CHAPTER

10

Wave Optics

A Quick Recapitulation of the Chapter

1. The locus of all those particles which are vibrating in the same phase at any instant is called **wavefront.** Thus, wavefront is a surface having same phase of vibrating particles at any instant at every point on it.

   For point source, shape of wavefront is spherical.

2. **Phase speed** is the speed with which wavefront moves and it is equal to wave speed.

   Each point on any waefront acts as independent source which emits spherical wave.

3. **Huygens' principle** is essentially a geometrical construction which gives the shape of the wavefront at any time, allows us to determine the shape of the wavefront at a later time.

4. The laws of reflection and refraction can be verified using Huygens' principle.

5. Wavelength is inversely proportional to refractive index (μ) of the medium

   i.e., $\lambda' = \dfrac{\lambda}{\mu}$

6. **Coherent sources** of light are the sources which emit light waves of same frequency, same wavelength and have a constant initial phase difference.

7. Two such sources of light, which do not emit light waves with a constant phase difference are called **incoherent sources**.

8. The phenomenon of redistribution of energy in the region of superposition of waves is called **interference.** The points of maximum intensity in the regions of superposition of waves are said to be in constructive interference whereas the points of minimum intensity are said to be in **destructive interference.**

9. **Conditions for Constructive Interference** If initial phase difference is zero, then the interference waves must have

   (i) phase difference $= 2n\pi$, where, $n = 0, 1, 2, 3, \ldots$

   (ii) path difference $= n\lambda$, where, $n = 0, 1, 2, 3, \ldots$

10. **Conditions for Destructive Interference**

    Assuming initial phase difference = 0

    Necessary conditions for interference of waves

    (i) phase difference $= (2n - 1)\pi$, where, $n = 1, 2, 3, \ldots$

    (ii) path difference $= (2n - 1)\dfrac{\lambda}{2}$, where, $n = 1, 2, 3, \ldots$

11. Two waves of amplitudes a_1 and a_2 interfere at a point where phase difference is ϕ, then resultant amplitude is given by

    $$A^2 = a_1^2 + a_2^2 + 2a_1a_2 \cos\phi$$

    For constructive interference, $A_{max} = (a_1 + a_2)^2$

    For destructive interference, $A_{min} = (a_1 - a_2)^2$

    Also, resultant intensity, $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\phi$

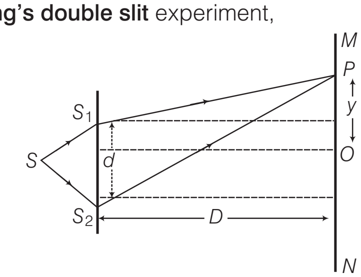
12. When $I_1 = I_2 = I_0$

    Then, resultant intensity,

    $$I = I_0 + I_0 + 2I_0\cos\phi = 2I_0(1 + \cos\phi)$$

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

13. In **Young's double slit** experiment,



    For point P, $\Delta x = d\sin\theta = d\tan\theta = dy/D$

    (i) **Fringe width** of bright and dark fringe, $\beta = \dfrac{D\lambda}{d}$

    where, λ = wavelength of wave

    D = distance between slit and screen

and $\quad d$ = distance between two slits

Angular fringe width, $\theta = \frac{\beta}{D} = \frac{\lambda}{d}$

(ii) Separation of nth order bright fringe from central fringe

$$y_n = \frac{Dn\lambda}{d}, n = 1, 2, 3, \ldots$$

(iii) Separation of nth order dark fringe from central fringe

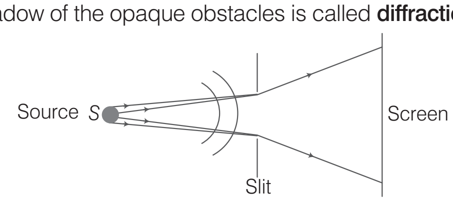
$$y_n = (2n - 1)\frac{D\lambda}{2d}, n = 1, 2, 3, \ldots$$

(iv) Angular position of nth order

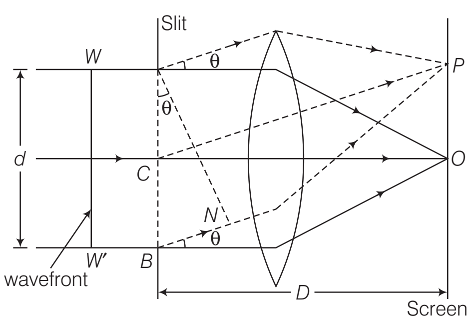
(a) Bright fringe $= \frac{y_n}{D} = \frac{n\lambda}{d}$

(b) Dark fringe $= \frac{y_n}{D} = (2n - 1)\frac{\lambda}{d}$, where $n = 1, 2, 3, \ldots$

14. 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**.



15. **Diffraction due to a Single Slit of Width (d)** A parallel beam of light with a plane wavefront WW' is made to fall on a single slit AB. Width of the slit is of the order of wavelength of light, therefore, diffraction occurs on passing through the slit. As shown in the diagram given below.



(i) **nth order secondary minima** is obtained when

$$d \sin \theta = n\lambda, \quad \text{where, } n = 1, 2, 3, \ldots$$

(ii) **nth order secondary maxima** is obtained when

$$d \sin \theta = (2n + 1)\frac{\lambda}{2}, \quad \text{where, } n = 0, 1, 2, 3, \ldots$$

(iii) **Angular separation** for nth minima,

$$\theta_n = \frac{n\lambda}{d}, \quad \text{where, } n = 1, 2, 3, \ldots$$

(iv) **Linear separation** of nth secondary minima,

$$y_n = \frac{Dn\lambda}{d}$$

(v) **Angular position** of nth order secondary maxima,

$$\theta_n = (2n + 1)\frac{\lambda}{2d}$$

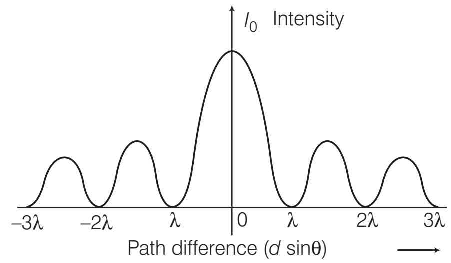
(vi) **Angular width** of central maxima $= 2\lambda/d$

(vii) **Linear width** of central maxima $= 2D\lambda/d$

(viii) **Angular width** of secondary maxima or minima $= \frac{\lambda}{d}$

(ix) **Linear width** of secondary maxima or minima $= \frac{D\lambda}{d}$

(x) **Intensity of central maxima** is maximum and intensity of secondary maxima decreases with the increase of their order. The diffraction pattern is graphically as shown below.



16. **Resolving Power of Optical Instruments** Resolving power of an optical instrument is the ability of the instrument to produce distinctly separate images of two close objects.

(i) Resolving power of a telescope $= \frac{1}{d\theta} = \frac{D}{1.22\lambda}$

(ii) Resolving power of microscope $= \frac{1}{\Delta d} = \frac{2\mu \sin\beta}{1.22\lambda}$

17. **Fresnel's Distance** The distance at which diffraction spread equal to the size of aperture, $Z_F = \frac{d^2}{\lambda}$.

The ray optics is applicable, when $Z < Z_F$.

18. The phenomenon of restricting the vibrations of light in a particular direction, perpendicular to the direction of wave motion is called **polarisation of light**.

19. **Malus' Law** According to law of Malus'

i.e. $\quad I \propto \cos^2\theta \Rightarrow I = I_0 \cos^2\theta$

This rule is also called cosine squared rule.

where, I_0 = intensity of plane polarised light

I = intensity of transmitted light from the analyser and

θ = angle between axis of the polariser and the analyser.

20. The angle of incidence at which the reflected light is completely plane polarised is called **polarising angle** or **Brewster's angle** (i_B).

21. **Brewster's Law** According to this law, when unpolarised light is incident at polarising angle, i_B on an interface separation air from a medium of refractive index μ, then the reflected light is plane polarised (perpendicular to the plane of incidence), provided,

$$\mu = \tan i_B$$

where, i_B = Brewster's angle and μ = refractive index of denser medium.

At polarising angle, $i_B + r = 90°$,

i.e. reflected plane polarised light is at right angle from refracted light.

