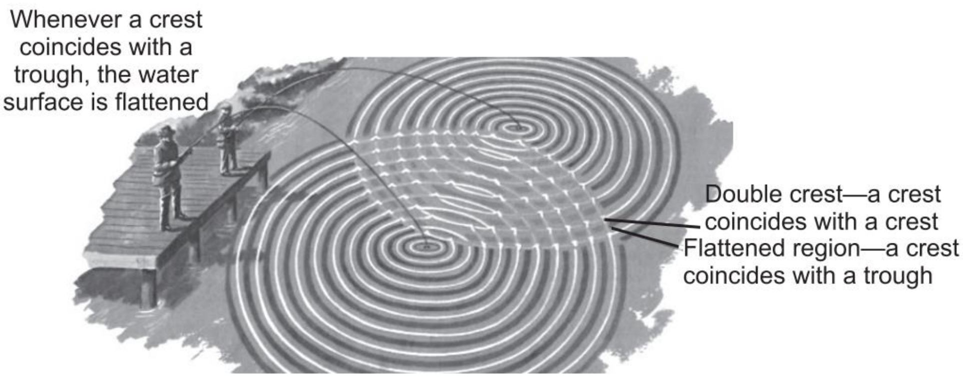
Wave Optics

Case Study Based Questions

Case Study 1

Jimmy and Johnny both were creating a series of circular waves while fishing in the water. The waves form a pattern similar to the diagram as shown. Their friend, Anita, advised Jimmy and Johnny not to play with water for a long time. She then observed beautiful patterns of ripples which became very colourful. When her friend Lata poured an oil drop on it. Lata, a 12th standard girl, had explained the cause for colourful ripple patterns to Anita earlier.



Read the given passage carefully and give the answer of the following questions:

Q1. Name the phenomenon involved in the activity :

a. reflection b. refraction

c. interference d. polarisation

Q2. A surface over which an optical wave has a constant phase is called :

a. wave b. wavefront

c. elasticity d. None of these

Q3. Which of the following is correct for light diverging from a point source?

a. The intensity decreases in proportion for the distance squared.

b. The wavefront is parabolic.

c. The intensity at the wavelength does not depend on the distance.

d. None of the above

Q4. Huygens' concept of secondary wave:

a. allows us to find the focal length of a thick lens

b. is a geometrical method to find a wavefront

c. is used to determine the velocity of light

d. is used to explain polarisation

Solutions

1. (c) interference

2. (b) wavefront

A wavefront is the locus of points having the same phase of oscillation.

3. (a) The intensity decreases in proportion for the distance squared.

4. (b) is a geometrical method to find a wavefront

Case Study 2

Geeta was watching her favourite TV programme KBC. Suddenly the picture started shaking on the TV screen. She asked her elder brother to check the dish antenna. Her brother found nothing wrong with the antenna. A little later, Geeta again noticed the same problem on the TV screen. At the same time, she heard the sound of a low flying aircraft passing over their house. She asked her brother again. Her brother being a Physics student explained the cause of shaking the picture on the TV screen when aircraft passes over head.

Read the given passage carefully and give the answer of the following questions:

Q1. Why does the picture started shaking when a low flying aircraft passes overhead?

a. Due to Interference

b. Due to reflection

c. Due to refraction

d. Due to polarisation

Q2. The main principle used in interference is ....

a. Heisenberg's Uncertainty Principle

b. Superposition Principle

c. Quantum Mechanics

d. Fermi Principle

Q3. When two waves of same amplitude add constructively, the intensity becomes :

a. double

b. half

c. four times

d. one-fourth

Q4. The shape of the fringes observed in interference is:

a. straight

b. circular

c. hyperbolic

d. elliptical

Solutions

1. (a) Due to Interference

2. (b) Superposition Principle

Interference is based on superposition principle.

3. (c) four times.

$$I \propto A^2$$

4. (c) hyperbolic

Fringes observed in interference is hyperbolic.

Case Study 3

Rohan observed a thin film such as soap bubble or a thin layer of oil on water show beautiful colours when illuminated by white light. He felt happy and surprised to see that. He went to his Physics teacher to understand the reason behind it.

The teacher explained him that a thin film of oil spread over water shows interference of light due to interference between the light waves reflected by the lower and upper surface of the thin film. On understanding the phenomenon, Rohan then gave an example of thin film of kerosene oil which is spread over water to prevent malaria and dengue.

