lambda D}{\mu d}$ (fringe width decreases). Angular fringe width (θ) is the angular separation between two consecutive maxima or minima

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

In the arrangement shown in figure, slit S_3 and S_4 are having a variable separation Z. Point O on the screen is at the common perpendicular bisector of S_1S_2 and S_3S_4.



(i) 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

(ii) In Young's double – slit experiment if yellow light is replaced by blue light, the interference fringes become

(a) wider (b) brighter (c) narrower (d) darker

(iii) In Young's double slit experiment, if the separation between the slits is halved and the distance between the slits and the screen is doubled, then the fringe width compared to the unchanged one will be

(a) Unchanged (b) Halved (c) Doubled (d) Quadrupled

(iv) When the complete Young's double slit experiment is immersed in water, the fringes

(a) remain unaltered (b) become wider (c) become narrower (d) disappear

(v) In a two slit experiment with white light, a white fringe is observed on a screen kept behind the slits. When the screen is moved away by 0.05 m, this white fringe

(a) does not move at all
(b) gets displaced from its earlier position
(c) becomes coloured
(d) disappears.

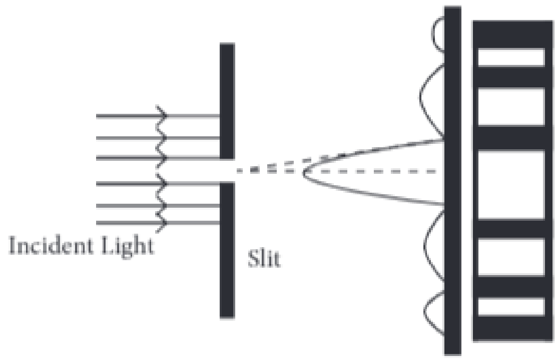
3

Diffraction at a Single Slit (Fraunhofer)

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.



(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 central bright band is

(a) 3 mm
(b) 1.5 mm
(c) 9 mm
(d) 4.5 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 (measured from minimum to minimum)

(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?

(a) bands disappear
(b) bands become broader and farther apart
(c) no change will take place
(d) diffraction bands become narrower and crowded together.

(v) To observe diffraction, the size of the obstacle

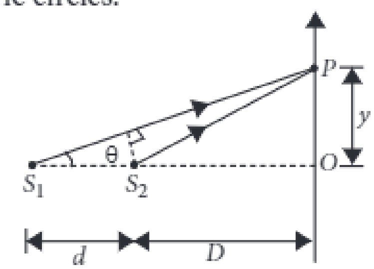
(a) should be $\lambda/2$, where λ is the wavelength.
(b) should be of the order of wavelength.
(c) has no relation to wavelength.
(d) should be much larger than the wavelength.

4

Interference Fringes

In Young's double slit experiment, the width of the central bright fringe is equal to the distance between the first dark fringes on the two sides of the central bright fringe.

In given figure below a screen is placed normal to the line joining the two point coherent source S_1 and S_2. The interference pattern consists of concentric circles.



(i) The optical path difference at P is

(a) $d\left[1+\frac{y^2}{2D}\right]$ (b) $d\left[1+\frac{2D}{y^2}\right]$ (c) $d\left[1-\frac{y^2}{2D^2}\right]$ (d) $d\left[2D-\frac{1}{y^2}\right]$

(ii) Find the radius of the n^{th} bright fringe.

(a) $D\sqrt{1\left(1-\frac{n\lambda}{d}\right)}$ (b) $D\sqrt{2\left(1-\frac{n\lambda}{d}\right)}$ (c) $2D\sqrt{2\left(1-\frac{n\lambda}{d}\right)}$ (d) $D\sqrt{2\left(1-\frac{n\lambda}{2d}\right)}$

(iii) If $d = 0.5$ mm, $\lambda = 5000$ Å and $D = 100$ cm, find the value of n for the closest second bright fringe

(a) 888 (b) 830 (c) 914 (d) 998

(iv) The coherence of two light sources means that the light waves emitted have

(a) same frequency (b) same intensity

(c) constant phase difference (d) same velocity.