Objective Questions Based on NCERT Text

Topic 1
Huygens' Principle

1. In geometrical optics, a ray of light is defined as
(a) path of propagation of light
(b) path of propagation of shadows
(c) direction of formation of image
(d) path of propagation of energy for $\lambda \to 0$

2. For a ray of light, which of the following statement holds true?
(a) A ray is defined as the path of energy propagation
(b) The wavelength for a ray of light in geometrical optics is assumed to be negligible, standing to zero
(c) A ray of light travels in a straight line
(d) All of the above

3. Which of the given phenomenon is based on the fact that light waves are transverse electromagnetic waves?
(a) Diffraction (b) Interference
(c) Polarisation (d) All of these

4. Huygens' principle of secondary wavelets may be used to
(a) find the velocity of light in vacuum
(b) explain the particle's behaviour of light
(c) find the new position of a wavefront
(d) explain photoelectric effect

5. Which one of the following phenomena is not explained by Huygens' construction of wavefront?
(a) Refraction (b) Reflection
(c) Diffraction (d) Origin of spectra

6. The direction of wavefront of a wave with the wave motion is
(a) parallel (b) perpendicular
(c) opposite (d) at an angle of θ

7. Ray diverging from a point source on a wavefront are
(a) cylindrical (b) spherical (c) plane (d) cubical

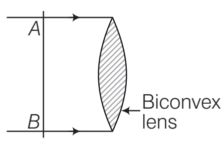
8. If a source is at infinity, then wavefronts reaching to observer are
(a) cylindrical (b) spherical (c) plane (d) conical

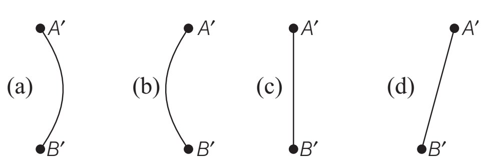
9. In Huygens' wave theory, the locus of all points in the same state of vibration is called
(a) a half period zone (b) oscillator
(c) a wavefronts (d) a ray

10. According to Huygens' principle, each point of the wavefront is the source of
(a) secondary disturbance (b) primary disturbance
(c) third disturbance (d) fourth disturbance

Topic 2
Refraction and Reflection of Plane

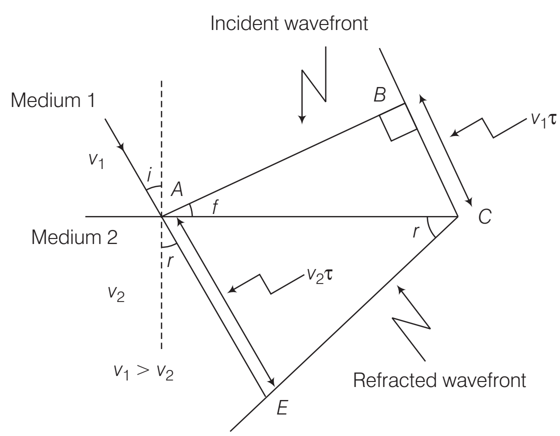
11. If AB is incident wavefront. Then, refracted wavefront is





12. When light is refracted into a denser medium
(a) its wavelength and frequency both increases
(b) its wavelength increases but frequency remains unchanged
(c) its wavelength decreases but frequency remains the same
(d) its wavelength and frequency both decreases

13. In given figure, light passes from denser medium 1 to rare medium 2.



When $i > i_c$ (critical angle of incidence). Then, wavefronts EC is

(a) formed further deep in medium 2
(b) formed closer to surface line AC
(c) formed perpendicular to AC
(d) formed in medium 1 (on same side of AB)

14. If a source of light is moving away from a stationary observer, then the frequency of light wave appears to change because of

(a) Doppler's effect (b) interference
(c) diffraction (d) None of these

15. In the context of Doppler effect in light, the term red shift signifies

(a) decrease in frequency (b) increase in frequency
(c) decrease in intensity (d) increase in intensity

16. If source and observer are moving towards each other with a velocity, v_{radial} and c indicates velocity of light, then fractional change in frequency of light due to Doppler's effect will be

(a) $\dfrac{\Delta\nu}{\nu} = \dfrac{v_{\text{radial}}}{c}$ (b) $\dfrac{\Delta\nu}{\nu} = \dfrac{-v_{\text{radial}}}{c}$
(c) $\dfrac{\Delta\nu}{\nu} = \dfrac{c}{v_{\text{radial}}}$ (d) $\dfrac{\Delta\nu}{\nu} = \dfrac{-c}{v_{\text{radial}}}$

17. The refractive index of glass is 1.5. The speed of light in glass is

(a) 3×10^8 ms^{-1} (b) 2×10^8 ms^{-1}
(c) 1×10^8 ms^{-1} (d) 4×10^8 ms^{-1}

18. Which of the colours of light travels fastest in prism made up of glass?

(a) Red
(b) Violet
(c) Blue
(d) Speed of light in glass is independent of the colour of light

19. A planet moves with respect to us so that light of 475 nm is observed at 475.6 nm. The speed of the planet is

(a) 206 kms^{-1} (b) 378 kms^{-1}
(c) 108 kms^{-1} (d) 100 kms^{-1}

20. The earth is moving towards a fixed star with a velocity of 50 kms^{-1}. An observer on the earth observes a shift of 0.50Å in the wavelength of light coming from the star. The actual wavelength of light emitted by the star is

(a) 3000 Å (b) 2400 Å (c) 6000 Å (d) 5800 Å

21. The wavelength of spectral line coming from a distant star shift from 400 nm to 400.1 nm. The velocity of the star relative to earth is

(a) 75 kms^{-1} (b) 100 kms^{-1} (c) 50 kms^{-1} (d) 200 kms^{-1}

22. The source of light is moving towards observer with relative velocity of 3 kms^{-1}. The fractional change in frequency of light observed is

(a) 3×10^{-3} (b) 3×10^{-5}
(c) 10^{-5} (d) None of these

Topic 3
Coherent and Incoherent Addition of Waves

23. Suppose displacement produced at some point P by a wave is $y_1 = a\cos\omega t$ and by another wave is $y_2 = a\cos\omega t$. Let I_0 represents intensity produced by each one of individual wave, then resultant intensity due to overlapping of both waves is

(a) I_0 (b) $2I_0$ (c) $\dfrac{I_0}{2}$ (d) $4I_0$

24. Interference can be observed in

(a) only longitudinal waves
(b) only transverse waves
(c) only electromagnetic waves
(d) All of the above

25. Two light waves interfere constructively at a point P. The total phase difference between the two waves at P may be

(a) 0 (b) 2π (c) 4π (d) All of these

26. Two waves interfere at point P having path difference 1.5λ between them. The interference is

(a) constructive
(b) destructive
(c) no interference pattern
(d) None of the above

27. Two coherent point sources S_1 and S_2 vibrating in phase emit light of wavelength λ. The separation between the sources is 2λ. The smallest distance from S_2 on a line passing through S_2 and perpendicular to S_1S_2, where minimum of intensity occurs, is

(a) $\dfrac{7\lambda}{12}$ (b) $\dfrac{15\lambda}{4}$
(c) $\dfrac{\lambda}{2}$ (d) $\dfrac{3\lambda}{2}$

28. Two identical coherent sources placed on a diameter of a circle of radius R at separation $x\,(<<R)$ symmetrically about the centre of the circle. The sources of points on the circle with maximum intensity is $(x=5\lambda)$.
(a) 20 (b) 22 (c) 24 (d) 26

29. Two sources S_1 and S_2 emitting light of wavelength 600 nm are placed at a distance 1.0×10^{-2} cm apart. A detector can be moved on the line S_1P which is perpendicular to S_1S_2. The position of the farthest minimum detected is approximately
(a) 1.5 m (b) 1.0 m
(c) 1.07 m (d) 1.03 m

30. The phase difference between the two light waves reaching at a point P is 100π. Their path difference is equal to
(a) 10λ (b) 25λ (c) 50λ (d) 100λ

31. In the phenomenon of interference, energy is
(a) destroyed at destructive interference
(b) created at constructive interference
(c) conserved but it is redistributed
(d) same at all points

32. Two distinct light bulbs as sources
(a) can produce an interference pattern
(b) cannot produce a sustained interference pattern
(c) can produce an interference pattern, if they produce light of same frequency
(d) can produce an interference pattern only when the light produced by them is monochromatic in nature

33. Two light waves superimposing at the mid-point of the screen are coming from coherent sources of light with phase difference π rad. Their amplitudes are 2 cm each. The resultant amplitude at the given point will be
(a) 8 cm (b) 2 cm (c) 4 cm (d) zero