Read the given passage carefully and give the answer of the following questions:

Q1. If instead of monochromatic light, white light is used for interference of light, what would be the change in the observation?

a. The pattern will not be visible.

b. The shape of the pattern will change from hyperbolic to circular.

c. Coloured fringes will be observed with a white bright fringe at the centre.

d. The bright and dark fringes will change position

Q2. Zero order fringe can be identified using:

a. white light

b. yellow light

c. achromatic light

d. monochromatic light

Q3. The interference pattern of soap bubble changes continuously.

a. True

b. False

c. Neither a. nor b.

d. Both a. and b.

Q4. A thin sheet of refractive index 1.5 and thickness 1 cm is placed in the path of light. What is the path difference observed?

a. 0.003 m

b. 0.004 m

c. 0.005 m

d. 0.006 m

Solutions

1. (c) Coloured fringes will be observed with a white bright fringe at the centre.

2. (a) white light

3. (a) True

4. (c) 0.005 m

Given, $\mu = 1.5$

Thickness t = 1cm = 0.01 m

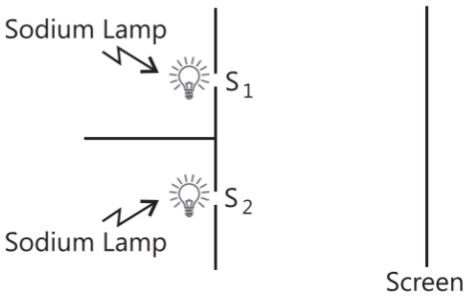
∴ Path difference = $(\mu - 1)\, t = (1.5 - 1) \times 0.01$

$= 0.5 \times 0.01 = 0.005$ m

Case Study 4

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.

Read the given passage carefully and give the answer of the following questions:

Q1. Two coherent sources of intensity 10 W/m² and 25 W/m² interfere to form fringes. Find the ratio of maximum intensity to minimum intensity.

Q2. What is the maximum number of possible interference maxima for slit separation equal to twice the wavelength in Young's double-slit experiment?

Q3. What is the resultant amplitude of a vibrating particle by the superposition of the two waves

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

Q4. Interference is based on which principle?

Solutions

1. Given $I_1 = 10 \text{ W/m}^2$ and $I_2 = 25 \text{ W/m}^2$

$$\therefore \quad \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} \Rightarrow \frac{10}{25} = \frac{a_1^2}{a_2^2} \Rightarrow \frac{a_1}{a_2} = \frac{3.16}{5}$$

$$\text{or } a_1 = \frac{3.16}{5} a_2 = 0.6324\, a_2$$

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

$$= \frac{\left(\frac{0.6324 a_2}{a_2} + 1\right)^2}{\left(\frac{0.6324 a_2}{a_2} - 1\right)^2} = \left(\frac{1.6324}{-0.3676}\right)^2 = 19.724$$

2. 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)

$$\therefore \quad 2\lambda \sin \theta = n\lambda$$

$$\text{or} \quad 2 \sin \theta = n$$

For number of interference maxima to be maximum,

$$\sin \theta = 1$$

$$\therefore \quad n = 2$$

The interference maxima will be formed when

$$n = 0, \pm 1, \pm 2$$

Hence, the maximum number of possible maxima is 5.

3. Given, $y_1 = a \sin\left(\omega t + \frac{\pi}{3}\right)$ and $y_2 = a \sin \omega t$

Resultant amplitude,

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

$$a_1 = a_2 = a$$

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

4. Superposition principle.

Case Study 5

Diffraction of light is bending of light around the corners of an object whose size is comparable with the wavelength of light. Diffraction actually defines the limits of ray optics. This limit for optical instruments is set by the wavelength of light. An experimental arrangement is set up to observe the diffraction pattern due to a single slit.

Read the given passage carefully and give the answer of the following questions:

Q1. How will the width of central maxima be affected if the wavelength of light is increased?

Q2. Under what condition is the first minima obtained?

Q3. Write two points of difference between interference and diffraction patterns.

Or

Two students are separated by a 7 m partition wall in a room 10 m high. If both light and sound waves can bend around obstacles, how is it that the students are unable to see each other even though they can converse easily? (CBSE 2023)

Solutions

1. The width of the central maxima is directly proportional to the wavelength, therefore if the wavelength of light is increased, then width of central maxima also increases.

2. Condition for first minima due to a single slit,

$a \sin \theta = \lambda$

where, a = width of slit.