(v) The phenomenon of interference is shown by

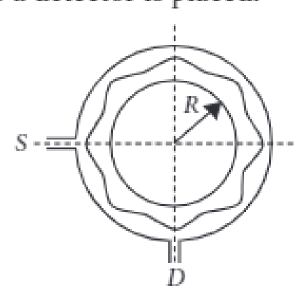
(a) longitudinal mechanical waves only (b) transverse mechanical waves only

(c) electromagnetic waves only (d) all of these

5

Maxima and Minima Intensity

A narrow tube is bent in the form of a circle of radius R, as shown in figure. Two small holes S and D are made in the tube at the positions at right angle to each other. A source placed at S generates a wave of intensity I_0 which is equally divided into two parts: one part travels along the longer path, while the other travels along the shorter path. Both the waves meet at point D where a detector is placed.



(i) If a maxima is formed at a detector, then the magnitude of wavelength λ of the wave produced is given by

(a) πR (b) $\frac{\pi R}{2}$ (c) $\frac{\pi R}{4}$ (d) all of these

(ii) If the intensity ratio of two coherent sources used in Young's double slit experiment is 49 : 1, then the ratio between the maximum and minimum intensities in the interference pattern is

(a) 1 : 9 (b) 9 : 16 (c) 25 : 16 (d) 16 : 9

(iii) The maximum intensity produced at D is given by

(a) $4I_0$ (b) $2I_0$ (c) I_0 (d) $3I_0$

(iv) In a Young's double slit experiment, the intensity at a point where the path difference is $\lambda/6$ (λ – wavelength of the light) is I. If I_0 denotes the maximum intensity, then I/I_0 is equal to

(a) $\frac{1}{2}$ (b) $\frac{\sqrt{3}}{2}$ (c) $\frac{1}{\sqrt{2}}$ (d) $\frac{3}{4}$

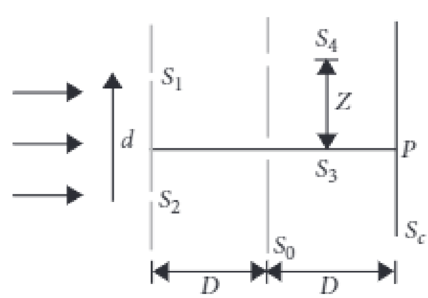
(v) Two identical light waves, propagating in the same direction, have a phase difference d. After they superpose the intensity of the resulting wave will be proportional to

(a) $\cos\delta$ (b) $\cos(\delta/2)$ (c) $\cos^2(\delta/2)$ (d) $\cos^2\delta$

6

Sources of Light

Consider the situation shown in figure. The two slits S_1 and S_2 placed symmetrically around the central line are illuminated by monochromatic light of wavelength λ. The separation between the slits is d. The light transmitted by the slits falls on a screen S_0 place at a distance D from the slits. The slits S_3 is at the central line and the slit S_4 is at a distance from S_3. Another screen S_c is placed a further distance D away from S_c.



(i) Find the path difference if $z = \frac{\lambda D}{2d}$.

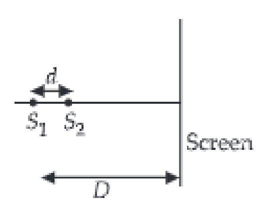
(a) λ (b) $\lambda/2$ (c) $3/2\lambda$ (d) 2λ

(ii) Find the ratio of the maximum to minimum intensity observed on S_c if $z = \frac{\lambda D}{d}$

(a) 4 (b) 2 (c) ∞ (d) 1

(iii) Two coherent point sources S_1 and S_2 are separated by a small distance d as shown in figure. The fringes obtained on the screen will be

(a) concentric circles
(b) points
(c) straight lines
(d) semi-circles



(iv) In the case of light waves from two coherent sources S_1 and S_2, there will be constructive interference at an arbitrary point P, if the path difference $S_1P - S_2P$ is

(a) $\left(n+\frac{1}{2}\right)\lambda$ (b) $n\lambda$ (c) $\left(n-\frac{1}{2}\right)\lambda$ (d) $\frac{\lambda}{2}$

(v) Two monochromatic light waves of amplitudes $3A$ and $2A$ interfering at a point have a phase difference of 60°. The intensity at that point will be proportional to

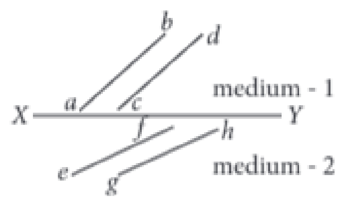
(a) $5A^2$ (b) $13A^2$ (c) $7A^2$ (d) $19A^2$

7

The Wavefront

Wavefront is a locus of points which vibratic in same phase. A ray of light is perpendicular to the wavefront. According to Huygens principle, each point of the wavefront is the source of a secondary disturbance and the wavelets connecting from these points spread out in all directions with the speed of wave.