34. If two waves of equal intensities $I_1=I_2=I_0$, meets at two locations P and Q with path difference Δ_1 and Δ_2 respectively, then the ratio of resultant intensity at points P and Q, $\left(\frac{I_P}{I_Q}\right)$ will be
(a) $\dfrac{\cos^2\left(\frac{\Delta_1}{\lambda}\right)}{\cos^2\left(\frac{\Delta_2}{\lambda}\right)}$ (b) $\dfrac{\cos^2\Delta_1}{\cos^2\Delta_2}$
(c) $\dfrac{\cos^2\left(\frac{\pi\Delta_1}{\lambda}\right)}{\cos^2\left(\frac{\pi\Delta_2}{\lambda}\right)}$ (d) $\dfrac{\Delta_1}{\Delta_2}$

35. The ratio of maximum and minimum intensities of two sources is 4 : 1. The ratio of their amplitudes is
(a) 1 : 81 (b) 3 : 1
(c) 1 : 9 (d) 1 : 16

36. When two coherent monochromatic beams of intensity I and $9I$ interference, the possible maximum and minimum intensities of the resulting beam are
(a) $9I$ and I (b) $9I$ and $4I$
(c) $16I$ and $4I$ (d) $16\,I$ and I

37. Two slits in Young's double slit experiments have width in ratio 1 : 25. The ratio of intensity at the maxima and minima in the interference pattern $\frac{I_{\max}}{I_{\min}}$ is **[CBSE AIPMT 2015]**
(a) $\frac{9}{4}$ (b) $\frac{121}{49}$
(c) $\frac{49}{121}$ (d) $\frac{4}{9}$

38. Two coherent light sources of intensity ratio n are employed in an interference experiment. The ratio of the intensities of maxima and minima is
(a) $\left(\frac{n+1}{n-1}\right)$ (b) $\left(\frac{n+1}{n-1}\right)^2$
(c) $\left(\frac{\sqrt{n}+1}{\sqrt{n}-1}\right)$ (d) $\left(\frac{\sqrt{n}+1}{\sqrt{n}-1}\right)^2$

39. Light from two coherent sources of the same amplitude A and wavelength λ interference. The maximum intensity recorded is I_0. If the sources were incoherent, the intensity at the same point will be
(a) $4I_0$ (b) $2I_0$ (c) I_0 (d) $I_0/2$

40. If two incoherent sources each of intensity I_0 produce wave which overlaps at some common point, then resultant intensity obtained is
(a) $4I_0$
(b) $2I_0$
(c) $\frac{I_0}{2}$
(d) dependent on phase difference

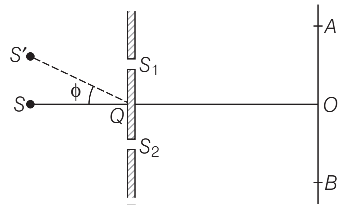
41. Two identical and independent sodium lamps act as
(a) coherent sources (b) incoherent sources
(c) Either (a) and (b) (d) None of these

42. In an experiment with two coherent sources, the amplitude of the intensity variation is found to be 5% of the average intensity. The relative intensities of the light waves of interferring sources will be
(a) 1600:1 (b) 900:1
(c) 40:1 (d) 400:1

Topic 4

Interference of Light Waves, Young's Double Slit Experiment

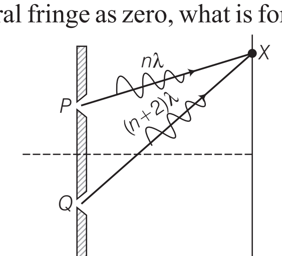
43. In Young's double slit experiment, if source S is shifted by an angle ϕ as shown in figure. Then, central-bright fringe will be shifted by angle ϕ towards



(a) end A of screen
(b) end B of screen
(c) does not shift at all
(d) Either end A and B depending on extra phase difference caused by shifting of source

44. White light may be considered to be mixture of wave with wavelength ranging between 3000 Å and 7800 Å. An oil film of thickness 10000 Å is examined normally by the reflected light. If $\mu = 1.4$, then the film appears bright for
(a) 4308 Å, 5091 Å, 6222 Å
(b) 4000 Å, 5091 Å, 5600 Å
(c) 4667 Å, 6222 Å, 7000 Å
(d) 4000 Å, 4667 Å, 5600 Å, 7000 Å

45. The figure shows a Young's double-slit experiment where, P and Q are the slits. The path lengths PX and QX are $n\lambda$ and $(n+2)\lambda$ respectively, where n is a whole number and λ is the wavelength. Taking, path difference at the central fringe as zero, what is formed at X?

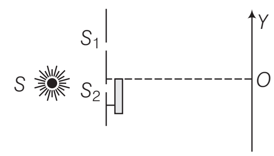


(a) First bright (b) First dark
(c) Second bright (d) Second dark

46. In Young's double slit experiment, a glass plate is placed before a slit which absorbs half the intensity of light. Under this case
(a) the brightness of fringes decreases
(b) the fringe width decreases
(c) no fringes will be observed
(d) the bright fringes become fainter and the dark fringes have finite light intensity

47. In Young's double slit experiment, intensity at a point is $\left(\frac{1}{4}\right)$th of the maximum intensity. Angular position of this point is
(a) $\sin^{-1}(\lambda/d)$ (b) $\sin^{-1}(\lambda/2d)$
(c) $\sin^{-1}(\lambda/3d)$ (d) $\sin^{-1}(\lambda/4d)$

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



The location of the central bright fringes on the Y-axis is
(a) 4.0 mm (b) 4.33 mm
(c) 5 mm (d) 4.5 mm

49. With reference of the above question, if 600 nm light is replaced by white light of range 400 nm to 700 nm, the wavelength of the light that form maxima exactly at point O are
(a) 650 nm and 400 nm (b) 650 nm and 433.33 nm
(c) 400 nm and 667 nm (d) 650 nm and 667 nm

50. A parallel beam of sodium light of wavelength 6000 Å is incident on a thin glass plate of refractive index 1.5 such that the angle of refraction in the plate is 60°. The smallest thickness of the plate which will make it dark by reflection.
(a) 4000 Å (b) 4200 Å
(c) 1390 Å (d) 2220 Å

51. In Young's double slit experiment two disturbance arriving at a point P have phase difference of $\pi/2$. The intensity of this point expressed as a fraction of maximum intensity I_0 is
(a) $\frac{3}{2}I_0$ (b) $\frac{1}{2}I_0$ (c) $\frac{4}{3}I_0$ (d) $\frac{3}{4}I_0$

52. Two monochromatic light wave of same amplitudes of $2A$ interferring at a point have a phase difference of 60°. The intensity at that point will be proportional to
(a) $5A^2$ (b) $12A^2$ (c) $7A^2$ (d) $19A^2$

53. The shape of the fringe obtained on the screen in case of Young's double slit experiment is
(a) a straight line (b) a parabola
(c) a hyperbola (d) a circle

54. In Young's double slit experiment, distance between slits in kept 1 mm and a screen is kept 1 m apart from slits. If wavelength of light used is 500 nm, then fringe spacing is
(a) 0.5 mm (b) 0.5 cm
(c) 0.25 mm (d) 0.25 cm

55. If the 8th bright band due to light of wavelength λ_1 coincides with 9th bright band from light of wavelength λ_2 in Young's double slit experiment, then the possible wavelengths of visible light are
(a) 400 nm and 450 nm (b) 425 nm and 400 nm
(c) 400 nm and 425 nm (d) 450 nm and 400 nm

56. The Young's double slit experiment is performed with light of wavelength 6000 Å, where in 16 fringes occupy a certain region on the screen. If 24 fringes occupy the same region with another light, of wavelength λ, then λ is
(a) 6000 Å (b) 4500 Å (c) 5000 Å (d) 4000 Å

57. The maximum intensity of fringes in Young's double slit experiment is I. If one of the slit is closed, then the intensity at that place becomes I_0. Which of the following relations is correct?
(a) $I = I_0$
(b) $I = 2I_0$
(c) $I = 4I_0$
(d) There is no relation between I and I_0

58. Young's double slit experiment is performed with sodium (Yellow) light of wavelength 589.3 nm and the interference pattern is observed on a screen 100 cm away. The 10th bright fringe has its centre at a distance of 12 nm from the central maximum. The separation between the slits is
(a) 0.49 mm (b) 0.6 mm
(c) 0.7 mm (d) 0.53 mm