3. Difference between Interference and Diffraction Pattern

S. No.	Basis of Difference	Interference Pattern	Diffraction Pattern
1.	Fringe width	Fringe width is constant.	Fringe width varies.
2.	Source of fringes	Fringes are obtained with the coherent light coming from two slits.	Fringes are obtained with the monochromatic light coming from single slit.

Or

Bending of waves by obstacles by a large angle is possible when the size of the obstacle is comparable to the wavelength of the waves. On the one hand, the wavelength of light waves is too small in comparison to the size of the obstacle. Thus, the diffraction angle will be very small. Hence, the students are unable to see each other. On the other hand, the size of the wall is comparable to the wavelength of the sound waves. Thus, the bending of waves takes place at a large angle. Hence, the students are able to hear each other.

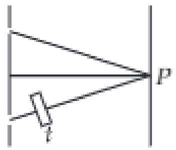
Solutions for Questions 6 to 15 are Given Below

Case Study 6

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.

Case Study 7

Fringe Width

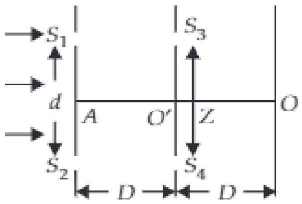
Distance between two successive bright or dark fringes is called fringe width.

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

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.

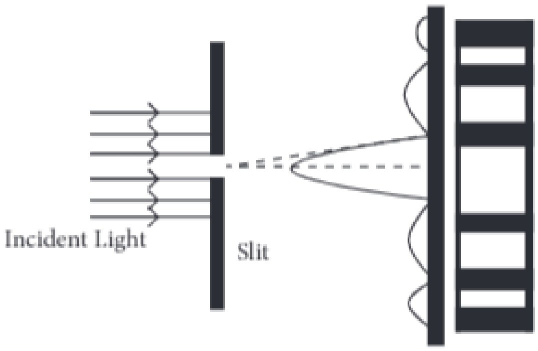
Case Study 8

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

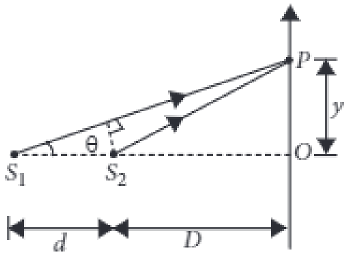
(a) should be $\lambda/2$, where λ is the wavelength.
(b) should be of the order of wavelength.
(c) has no relation to wavelength.
(d) should be much larger than the wavelength.

Case Study 9

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

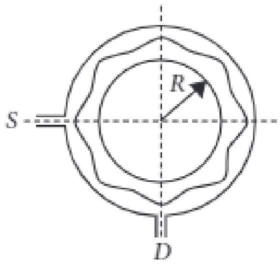
(a) longitudinal mechanical waves only (b) transverse mechanical waves only

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

Case Study 10

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) $\frac{3}{4}$

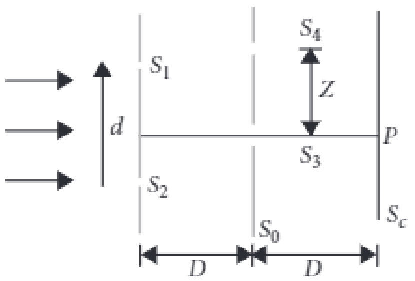
(v) Two identical light waves, propagating in the same direction, have a phase difference d. After they superpose the intensity of the resulting wave will be proportional to

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

Case Study 11

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 $z = \frac{\lambda D}{2d}$.

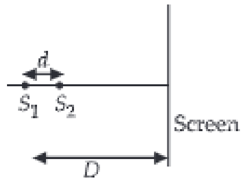
(a) λ (b) $\lambda/2$ (c) $3/2\lambda$ (d) 2λ

(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

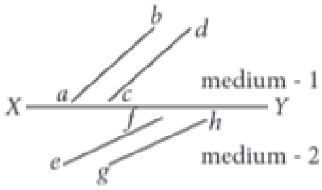
(a) $5A^2$ (b) $13A^2$ (c) $7A^2$ (d) $19A^2$

Case Study 12

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 ?

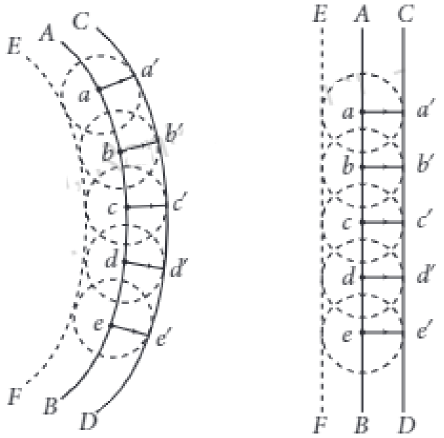
(a) Spherical (b) Cylindrical (c) Plane (d) All of these

Case Study 13

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?