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



(i) Light travels as a

(a) parallel beam in each medium (b) convergent beam in each medium

(c) divergent beam in each medium

(d) divergent beam in one medium and convergent beam in the other medium.

(ii) The phases of the light wave at c, d, e and f are ϕ_c, ϕ_d, ϕ_e and ϕ_f respectively. It is given that $\phi_c \neq \phi_f$

(a) ϕ_c cannot be equal to ϕ_d (b) ϕ_d can be equal to ϕ_e

(c) $(\phi_d - \phi_f)$is equal to $(\phi_c - \phi_e)$ (d) $(\phi_d - \phi_c)$ is not equal to $(\phi_f - \phi_e)$

(iii) Wavefront is the locus of all points, where the particles of the medium vibrate with the same

(a) phase (b) amplitude (c) frequency (d) period

(iv) A point source that emits waves uniformly in all directions, produces wavefronts that are

(a) spherical (b) elliptical (c) cylindrical (d) planar

(v) What are the types of wavefronts ?

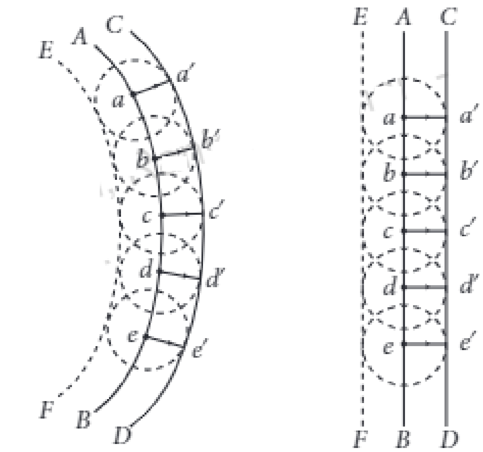
(a) Spherical (b) Cylindrical (c) Plane (d) All of these

8

Huygens Principle

Huygen's principle is the basis of wave theory of light. Each point on a wavefront acts as a fresh source of new disturbance, called secondary waves or wavelets. The secondary wavelets spread out in all directions with the speed light in the given medium.

An initially parallel cylindrical beam travels in a medium of refractive index $\mu(I) = \mu_0 + \mu_2 I$, where μ_0 and μ_2 are positive constants and I is the intensity of the light beam. The intensity of the beam is decreasing with increasing radius.



(a) (b)

(i) The initial shape of the wavefront of the beam is

(a) planar
(b) convex
(c) concave
(d) convex near the axis and concave near the periphery

(ii) According to Huygens Principle, the surface of constant phase is

(a) called an optical ray
(b) called a wave
(c) called a wavefront
(d) always linear in shape

(iii) As the beam enters the medium, it will

(a) travel as a cylindrical beam
(b) diverge
(c) converge
(d) diverge near the axis and converge near the periphery.

(iv) Two plane wavefronts of light, one incident on a thin convex lens and another on the refracting face of a thin prism. After refraction at them, the emerging wavefronts respectively become

(a) plane wavefront and plane wavefront
(b) plane wavefront and spherical wavefront
(c) spherical wavefront and plane wavefront
(d) spherical wavefront and spherical wavefront

(v) Which of the following phenomena support the wave theory of light?

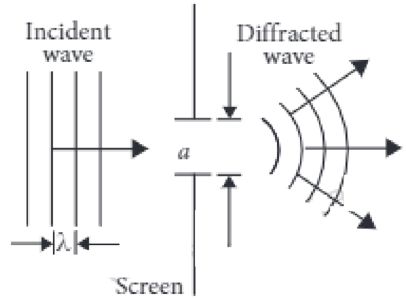
1. Scattering
2. Interference
3. Diffraction
4. Velocity of light in a denser medium is less than the velocity of light in the rarer medium

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

9

Diffraction of Light

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
  (c) 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) Resolving power of telescope increases when
  (a) wavelength of light decreases
  (b) wavelength of light increases
  (c) focal length of eye-piece increases
  (d) focal length of eye-piece decreases

(v) 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
  (a) 2 : 1
  (b) 1 : 2
  (c) 1 : 1
  (d) 3 : 1

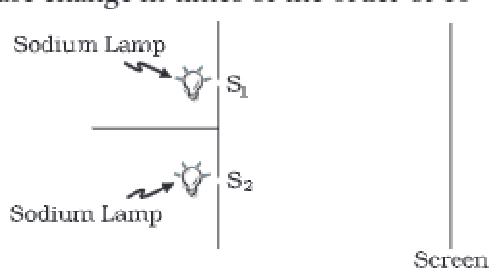
10

Interference of Light Waves and Young's Experiment

Interference is based on the superposition principle. 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 sodium lamps illuminate two pinholes 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.