59. If Young's double slit experiment, is performed in water, the fringe width recorded is ω_2. If it is performed in air, the fringe width recorded is ω_1. Then, ω_1/ω_2 is ($\mu_{water} = 4/3$)
(a) 3/2 (b) 3/4
(c) 4/3 (d) Data insufficient

60. In a Young's double slit experiment, the slit separation is 1mm and the screen is 1m from the slit. For a monochromatic light of wavelength 500 nm, the distance of 3rd minima from the central maxima is
(a) 0.50 mm (b) 1.25 mm
(c) 1.50 mm (d) 1.75 mm

61. In Young's double slit experiment the two slits are d distance apart. Interference pattern is observed on a screen at a distance D from the slits. A dark fringe is observed on the screen directly opposite to one of the slit. The wavelength of light is
(a) $\frac{D^2}{2d}$ (b) $\frac{d^2}{2D}$ (c) $\frac{D^2}{d}$ (d) $\frac{d^2}{D}$

62. The Young's double slit experiment is performed with blue and with green light of wavelengths 4360 Å and 5460 Å, respectively. If x is the distance of 4th maximum from the central one, then
(a) $x(\text{blue}) = x(\text{green})$ (b) $x(\text{blue}) > x(\text{green})$
(c) $x(\text{blue}) < x(\text{green})$ (d) $\frac{x(\text{blue})}{x(\text{green})} = \frac{5460}{4360}$

63. In a Young's double slit experiment, two coherent sources are placed 0.90 nm apart and the fringes are observed 1 m away. If it produces the second dark fringe at a distance of 1mm from the central fringe, the wavelength of monochromatic light used would be
(a) 60×10^{-4} cm (b) 10×10^{-4} cm
(c) 10×10^{-5} cm (d) 6×10^{-5} cm

64. In Young's double slit experiment, the slits are 2 mm apart and are illuminated by photons of two wavelengths $\lambda_1 = 12000$ Å and $\lambda_2 = 10000$ Å. At what minimum distance from the common central bright fringe on the screen 2 m from the slit will a bright fringe from one interference pattern coincide with a bright fringe from the other? **[NEET 2013]**
(a) 8 mm (b) 6 mm (c) 4 mm (d) 3 mm

65. In a two slit experiment with monochromatic light fringes are obtained on a screen placed at some distance from the slits. If the screen is moved by 5×10^{-2} m towards the slits, the change in fringe width is 3×10^{-5} m. If separation between the slits is 10^{-3} m, the wavelength light used is
(a) 6000Å (b) 5000Å (c) 3000Å (d) 4500Å

66. In Young's double slit experiment, the distance between two slits is 0.1mm and these are illuminated with light of wavelength 5460Å. The angular positions of first dark fringe on the screen distant 20 cm from slits will be
(a) 0.8° (b) 0.6° (c) 0.4° (d) 0.16°

67. In Young's double slit experiment the fringe width is 1×10^{-4} m. If the distance between the slit and screen is double and distance between the two slit is reduced to half and wavelength is changed from 6.4×10^{-7} m to 4.0×10^{-7} m, the value of new fringe width will be
(a) 0.15×10^{-4} m (b) 2.0×10^{-4} m
(c) 1.25×10^{-4} m (d) 2.5×10^{-4} m

68. Two beams of light having intensities I and $4I$ interfere to produce a fringe pattern on a screen in Young's double slit experiment. The phase difference between the beams is $\pi/2$ at point A and π at point B. Then, the difference between the resultant intensities at A and B is

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

69. In Young's double slit experiment, let S_1 and S_2 be the two slits and C be the centre of the screen. If the $\angle S_1CS_2 = \theta$ and λ is the wavelength, then fringe width will be

(a) $\frac{\lambda}{\theta}$ (b) $\lambda\theta$ (c) $\frac{2\lambda}{\theta}$ (d) $\frac{\lambda}{2\theta}$

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

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

71. Young's double slit experiment is made in a liquid. The 10th bright fringe in liquid lies, where 6th dark fringes lies in vacuum. The refractive index of the liquid is approximately

(a) 1.8 (b) 1.54
(c) 1.67 (d) 1.2

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

[JEE Advanced 2013]

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

73. In a Young's double slit experiment, the separation between the slits = 2.0 mm, the wavelength of the light = 600 nm and the distance of the screen from the slits = 2.0 m. If the intensity at the centre of the central maximum is 0.20 Wm^{-2}, then the intensity at a point 0.5 cm away from this centre along the width of the fringes will be

(a) 0.05 Wm^{-2} (b) 0.15 Wm^{-2}
(c) 0.20 Wm^{-2} (d) 0.10 Wm^{-2}

74. In Young's double slit experiment, the slit width and the distance of slits from the screen both are double. The fringe width

(a) increases (b) decreases
(c) remain unchanged (d) None of these

75. Two sources of light of wavelengths 1500Å and 2500Å are used in Young's double slit experiment simultaneously. Which orders of fringes of two wavelength patterns coincide?

(a) 3rd order of 1st source and 5th of 2nd
(b) 7th order of 1st and 5th order of 2nd
(c) 5th order of 1st and 3rd order of 2nd
(d) 5th order of 1st and 7th order of 2nd

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

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

77. In a Young's double slit experiment the distance between slits is increased five times where as their distance from screen in halved, then the fringe width is

(a) becomes $\frac{1}{90}$ (b) becomes $\frac{1}{20}$
(c) becomes $\frac{1}{10}$ (d) it remains same

78. The fringe width in a Young's double slit interference pattern is 3.2×10^{-4} m, when red light of wavelength 5600Å is used. How much will it change, if blue light of wavelength 4200Å is used?

(a) 8×10^{-4} m (b) 0.8×10^{-4} m
(c) 4.2×10^{-4} m (d) 0.45×10^{-4} m

79. In the Young's double-slit experiment, the intensity of light at a point on the screen (where the path difference is λ) is K, (λ being the wavelength of light used). The intensity at a point where the path difference is $\lambda/4$, will be **[CBSE AIPMT 2014]**

(a) K (b) $K/4$ (c) $K/2$ (d) zero

80. If the intensities of the two interferring beams in Young's double slit experiment be I_1 and I_2, then the contrast between the maximum and minimum intensity is good when

(a) I_1 is much greater than I_2
(b) I_2 is smaller than I_2
(c) $I_1 = I_2$
(d) Either $I_1 = 0$ or $I_2 = 0$

81. 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

82. In Young's double slit experiment, the central bright fringes can be identified

(a) as it is greater intensity than the other bright fringes
(b) as it has wider than the other bright fringes
(c) as it is narrower than the other bright fringes
(d) by using white light instead of monochromatic light

83. Yellow light is used in a single-slit diffraction experiment with slit width of 0.6 mm. If yellow light is replaced by X-rays, then the observed pattern will reveal

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

Topic 5
Diffraction

84. What should be the slit width to obtain 10 maxima of the double slit pattern within the central maxima of the single slit pattern of slit width 0.4 mm?

(a) 0.4 mm (b) 0.2 mm
(c) 0.6 mm (d) 0.8 mm

85. In a single slit diffraction of light of wavelengths λ is used and slit of width e, the size of the central maxima on a screen at a distance b is

(a) $2b\lambda + e$ (b) $\frac{2b\lambda}{e}$
(c) $\frac{2b\lambda}{e} + e$ (d) $\frac{2b\lambda}{e} - e$

86. A parallel beam of light of wavelength 6000 Å gets diffracted by a single-slit width 0.3 mm. The angular position of the first minima of diffracted light is

(a) 6×10^{-3} rad (b) 1.8×10^{-3} rad
(c) 3.2×10^{-3} rad (d) 2×10^{-3} rad

87. Yellow light from atomic sodium with a wavelength of 589 nm illuminates a single-slit. The dark fringes in the diffraction pattern are found to be seperated on either side of central bright by 2.2 mm, on a screen 1.0 m from the slit. The slit width is

(a) 0.7 mm (b) 0.54 mm
(c) 1.0 mm (d) 0.24 mm

88. In a single-slit diffraction pattern observed on a screen placed at D m distance from the slit of width d m, the ratio of the width of the central maximum to the width of other secondary maximum is

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

89. Consider diffraction pattern obtained with a single slit at normal incidence. At the angular position of the first order diffraction maximum, the phase difference between the wavelets from the opposite edges of the slit is