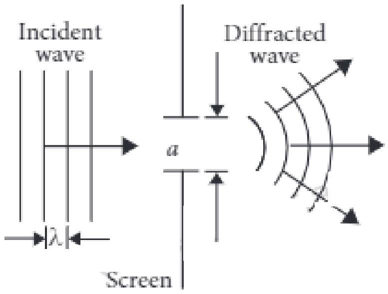
1. Scattering
2. Interference
3. Diffraction
4. Velocity of light in a denser medium is less than the velocity of light in the rarer medium

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

Case Study 14

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

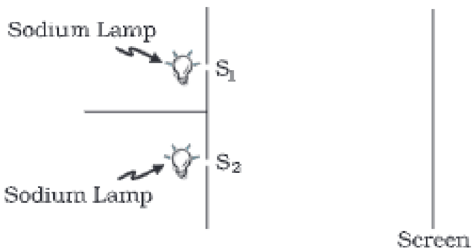
Case Study 15

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) $\sqrt{3}a$

6. (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.

7. (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) $\quad \therefore\ 2\lambda\sin\theta = n\lambda$ 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.

(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.

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

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

$$y = \frac{3D\lambda}{d} = \frac{3\times0.5\times6\times10^{-7}}{0.1\times10^{-3}} = 9\times10^{-3}\ \text{m} = 9\ \text{mm}$$

(ii) (b): Given $d = 0.2$ mm $= 0.2\times10^{-3}$ m, $D = 2$ m

$\lambda = 5000$ Å $= 5\times10^{-7}$ m

The distance between the first minimum on other side of the central maximum

$$x = \frac{2\lambda D}{d} = \frac{2\times5\times10^{-7}\times2}{0.2\times10^{-3}} \Rightarrow x = 10^{-2}\ \text{m}$$

(iii) (a) : Here, $\lambda = 600$ nm $= 6\times10^{-7}$ m

$a = 0.2$ mm $= 2\times10^{-4}$ m, $\theta = ?$

Angular width of central maxima,

$$\theta = \frac{2\lambda}{a} = \frac{2\times6\times10^{-7}}{2\times10^{-4}} = 6\times10^{-3}\ \text{rad}$$

(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.

9. (i) (c) : The optical path difference at P is

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

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

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

(ii) (b): For n^{th} maxima,

$\Rightarrow \quad \Delta x = n\lambda$

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

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

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

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

$\Delta x = d = n\lambda$

$$\Rightarrow \quad n=\frac{d}{\lambda}=\frac{0.5}{0.5\times10^{-3}}=1000$$

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.

10. (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 $I\propto A^2 \quad \therefore I\propto A^2\propto\cos^2\frac{\delta}{2} \Rightarrow I\propto\cos^2\frac{\delta}{2}$

11. (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 $\phi = 60°$

The resultant amplitude at a point is

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

$$=\sqrt{(3A)^2+(2A)^2+2\times3A\times2A\times\cos60^\circ}$$

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

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

Therefore, intensity at the same point is

$I \propto 19A^2$

12. (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 $\phi_f = \phi_e$

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

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

(iv) (a)

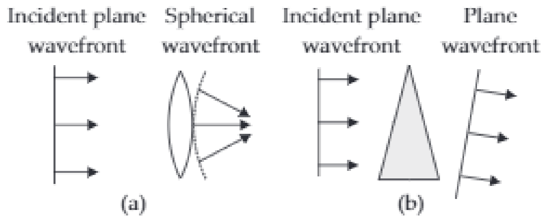
(v) (d)

13. (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).

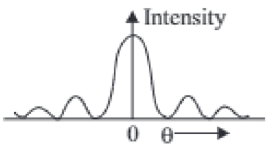


(v) (c)

14. (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 $= \dfrac{a}{1.22\lambda}$

$\therefore$ 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

$= 2 : 1$

15. (i) (c) : Given $I_1 = 10\ \text{W/m}^2$ and $I_2 = 25\ \text{W/m}^2$

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

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

(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, $\beta = \dfrac{\lambda D}{d}$ for $d = 2d$,

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

$\therefore\ D_1 = 2D$

(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, $\sin\theta = 1 \quad \therefore\ n = 2$

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

Hence the maximum number of possible maxima is 5.

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

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

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