(i) Two coherent sources of intensity 10 W/m^2 and 25 W/m^2 interfere to form fringes. Find the ratio of maximum intensity to minimum intensity.

(a) 15.54 (b) 16.78 (c) 19.72 (d) 18.39

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

(a) Soap bubble (b) Excessively thin film (c) A thick film (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 to

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

(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

$y_1 = a\sin\left[\omega t + \frac{\pi}{3}\right]$ and $y_2 = a\sin\omega t$ is

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

ASSERTION & REASON

For question numbers 11-30, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(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

11. Assertion (A) : A narrow pulse of light is sent through a medium. The pulse will retain its shape as it travels through the medium.

Reason (R) : A narrow pulse is made of harmonic waves with a large range of wavelengths.

12. Assertion (A) : 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.

Reason (R) : The frequency of monochromatic light depends on media.

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

Reason (R) : The destructive interference of two coherent light sources may give dark fringe.

14. Assertion (A) : In YDSE bright and dark fringe are equally spaced.

Reason (R) : It only depends upon phase difference.

15. Assertion (A) : When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the shadow of the obstacle.

Reason (R) : Wave diffracted from the edges of circular obstacle interfere constructively at the centre of the shadow resulting in the formation of bright spot.

16. Assertion (A) : Newton's rings are formed in the reflected system. When the space between the lens and the glass plate is filled with a liquid of refractive index greater than that of glass, the central spot of the pattern is dark.

Reason (R) : The reflections in Newton's ring cases will be from a denser to a rarer medium and the two interfering rays are reflected under similar conditions

17. Assertion (A) : In interference all the fringes are of same width.
Reason (R) : In interference fringe width is independent of position of the fringe.

18. Assertion (A) : For best contrast between maxima and minima in the interference pattern of Young's double slit experiment, the intensity of light emerging out of the two slits should be equal.
Reason (R) : The intensity of interference pattern is proportional to square of amplitude.

19. Assertion (A) : In Young's double slit experiment the two slits are at distance d apart. Interference pattern is observed on a screen at distance D from the slits. At a point on the screen when it is directly opposite to one of the slits, a dark fringe is observed. Then the wavelength of wave is proportional to square of distance of two slits.
Reason (R) : For a dark fringe intensity is zero.

20. Assertion (A) : In Young's experiment the fringe width is directly proportional to wavelength of the source used.
Reason (R) : When a thin transparent sheet is placed in front of both the slits of Young's experiment, the fringe width will increase.

21. Assertion (A) : Interference obeys the law of conservation of energy.
Reason (R) : The energy is redistributed in case of interference.

22. Assertion (A) : Two point coherent sources of light S_1 and S_2 are placed on a line as shown. P and Q are two points on that line. If at point P maximum intensity is observed then maximum intensity should also be observed at Q.

Reason (R) : In the figure of assertion the distance $|S_1P - S_2P|$ is equal to distance $|S_2Q - S_1Q|$.

23. 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.

24. Assertion (A) : When a light wave travels from a rarer to a denser medium, it loses speed. The reduction in speed imply a reduction in energy carried by the light wave.
Reason (R) : The energy of a wave is proportional to velocity of wave.

25. Assertion (A) : The interference pattern is observed when source is monochromatic and coherent.
Reason (R) : In Young's double slit experiment, we observe an interference pattern on the screen if both the slits are illuminated by two bulbs of same power.

26. Assertion (A) : Young's double slit experiment can be performed using a source of white light.
Reason (R) : The wavelength of red light is less than the wavelength of other colours in white light.

27. Assertion (A) : The film which appears bright in reflected system will appear dark in the transmitted light and vice-versa.
Reason (R) : The conditions for film to appear bright or dark in reflected light are just reverse to those in the transmitted light.

28. Assertion (A) : In Young's double slit experiment, the fringes become indistinct if one of the slits is covered with cellophane paper.
Reason (R) : The cellophane paper decrease the wavelength of light.

29. Assertion (A) : One of the condition for interference is that the two source should be very narrow.
Reason (R) : One broad source is equal to large number of narrow sources.