(a) $\frac{\pi}{4}$ (b) $\frac{\pi}{2}$ (c) 3π (d) 2π

90. In a diffraction pattern due to a single slit of width a, the first minimum is observed at an angle 30° when light of wavelength 5000 Å is incident of the slit. The first secondary maximum is observed at an angle of **[NEET 2016]**

(a) $\sin^{-1}\left(\frac{2}{3}\right)$ (b) $\sin^{-1}\left(\frac{1}{2}\right)$ (c) $\sin^{-1}\left(\frac{3}{4}\right)$ (d) $\sin^{-1}\left(\frac{1}{4}\right)$

91. A parallel beam of fast moving electrons is incident normally on a narrow slit. A fluorescent screen is placed at a large distance from the slit. If the speed of the electrons is increased, then which of the following statements is correct? **[NEET 2013]**

(a) Diffraction pattern is not observed on the screen in the case of electrons
(b) The angular width of the central maximum of the diffraction pattern will increases
(c) The angular width of the central maximum will decreases
(d) The angular width of the central maximum will be unaffected

92. A single-slit diffraction pattern is formed with white light. For what wavelength of light the third secondary maximum in the diffraction pattern coincides with the second secondary maximum in the pattern for red light of wavelength 6500 Å.

(a) 4400 Å (b) 4100Å (c) 4642.8 Å (d) 9100 Å

93. A single-slit of width d is illuminated by violet light of wavelength 400 nm and the width of the central maxima is measured as y. When half of the slit width is covered and illuminated by yellow light of wavelength 600 nm, the width of the central diffraction pattern is

(a) the pattern vanishes and the width is zero
(b) $y/3$
(c) $3y$
(d) None of the above

94. A beam of light of wavelength 600 nm from a distant source falls on a single-slit 1mm wider and the resulting diffraction pattern is observed on a screen 2m away.

The distance between the first dark fringes on either side of the central bright fringes is
(a) 1.2 cm (b) 1.2 mm (c) 2.4 cm (d) 2.4 mm

95. If we observe the single-slit diffraction with wavelength λ and slit width e, the width of the central maximum is 2θ. On decreasing the slit width for the same λ, then
(a) θ increases
(b) θ remains unchanged
(c) θ decreases
(d) θ increases or decreases depending on the intensity of light

96. In diffraction from a single slit the angular width of the central maxima does not depend on
(a) λ of light used
(b) width of slit
(c) distance of slits from the screen
(d) ratio of λ and slit width

97. A parallel beam of light of wavelength 4000 Å gets diffraction by a single slit of width 0.2 mm. The angular position of the first minima of diffracted light is
(a) 2×10^{-3} rad (b) 3×10^{-3} rad
(c) 1.8×10^{-3} rad (d) 6×10^{-3} rad

98. A beam of light of $\lambda = 600$ nm from a distant source falls on a single slit 1 mm wide and the resulting diffraction pattern is observed on a screen 2 m away. The distance between first dark fringes on either side of the central bright fringe is **[CBSE AIPMT 2014]**
(a) 1.2 cm (b) 1.2 mm (c) 2.4 cm (d) 2.4 mm

99. In a Young's double slit experiment the angular width of a fringe is found to be 0.2° on a screen placed 1 m away. The wavelength of light used is 600 nm. If the entire experimental apparatus is immersed in water (Refractive index of water is 4/3), then angular width of the fringe will be
(a) 0.25° (b) 0.15° (c) 0.75° (d) 1°

100. In a Young's double slit experiment, the screen is placed at a distance of 1.25m from the slits. When the apparatus is immersed in water ($\mu\omega = 4/3$), the angular width of a fringe is found to be 0.2°.
When the experiment is performed in air with same set up, the angular width of the fringe is
(a) 0.4° (b) 0.28° (c) 0.35° (d) 0.15°

101. The angular resolution of the telescope is determined by the
(a) image produced by the telescope
(b) objective of the telescope
(c) Both (a) and (b)
(d) Neither (a) nor (b)

102. In telescope, the radius of the central bright region (r_0) is
(a) $\frac{0.61\lambda f}{a}$ (b) $\frac{0.75\lambda f}{a}$ (c) $\frac{1.94\lambda f}{a}$ (d) $\frac{2.43\lambda f}{a}$

103. For better resolution, a telescope must have a
(a) large diameter objective
(b) small diameter objective
(c) may be large
(d) Neither large nor small

104. The diameter of objective lens of a telescope is 6 cm and wavelength of light used is 540 nm. The resolving power of telescope is
(a) $9.1\times10^4\ \text{rad}^{-1}$ (b) $10^5\ \text{rad}^{-1}$
(c) $3\times10^4\ \text{rad}^{-1}$ (d) None of these

105. A telescope is used to resolve two stars separated by 3.2×10^{-6} rad. If the wavelength of light used in 5600Å, what should be the aperture of the objective of the telescope?
(a) 0.2135 m (b) 0.1488 m
(c) 0.567 m (d) 1 m

106. What will be the ratio (D/f) in microscope, where D is the diameter of the aperture and f is the focal length of the objective lens?
(a) $\tan\beta$ (b) $\tan\frac{\beta}{2}$ (c) $2\tan\beta$ (d) $\tan\frac{\beta}{6}$

107. If the medium between the object and the objective lens of a microscope is not air but refractive index n, then minimum separation gets modified to
(a) $\frac{1.44\lambda}{2n\sin\beta}$ (b) $\frac{1.22\lambda}{2n\sin\beta}$ (c) $\frac{3.2\lambda}{2n\sin\beta}$ (d) $\frac{1.49\lambda}{n\sin\beta}$

108. The resolving power of a compound microscope increases when
(a) refractive index of the medium is increased keeping wavelength of light (λ) constant (or same)
(b) for the same medium, wavelength of light is decreased
(c) refractive index of the medium and wavelength of light used both are decreased
(d) Both (a) and (b)

109. In a Fresnel biprism experiment, the two positions of lens give separation between the slits as 25 cm and 16 cm respectively. The actual distance of separation is
(a) 20 cm (b) 16 cm
(c) 18 cm (d) 20.5 cm

110. For what distance is ray optics a good approximately when the aperture is 3mm wide and wavelength is 500 nm?
(a) 18 m (b) 25 m
(c) 30 m (d) 35 m

Topic 6
Polarisation

111. When the displacement of the wave is at right angles to the direction of its propagation, it is known as
(a) transverse wave (b) longitudinal wave
(c) Either (a) or (b) (d) Both (b) and (c)

112. Light waves are
(a) longitudinal waves (b) electromagnetic waves
(c) transverse wave (d) Both (b) and (c)

113. Which of the following can be used to control the intensity, in sunglasses, window pares etc?
(a) Transverse wave (b) Polaroids
(c) Plane polarised wave (d) Polarised wave

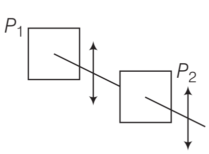
114. The phenomenon of polarisation of light indicates that
(a) light is a longitudinal wave
(b) light is a transverse electromagnetic wave
(c) light is a transverse wave only
(d) Either (b) or (c)

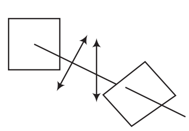
115. Which of the following cannot be polarised?
(a) Ultraviolet (b) Ultrasonic waves
(c) X-rays (d) Radio waves

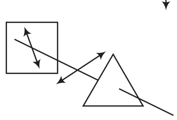
116. Which of the following is a dichronic crystal?
(a) Quartz (b) Tourmaline
(c) Mica (d) Selenite

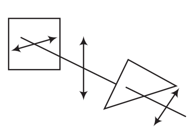
117. In the propagation of light waves, the angle between the direction of vibration and plane of polarisation is
(a) 0° (b) 90°
(c) 45° (d) 80°

118. When light passes through two polaroids P_1 and P_2, then transmitted polarisation is the component parallel to the polaroid axis. Which of the following is correct?

(a)


(b)


(c)


(d)


119. At which angle the intensity of transmitted light is maximum when a polaroid sheet is rotated between two crossed polaroids?
(a) $\pi/4$ (b) $\pi/2$ (c) $\pi/3$ (d) π

120. Unpolarised light is incident on a plane glasses surface. What should be the angle of incidence so that the reflected and refracted rays are perpendicular to each other? [μ for glass $=1.5$]
(a) 60° (b) 90° (c) 0° (d) 57°

121. An unpolarised beam of light of intensity I_0 falls on a polariod. The intensity of the emergent beam is
(a) $\frac{I_0}{2}$ (b) I_0 (c) $\frac{I_0}{4}$ (d) zero

122. For good polariser in case of unpolarised light, we will observe
(a) reflection and no transmission of light
(b) no reflection and total transmission of light
(c) diffraction
(d) total internal reflection of light

123. When both the components of electric field of light waves are present such that one is stronger than the other and such light is viewed through a rotating analyser, one sees a maximum and a minimum of intensity but not complete darkness. This kind of light is called
(a) polarised (b) linearly polarised
(c) partially polarised (d) None of these

124. An unpolarised beam intensity I_0 is incident on a pair of nicols making an angle of 60° with each other. The intensity of light emerging the pair is
(a) I_0 (b) $I_0/2$
(c) $I_0/4$ (d) $I_0/8$

125. A beam of unpolarised light of intensity I_0 is passed through a polaroid A and then through another polaroid B which is oriented so that its principal plane makes an angle of 45° relative to that of A. The intensity of the emergent light is **[JEE Main 2013]**
(a) I_0 (b) $I_0/2$
(c) $I_0/4$ (d) $I_0/8$

126. A beam of ordinary unpolarised light passes through a tourmaline crystal C_1 and then its passes through another tourmaline crystal C_2, which is oriented such that its principle plane is parallel to that of C_2. The intensity of emergent light is I_0.
Now, C_2 is rotated by 60° about the ray. The emergent ray have an intensity.
(a) $2I_0$ (b) $I_0/2$
(c) $I_0/4$ (d) $I_0/\sqrt{4}$

127. When unpolarised light beam is incident from air to glass ($\mu = 1.5$) at the polarising angle.

(a) reflected beam is polarised 100%
(b) reflected and refracted beams are partially polarised
(c) the reason for (a) is that almost all the light is reflected
(d) All of the above

128. At what angle should an unpolarised beam to incident on a crystal of $\mu = \sqrt{3}$, so that reflected beam is polarised?

(a) 45° (b) 60° (c) 90° (d) 0°

129. The critical angle of a certain medium is $\sin^{-1}\left(\frac{4}{5}\right)$. The polarising angle of medium is

(a) $\tan^{-1}\left(\frac{5}{4}\right)$ (b) $\sin^{-1}\left(\frac{4}{5}\right)$ (c) $\sin^{-1}\left(\frac{5}{4}\right)$ (d) $\tan^{-1}\left(\frac{4}{3}\right)$

130. When the angle of incidence is 45° on the surface of a glass slab, it is found that the reflected ray is completely polarised. The velocity is light in glass in

(a) $\sqrt{3}\times10^8$ ms^{-1}
(b) 3×10^8 ms^{-1}
(c) 2×10^8 ms^{-1}
(d) $\sqrt{2}\times10^8$ ms^{-1}

131. The refractive index of a medium is 1. If the unpolarised light is incident on it at the polarising angle of the medium, the angle of refraction is

(a) 60° (b) 45° (c) 30° (d) 0°

132. Find the angle of incidence at which light reflected from glass ($\mu = 1.5$) be completely polarised.

(a) 72.8° (b) 51.6° (c) 40.3° (d) 56.3°

Special Format Questions

I. Assertion and Reason

■ **Directions** (Q. Nos. 133-145) *In the following questions, a statement of assertion is followed by a corresponding statement of reason. Of the following statements, choose the correct one.*

(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

133. Assertion In the field of geometrical optics, light can in assumed to approximately travel in straight line.

Reason The wavelength of visible light is very small in comparison to the dimensions of typical mirrors and lenses, then light can be assumed to approximately travel in straight line.

134. Assertion 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 Speed of light and wavelength of light both changes in refraction and hence, the ratio $v = c/\lambda$ is a constant.

135. Assertion The emergent plane wavefront is tilted on refraction of a plane wave by a thin prism.

Reason The speed of light waves is more in glass and the base of the prism is thicker than the top.

136. Assertion If we have a point source emitting waves uniformly in all directions, the locus of point which have the same amplitude and vibrate in the same phase are spheres.

Reason Each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these points spread out in all directions with the speed of the wave.

137. Assertion Increase in the wavelength of light due to Doppler's effect is red shift.

Reason When the wavelength increases, then wavelength in the middle of the visible region of the spectrum moves towards the red end to the spectrum.

138. Assertion No interference pattern is detected when two coherent sources are infinitely close to each other.

Reason The fringe width is inversely proportional to the distance between the two slits.

139. Assertion If the initial phase difference between the light waves emerging from the slits of Young's double slit experiment is π-radian, the central fringe will be dark.

Reason Phase difference is equal to $\frac{2\pi}{\lambda}$ times the path difference.

140. Assertion In Young's double slit experiment, for two coherent sources, the resultant intensity by

$$I = 4I_0 \cos^2 \frac{\phi}{2}$$

Reason Ratio of maximum and minimum intensity

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

141. Assertion In Young's double slit experiment, the fringes become in distinct, if one of the slits is covered with cellophane paper.

Reason The cellophane paper decreases the wavelength of light.

142. Assertion In interference, the film which appear bright in reflected system will appear dark in the transmitted system and *vice-versa.*

Reason The condition for film to appear bright or dark in reflected light are just reverse to those in the transmitted light.

143. Assertion In Young's double slit experiment, the fringe width for dark fringes is same as that for white fringes.

Reason In Young's double slit experiment, when the fringes are performed with a source of white light, then only dark and bright fringes are observed.

144. Assertion In Young's doule slit experiment, the fringe width is directly proportional to wavelength of the source used.

Reason When a thin transparent sheet is placed infront of both the slits of Young's double slit experiment, the fringe width will increase.

145. Assertion To observe diffraction of light the size of obstacle aperture should be of the order of 10^{-7}m.

Reason 10^{-7}m is the order of wavelength of visible light.

II. Statement Based Questions Type I

■ **Directions** (Q. Nos. 146-154) *In the following questions, a statement I is followed by a corresponding statement II. Of the following statements, choose the correct one.*

(a) Both Statement I and Statement II are correct and Statement II is the correct explanation of statement I.
(b) Both Statement I and Statement II are correct but Statement II is not the correct explanation of Statement I.
(c) Statement I is correct but Statement II is incorrect.
(d) Statement I is incorrect but Statement II is correct.

146. Statement I Maxwell's electromagnetic theory of light proved that light is an electromagnetic wave.

Statement II Light waves propagates even in vacuum according to wave theory of light.

147. Statement I When monochromatic light is incident on a surface separating two media, the reflected light both have the same frequency as the incident frequency.

Statement II Reflection and refraction arise through interaction of incident light with the atomic constituents of matter. Atoms may be viewed as oscillators, which take up the frequency of the external agency (light) causing forced oscillations.

148. Statement I Speed of light is independent of its colour only in vacuum.

Statement II Red colour travels slower than violet in glass.

149. Statement I When light travels from a rarer to a denser medium, the speed decreases but energy of the wave remains same.

Statement II Intensity of light wave is directly proportional to the square of the amplitude of the wave.

150. Statement I Sound waves cannot be polarised.

Statement II Sound waves are longitudinal in nature.

151. Statement I The intensity at the bright band on the screen is maximum and equal to $4I_0$, where I_0 is the intensity of light from each sources.

Statement II The intensity at the dark band is always zero irrespective of the intensity of light waves coming from the two sources.

152. Statement I In Young's double slit experiment, at centre line of screen, a bright fringe is obtained.

Statement II Path difference between two waves is given by $S_2P - S_1P$ which is zero at centre line.

153. Statement I In Young's double slit experiment, the width of one of the slits is slowly increased to make it twice the width of the other slit. The intensity of both the maxima and minima increases.

Statement II Intensity of light from the slits is directly proportional to the width of the slit.

154. Statement I Diffraction determines the limitations of the concepts of light rays.

Statement II A beam of width a starts to spread out due to diffraction after it has travelled a distance $(2a^2 / \lambda)$.