30. Assertion (A) : When tiny circular obstacle is placed in the path of light from some distance, a bright spot is seen at the centre of the shadow of the obstacle.
Reason (R) : Destructive interference occurs at the centre of the shadow.

HINTS & EXPLANATIONS

1. (i) (c): In Young's double slit experiment, the fringe width is $\beta = \frac{D\lambda}{d}$ where D is the distance of the slits from the screen, d is the separation of the slits and λ, the wavelength. Therefore the fringe width β can be changed either by changing the separation between the sources or the distance of the screen from the sources.

(ii) (c): As the width of one of the slits is increased to $2w$, the amplitude due to slit become $2a$.

(iii) (d): $\Delta x = (\mu_A - 1)t_A - (\mu_B - 1)t_B$
$= \mu_A t_A - \mu_B t_B - t_A + t_B = t_B - t_A$
If $\Delta x > 0$, then fringe pattern will shift upward.
If $\Delta x < 0$, then fringe pattern will shift downwards.

(iv) (b): Contrast between the bright and dark fringes will be reduced.

(v) (a): Since, one of the slit is covered, interference will not occur and fringe pattern will disappear.

2. (i) (b): The condition for possible interference maxima on the screen is, $d\sin\theta = n\lambda$
where d is slit separation and λ is the wavelength.
As $d = 2\lambda$ (given) $\therefore$ $2\lambda\sin\theta = n\lambda$ or $2\sin\theta = n$

For number of interference maxima to be maximum,
$\sin\theta = 1$ $\therefore$ $n = 2$
The interference maxima will be formed when
$n = 0, \pm 1, \pm 2$
Hence the maximum number of possible maxima is 5.

(ii) (c): Fringe width, $\beta = \frac{\lambda D}{d}$

$\therefore$ If we replace yellow light with blue light, *i.e.*, longer wavelength with shorter one, therefore the fringe width decreases.

(iii) (d): $d' = \frac{d}{2}$ and $D' = 2D$

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

New fringe width $\beta' = \lambda\left(\frac{2D}{d/2}\right) = 4\beta$

(iv) (c): When Young's double slit experiment is repeated in water, instead of air. $\lambda' = \frac{\lambda}{\mu}$, *i.e.*, wavelength decreases. $\beta = \frac{\lambda' D}{d}$, *i.e.*, fringe width decreases.

$\therefore$ The fringe become narrower.

(v) (a): Using white light, we get white fringe at the centre *i.e.*, white fringe is the central maximum. When the screen is moved, its position is not changed.

3. (i) (c): Here, $d = 0.1$ mm, $\lambda = 6000$ Å, $D = 0.5$ m

For third dark band, $d\sin\theta = 3\lambda$; $\sin\theta = \frac{3\lambda}{d} = \frac{y}{D}$

$$y = \frac{3D\lambda}{d} = \frac{3\times 0.5\times 6\times 10^{-7}}{0.1\times 10^{-3}} = 9\times 10^{-3}\text{ m} = 9\text{ mm}$$

(ii) (b): Given $d = 0.2$ mm $= 0.2\times 10^{-3}$ m, $D = 2$ m
$\lambda = 5000$ Å $= 5\times 10^{-7}$ m
The distance between the first minimum on other side of the central maximum

$$x = \frac{2\lambda D}{d} = \frac{2\times 5\times 10^{-7}\times 2}{0.2\times 10^{-3}} \Rightarrow x = 10^{-2}\text{ m}$$

(iii) (a): Here, $\lambda = 600$ nm $= 6\times 10^{-7}$ m
$a = 0.2$ mm $= 2\times 10^{-4}$ m, $\theta = ?$
Angular width of central maxima,

$$\theta = \frac{2\lambda}{a} = \frac{2\times 6\times 10^{-7}}{2\times 10^{-4}} = 6\times 10^{-3}\text{ rad}$$

(iv) (d): When red light is replaced by blue light ($\lambda_B < \lambda_R$) the diffraction pattern bands becomes narrow and crowded together.

(v) (b): To observe diffraction, the size of the obstacle should be of the order of wavelength.

4. (i) (c): The optical path difference at P is
$\Delta x = S_1P - S_2P = d\cos\theta$

$\because$ $\cos\theta = 1 - \frac{\theta^2}{2}$ for small θ

$\therefore$ $\Delta x = d\left(1 - \frac{\theta^2}{2}\right) = d\left[1 - \frac{y^2}{2D^2}\right]$, where $D + d = D$

(ii) (b): For n^{th} maxima,
$\Rightarrow$ $\Delta x = n\lambda$

$$d\left[1-\frac{y^2}{2D^2}\right]=n\lambda$$

y = radius of the n^{th} bright ring

$$= D\sqrt{2\left(1-\frac{n\lambda}{d}\right)}$$

(iii) (d): At the central maxima, $\theta = 0$.