Statement Based Questions Type II

155. According to Maxwell's electromagnetic theory following phenomenon can be explained.

I. propagation of light in vaccum
II. interference of light
III. polarisation of light
IV. photoelectric effect

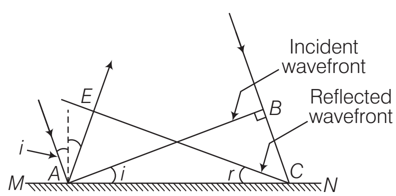
(a) I, II and III (b) I, II, IV
(c) I, III and IV (d) II, III and IV

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

I. A point source emitting waves uniformly in all directions.
II. In spherical wave, the locus of point which have the some amplitude and vibrate in same phase are spheres.
III. At a small distance from the source, a small portion of sphere can be considered as plane wave.

(a) Only I (b) Both I and II
(c) Only III (d) All of the above

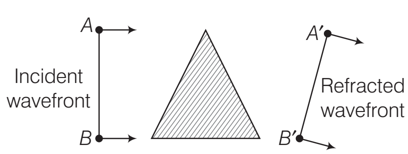
157. In case of reflection of a wavefront from a reflecting surface,



I. points A and E are in same phase
II. points A and C are in same phase
III. points B and A are in same phase
IV. points C and E are in same phase

(a) I and II (b) II and III (c) III and IV (d) I and IV

158. Figure shows behaviour of a wavefront when it passes through a prism.



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

I. Lower portion of wavefront (B') is delayed resulting in a tilt.
II. Time taken by light to reach A' from A is equal the time taken to reach B' from B.
III. Speed of wavefront is same everywhere.
IV. A particle on wavefront $A'B'$ is in phase with a particle on wavefront AB.

(a) I and II (b) II and III
(c) III and IV (d) I and III

159. Monochromatic light of wavelength 589 nm is incident from air on a water surface.

(Refractive index of water is 1.33).

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

I. Frequency of reflected light and refracted light are same.
II. Wavelength of reflected light is more than that of refracted light.
III. Speed of reflected light is equal to that of refracted light.
IV. Intensity of reflected light is always more than that of refracted light.

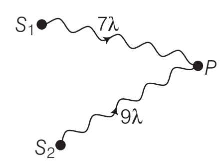
(a) I and III (b) II and IV
(c) I and II (d) III and IV

160. Shape of wavefront in case of

I. light diverging from a point source.
II. light emerging out of convex lens when a point source is placed at its focus.
III. the portion of the wavefront of light from a distant star intercepted by the earth are respectively.

(a) cylindrical, concave, plane
(b) spherical, plane, plane
(c) spherical, convex, plane
(d) spherical, cylindrical, plane

161. Let S_1 and S_2 are two sources and if wave from S_1 reaches some common point P be covering seven time of wavelength (λ) and from S_2 by covering nine times of wavelength (λ).



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

I. $S_2P - S_1P = 2\lambda$
II. Waves from S_1 arrives exactly two cycles earlier than waves from S_2.
III. At P waves from S_1 and S_2 are in phase.
IV. At P waves from S_1 and S_2 are out of phase.

(a) I, II and III (b) I, III and IV
(c) II, III and IV (d) I, II and IV

162. The conditions for producing sustained interference are

I. phase difference between interferring waves remains constant with time.
II. interferring waves have nearly same amplitude levels
III. interferring waves are of same frequency.
IV. interferring waves are moving in opposite directions.

(a) I, II and III (b) II and III
(c) III and IV (d) I and IV

163. Which of the following statement is/are correct for coherent sources?

I. Two coherent sources emit light waves of same wavelength.

II. Two coherent sources emit light waves of same frequency.

III. Two coherent sources have zero or constant initial phase difference with respect to time.

Choose the correct option from the codes given below.

(a) Only I (b) I and III (c) II and III (d) I, II and III

164. Choose the correct option for the statements given below.

I. The interference pattern has a number of equally spaced bright and dark bands, while the diffraction pattern has a central bright maximum, which is twice as wide as the other maxima.

II. The interference pattern is superposing two waves originating from the two narrow slits, while the diffraction pattern is a superposition of a continuous family of waves originating from each point on a single slit.

III. For a single slit of width a, the first null of the interference pattern occurs at an angle of λ / a while at the same angle of λ / a, a maximum (not a null) for two narrow slits separated by a distance a.

(a) I and II are correct, III is incorrect
(b) I and II are correct, II is incorrect
(c) I, II and III are correct
(d) I, II and III are incorrect

165. Which of the given statements is/are correct for phenomenon of diffraction?

I. For diffraction through a single-slit, the wavelength of wave must be comparable to the size of slit.

II. The diffraction is very common in sound waves but not so common in light waves.

III. Diffraction is only observed in electromagnetic waves.

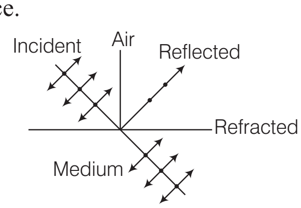
(a) Only I (b) II and III (c) I and II (d) I, II and III

166. Which of the following statement(s) is/are correct with reference to the figure given below?

I. Dots and arrows indicates that both polarisations are present in the incident and refracted waves.

II. The reflected light is not linearly polarised.

III. Transmitted intensity will be zero when the axis of the analyser is in the plane of the figure *i.e.,* the plane of incidence.



(a) Only I (b) Only II
(c) Both I and III (d) Both I and II

III. Matching Type

167. Light waves travels in vacuum along X-axis, Y-axis and Z-axis. Column I lists the equation of the plane wavefront and Column II lists the direction of propagation of the wave. Match the items in Column I with terms in Column II and choose the correct options from the codes given below.

Column I	Column II
A. $X = C$	1. Along Y-axis
B. $Y = C$	2. Along X-axis
C. $Z = C$	3. Along Z-axis

	A	B	C		A	B	C
(a)	1	2	3	(b)	3	2	1
(c)	2	1	3	(d)	2	3	1

168. Match the following columns and choose the correct options from the codes given below.

Column I	Column II
A. Constructive interference	1. $n\lambda$
B. Destructive interference	2. $(n+1)\lambda/2$
C. Path difference for constructive interference	3. Waves are in phase at point of interference
D. Path difference for destructive interference	4. Waves are out of phase at point of interference

(a) A → 4, B → 1, C → 3, D → 2
(b) A → 4, B → 3, C → 1, D → 2
(c) A → 3, B → 4, C → 1, D → 2
(d) A → 3, B → 4, C → 2, D → 1

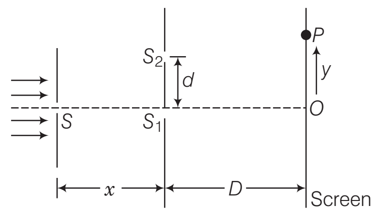
169. Two slits are made one millimetre apart and the screen is placed 1 m away and blue-green light of wavelength 500 nm is used.

Now, match the activity given in Column I with the change in fringe pattern obtained in Column II.

Column I	Column II
A. Screen is moved away from the plane of slits	1. Linear width of fringes (β) increases.
B. Source is replaced by another source of shorter wavelength	2. Angular separation of fringe remains constant.
C. Set up of experiment is dipped completely in water	3. Fringe separation decreases.
D. Distance between slits is reduced.	4. Fringe width become 3/4th.

(a) A → 1, B → 3, C → 4, D → 2
(b) A → 3, B → 1, C → 4, D → 2
(c) A → 2, B → 3, C → 4, D → 1
(d) A → 2, B → 3, C → 1, D → 4

170. Consider the arrangement shows in the figure. The distance D is large compared to the separation d between the slits. For this arrangement, match the items in Column I with terms in Column II and choose the correct option from codes given below.



	Column I		Column II
A.	The minimum value of d so that there is a dark fringe at O for $x = D$ is	1.	$\sqrt{\frac{\lambda D}{3}}$
B.	For $x = D$ and d minimum such that there is dark fringe at O, the distance y at which next bright fringe is located is	2.	$2d$
C.	fringe width for $x = D$	3.	d
D.	The minimum value of d so that there is a dark fringe at O for $x = D/2$ is	4.	$\sqrt{\frac{\lambda D}{2}}$

(a) A → 4, B → 3, C → 2, D → 1
(b) A → 1, B → 2, C → 3, D → 4
(c) A → 1, B → 3, C → 2, D → 4
(d) A → 4, B → 2, C → 3, D → 1

171. Column I shows the changes introduced in Young's double-slit experiment while Column II tells the changes in the fringe pattern while performing the experiment. Match each situation given in Column I with the result given in Column II.