$\Delta x = d = n\lambda$

$$\Rightarrow \quad n = \frac{d}{\lambda} = \frac{0.5}{0.5\times 10^{-3}} = 1000$$

Hence, for the closet second bright fringe, $n = 998$.

(iv) (c): Light waves from two coherent sources must have a constant phase difference.

(v) (d): Interference is shown by transverse as well as mechanical waves.

5. (i) (d): Path difference produced is

$$\Delta x = \frac{3}{2}\pi R - \frac{\pi}{2}R = \pi R$$

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

$\therefore \quad n\lambda = \pi R$

$$\Rightarrow \quad \lambda = \frac{\pi R}{n},\ n = 1, 2, 3, ...$$

Thus, the possible values of λ are $\pi R, \frac{\pi R}{2}, \frac{\pi R}{3}, ...$

(ii) (d)

(iii) (b): Maximum intensity, $I_{max} = \left(\sqrt{I_1}+\sqrt{I_2}\right)^2$

Here, $I_1 = I_2 = \frac{I_0}{2}$ (given)

$$\therefore \quad I_{max} = \left(\sqrt{\frac{I_0}{2}}+\sqrt{\frac{I_0}{2}}\right)^2 = 2I_0$$

(iv) (d): Phase difference $\phi = \frac{2\pi}{\lambda}\times$ Path difference

$$\phi = \frac{2\pi}{\lambda}\times\frac{\lambda}{6} = \frac{\pi}{3} = 60^\circ \quad \text{As } I = I_{max}\cos^2\frac{\phi}{2}$$

$$\therefore \quad I = I_0\cos^2\frac{60^\circ}{2} = I_0\times\left(\frac{\sqrt{3}}{2}\right)^2 = \frac{3}{4}I_0 \Rightarrow \frac{I}{I_0} = \frac{3}{4}$$

(v) (c): Here $A^2 = a_1^2 + a_2^2 + 2a_1a_2\cos\delta \because a_1 = a_2 = a$

$$\therefore A^2 = 2a^2(1+\cos\delta) = 2a^2\left(1+2\cos^2\frac{\delta}{2}-1\right)$$

or $A^2 \propto \cos^2\frac{\delta}{2}$

Now $I \propto A^2 \quad \therefore I \propto A^2 \propto \cos^2\frac{\delta}{2} \Rightarrow I \propto \cos^2\frac{\delta}{2}$

6. (i) (b): As $z = \frac{\lambda D}{2d}$

At S_4: $\frac{\Delta x}{d} = \frac{z}{D}$

$$\Rightarrow \quad \Delta x = \frac{\lambda D}{2d}\frac{d}{d} = \frac{\lambda}{2}$$

(ii) (c): $z = \frac{\lambda D}{d}$

Δx at S_4: $\Delta x = \frac{\lambda D}{d}\frac{d}{d} = \lambda$

Hence, maxima at S_4 as well as S_3.

Resultant intensity at S_4, $I = 4I_0$

$$\therefore \quad \frac{I_{max}}{I_{min}} = \frac{[(4I_0)^{1/2}+4(4I_0)^{1/2}]^2}{[(4I_0)^{1/2}-(4I_0)^{1/2}]^2} = \infty$$

(iii) (a): When the screen is placed perpendicular to the line joining the sources, the fringes will be concentric circles.

(iv) (b): Constructive interference occurs when the path difference ($S_1P - S_2P$) is an integral multiple of λ.

or $\quad S_1P - S_2P = n\lambda$, where $n = 0, 1, 2, 3, ...$

(v) (d): Here, $A_1 = 3A$, $A_2 = 2A$ and $\phi = 60^\circ$

The resultant amplitude at a point is

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

$$= \sqrt{(3A)^2 + (2A)^2 + 2\times 3A\times 2A\times\cos 60^\circ}$$

$$= \sqrt{9A^2 + 4A^2 + 6A^2} = A\sqrt{19}$$

As, Intensity $\propto$ (Amplitude)^2

Therefore, intensity at the same point is

$I \propto 19A^2$

7. (i) (a): Since the path difference between two waveform is equal, light traves as parallel beam in each medium.

(ii) (c): Since all points on the wavefront are in the same phase,

$\phi_d = \phi_c$ and $\phi_f = \phi_e$

$\therefore \quad \phi_d - \phi_f = \phi_c - \phi_e$.

(iii) (a): Wavefront is the locus of all points, where the particles of the medium vibrate with the same phase.

(iv) (a)

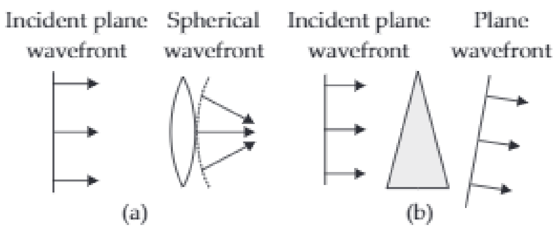
(v) (d)

8. (i) (a) : As the beam is initially parallel, the shape of wavefront is planar.

(ii) (c) : According to Huygens Principle, the surface of constant phase is called a wavefront.

(iii) (c)

(iv) (c) : After refraction, the emerging wavefronts respectively become spherical wavefront and plane wavefront as shown in figures (a) and (b).

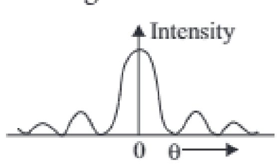


(v) (c)

9. (i) (b) : The wavelength of visible light is very small, that is hardly shows diffraction, so it seems to propagate in rectilinear path,

(ii) (c) : Angular width of central maxima, $2\theta = 2\lambda/e$. Thus, θ does not depend on screen *i.e.*, distance between the slit and the screen.

(iii) (c) : The intensity distribution of single slit diffraction pattern is shown in the figure. From the graph it is clear that the intensity of the central point is finite but much larger than the surrounding maxima.



(iv) (a) : Resolving power of telescope = $\frac{a}{1.22\lambda}$

$\therefore$ It increases when wavelength of light decreases and/or objective lens of greater diameter is used.

(v) (a) : Width of central maxima = $2\lambda D/e$

width of other secondary maxima = $\lambda D/e$

$\therefore$ Width of central maxima : width of other secondary maxima

= 2 : 1

10. (i) (c) : Given $I_1 = 10$ W/m^2 and $I_2 = 25$ W/m^2

$$\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{10}{25} \Rightarrow \frac{a_1}{a_2} = \frac{3.16}{5} \text{ or } a_1 = \frac{3.16}{5}a_2 = 0.6324a_2$$

$$\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \frac{[0.6324a_2+a_2]^2}{[0.6324a_2-a_2]^2} = 19.724$$

(ii) (b) : In an excessively thin film, the thickness of the film is negligible. Thus the path difference between the reflected rays becomes $\lambda/2$ which produces a minima.

(iii) (a) : Since, $\beta = \frac{\lambda D}{d}$ for $d = 2d$,

$$\beta' = \frac{\lambda D'}{2d} = \beta(\text{Gives})$$

$\therefore \quad D_1 = 2D$

(iv) (b) : The condition for possible interference maxima on the screen is, $d\sin\theta = n\lambda$

where d is slit separation and λ is the wavelength.

As $d = 2\lambda$ (given) $\quad \therefore\ 2\lambda\sin\theta = n\lambda$ or $2\sin\theta = n$

For number of interference maxima to be maximum, $\sin\theta = 1 \quad \therefore \quad n = 2$

The interference maxima will be formed when $n = 0, \pm 1, \pm 2$

Hence the maximum number of possible maxima is 5.

(v) (d): $y_1 = a\sin\left(\omega t + \frac{\pi}{3}\right)$ and $y_2 = a\sin\omega t$

$$A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}, \text{ where } \phi = \frac{\pi}{3}$$

$$= \sqrt{a^2 + a^2 + 2aa\cos\frac{\pi}{3}} = \sqrt{3}a$$

11. (c) : A narrow pulse is made of harmonic waves with a large range of wavelengths. As speed of propagation is different for different wavelengths, the pulse cannot retain its shape while travelling through the medium.

12. (c) : The reflection and refraction of light occurs on account of interaction of light with the atoms of the surface of separation. These atoms can be regarded as oscillators.

Light incident on the interface forces the atomic oscillators to oscillate with frequency of incident light. As frequency of light emitted by these (charged) oscillators is equal to their own frequency of oscillation, therefore, reflected and refracted light have the same frequency as that of incident light.

13. (a) : When light waves from two coherent sources superimpose at any particular point, crest of one wave falls on trough of the other and trough falls on the crest, the amplitude of the resultant wave is zero. Hence resultant intensity is zero. This is the phenomenon of destructive interference. Thus destructive interference produces darkness.

14. (c) : Fringe width is given by, $\beta = \frac{D\lambda}{d}$

where, D = distance between slit and screen, d = distance between coherent sources of light and λ = wavelength of incident light.

15. (a) : Point of constructive interference or maxima is obtained when path difference between the two interfering waves is an integral multiple of wavelength.

16. (a) : The central spot of Newton's rings is dark when the medium between plano convex lens and plane glass is rarer than the medium of lens and glass. The central spot is dark because the phase change of π is introduced between the rays reflected from surfaces of denser to rarer and rarer to denser media.

17. (a) : As given in the expression $\beta = \frac{D\lambda}{d}$, fringe width β is independent of n (position of fringe), hence all the fringes are of same width.

18. (b) : When intensity of light emerging from two slits is equal, the intensity at minima,

$$I_{min} = \left(\sqrt{I_a} - \sqrt{I_b}\right)^2 = 0, \text{ or absolute dark.}$$

19. (b) : For case when dark fringe is observed opposite to one of the slit.

$$\text{here } S_1P = D \text{ and } S_2P = \sqrt{D^2 + d^2} = D\left[1 + \frac{d^2}{2D^2}\right]$$

$$\text{Path difference} = S_2P - S_1P = \frac{d^2}{2D} = \frac{\lambda}{2} \text{ or, } \lambda = \frac{d^2}{D}.$$

20. (c) : Fringe width $\beta = \lambda D/d$ shall remain the same as the waves travel in air only, after passing through the thin transparent sheet. Due to introduction of thin sheet, only path difference of the wave is changed due to which there is shift of position of fringes only, which is given as $\Delta x = \frac{D(\mu - 1)t}{d}$, where μ is refractive index of thin sheet and t is its thickness.

21. (a) : In case of interference, intensity of maxima is $I_{max} = \left(\sqrt{I_a} + \sqrt{I_b}\right)^2$ and intensity of minima is $I_{min} = \left(\sqrt{I_a} - \sqrt{I_b}\right)^2$. Thus, whatever energy disappears at the minimum is actually appearing at the maximum. So, the law of conservation of energy holds good in the phenomenon of interference because in interference energy is neither created nor destroyed but is redistributed.

22. (b) : If maximum intensity is observed at P then for maximum intensity to be also observed at Q, S_1 and S_2 must have phase difference of $2\,m\pi$ (where m is an integer).

23. (b) : When slit is wide (*i.e.* $a >> \lambda$), bending of light becomes so small that it cannot be detected upto a certain distance of screen from the slit. Hence, practically, no diffraction occurs.

24. (d) : When a light wave travel from a rarer to a denser medium it loses speed, but energy carried by the wave does not depend on its speed. Instead, it depends on the amplitude of wave. The frequency also remain constant.

25. (c) : If both the slits are illuminated by two bulbs of same power, no interference pattern will be observed on the screen. This is because waves reaching at any point on the screen do not have a constant phase difference, as phase difference from two incoherent sources changes randomly. Therefore, maxima and minima would also change their positions randomly and in quick succession. This will result in general illumination of the screen.

26. (c) : When source in Young's double slit experiment is of white light, the central fringe is white as all colours meet there in phase.

27. (a) : For reflected system of the film, the maxima or constructive interference is $2\mu t\cos r$ = while the maxima for transmitted system of film is given by equation

$2\mu t \cos r = n\lambda$

where t is thickness of the film and r is angle of refraction.

From these two equations we can see that condition for maxima in reflected system and transmitted system are just opposite.

28. **(c) :** When one of slits is covered with cellophane paper, the intensity of light emerging from the slit is decreased (because this medium is translucent). Now the two interfering beam have different intensities or amplitudes. Hence, intensity at minima will not be zero and fringes will become indistinct.

29. **(a) :** As a broad source is equivalent to a large number of narrow sources lying side by side. Each set of these sources will produce an interference pattern of its own which will overlap on another to such an extent that all traces of a fringe system is lost and results in general illumination. Because of this reason, for interference a narrow slit should be used.

30. **(c) :** The waves diffracted from the edges of circular obstacle, placed in the path of light, interfere constructively at the centre of the shadow resulting in the formation of a bright spot.