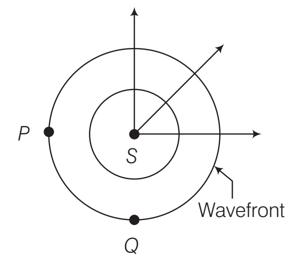
	Column I		Column II
A.	If sodium light is replaced by red light of same intensity	1.	All fringes are coloured except central fringe
B.	Monochromatic light is replaced by white light	2.	Fringe width will became quadrupled
C.	Distance between slits and screen is doubled and the distance betwen slits is halved	3.	The bright fringe will bocame less bright
D.	If one of the slits is covered by cellophone paper	4.	The fringe width will increase

	A	B	C	D
(a)	4	1	2	3
(b)	1	2	3	4
(c)	2	3	1	4
(d)	3	2	4	1

IV. Passage Based Questions

■ **Directions** (Q.Nos. 172-173) *Answer the following questions based on the given passage. Choose the correct options from those given below.*

The figure represents a wavefront emanating from a point source.



172. The phase difference between the two points P and Q on the wavefront is
(a) $\pi/2$ (b) 0
(c) $\pi/3$ (d) Data insufficient

173. The amplitude of point P and Q on the wavefront is
(a) same (b) different (c) zero (d) Data sufficient

■ **Directions** (Q.Nos. 174-175) *Answer the following questions based on the given passage. Choose the correct options from those given below.*

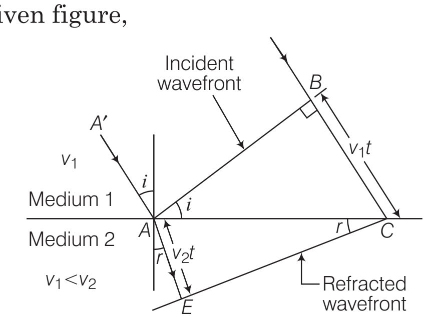
A point source emits wave diverging in all directions.

174. At a finite distance r from the source the shape of wavefront is
(a) spherical (b) plane
(c) Either (a) or (b) (d) None of these

175. At a very large distance from the source, the shape of the wavefront will be
(a) spherical (b) plane
(c) Either (a) or (b) (d) None of these

■ **Directions** (Q.Nos 176-178) *Answer the following questions based on the given passage. Choose the correct options from those given below.*

In the given figure,



AB is an incident wavefront and EC is refracted wavefront. Speed of light in medium 1 is v_1 and speed of light in medium 2 is v_2.

176. The ratio of $\frac{\sin i}{\sin r}$ is equal to

(a) $\frac{BC}{AC}$ (b) $\frac{AE}{EC}$ (c) $\frac{BC}{AE}$ (d) $\frac{AE}{BC}$

177. When light travelling through medium 1, passes through medium 2, which of the following statements is correct.

(a) $\frac{\sin i}{\sin r} = \frac{v_2}{v_1}$ (b) $\eta = \frac{C}{v_1}$

(c) $\eta_{21} = \frac{v_2}{v_1}$ (d) $\frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_2}$

178. In case of refraction of a light beam, which of these remains constant?

(a) Speed (b) Wavelength
(c) Frequency (d) Intensity

■ **Directions** (Q. Nos 179-180) *Answer the following questions based on the given passage. Choose the correct options from those given below.*

Monochromatic light of wavelength 589 nm in incident from air on a water surface. λ_1 and λ_2 are the wavelength of reflected and refracted light respectively, v_1 and v_2 are the velocities of reflected and refractive light, respectively.

[Refractive index of water is 1.33]

179. The velocities of reflected and refracted light is v_1 and v_2, respectively. Then, $\frac{v_1}{v_2}$ is (ratio of frequency) is

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

180. Match the items in Column I with terms in Column II and choose the correct option from the codes given below.

	Column I		Column II
A.	λ_1 (in nm)	1.	442
B.	λ_2 (in nm)	2.	225
C.	v_1 (in 10^6 ms^{-1})	3.	589
D.	v_2 (in 10^6 ms^{-1})	4.	300

	A	B	C	D		A	B	C	D
(a)	3	1	4	2	(b)	1	2	3	4
(c)	2	4	1	3	(d)	1	3	2	4

■ **Directions** (Q.Nos 181-182) *Answer the following questions based on the given passage. Choose the correct options from those given below.*

The expression for Doppler's shift is given by

$$\frac{\Delta\nu}{\nu} = \frac{v_{\text{radial}}}{c}$$

[Consider the directions from observer to source as positive]

181. Here, v_{radial} refers to

(a) the component of the source velocity along the line joining the source to observer
(b) the component of the source velocity along the line joining the observer to the source relative to the observer
(c) the frequency of light as observed by the observer
(d) None of the above

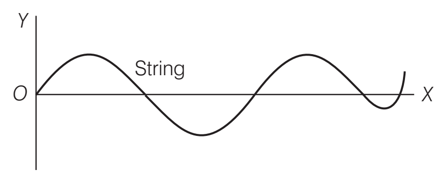
182. **Statement I** The Doppler's shift expression is valid only when the speed of the source is small compared to that of light.

Statement II Doppler's effect in light can be used to estimate the velocity of aeroplanes, rockets submarines etc.

(a) Both the Statements are correct
(b) Both the Statements are incorrect
(c) Statement I is correct, Statement II is incorrect
(d) Statement I is incorrect, Statement II is correct

■ **Directions** (Q. Nos 183-184) *Answer the following questions based on the given passage. Choose the correct options from those given below.*

The string shown above is given an up and down jerk at one end of it while the outer end is fixed at origin.



183. If the string always remains confined to the XY-plane, then it represents

(a) a plane polarised wave
(b) an unpolarised wave
(c) linearly polarised wave
(d) Both (a) and (c)

184. If the plane of the vibrations of the string is changed randomly in a very short intervals of time, it is known as

(a) polarised wave (b) plane polarised wave
(c) unpolarised wave (d) Both (a) and (b)

■ **Direction** (Q. Nos. 185-186) *Answer the following questions based on the given passage. Choose the correct options from those given below.*

Light passes through two polaroids P_1 and P_2 with pass axis of P_2 making an angle θ with the pass axis of P_1.

185. The value of θ for which the intensity of emergent light is zero, is

(a) 45° (b) 90°
(c) 60° (d) 30°

186. A third polaroid is placed between P_1 and P_2 with its pass axis making an angle β with the pass axis of P_1. The value of β for which the intensity of light from P_2 is $\frac{I_0}{8}$, where I_0 is the intensity of light on the polaroid P_1 is

(a) 0° (b) 30° (c) 45° (d) 60°

V. More than One Option Correct

187. In the Young's double slit experiment, the ratio of intensities bright and dark fringes is 9. This mean that

(a) the intensities of individual sources are 5 and 4 units respectively

(b) the intensities of individual sources are 4 and 1 units respectively

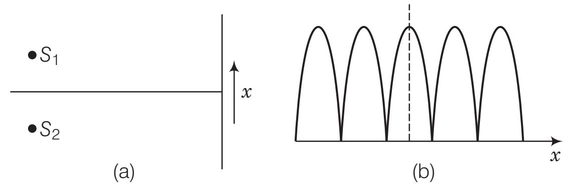
(c) the ratio of their amplitudes is 3

(d) the ratio of their amplitudes is 2

188. A thin film of thickness t and index of refraction 1.33 coats a glass with index of refraction 1.50. Which of the following thickness t will not reflect normally incident light with wavelength 640 nm in air?

(a) 120 nm (b) 240 nm (c) 360 nm (d) 480 nm

189. Two sources S_1 and S_2 of intensity I_1 and I_2 are placed infront of a screen Fig. (a). The pattern of intensity distribution seen in the central portion is given by Fig. (b).



In this case, which of the following statements are true?

(a) S_1 and S_2 have the same intensities

(b) S_1 and S_2 have a constant phase difference

(c) S_1 and S_2 have the same phase

(d) S_1 and S_2 have the same wavelength

190. Consider the sunlight incident on a pinhole of width 10^3 Å. The image of the pinhole seen on a screen shall be

(a) a sharp white ring

(b) different from a geometrical image

(c) a diffused central spot, white in colour

(d) diffused coloured region around a sharp central white spot

191. For light from a point source,

(a) the wavefront is spherical

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

(c) the wavefront is parabolic

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

NCERT & NCERT Exemplar Questions

NCERT

192. Monochromatic light of wavelength 589 nm is incident from air on a water surface. What are the wavelength, frequency and speed of (i) reflected and (ii) refracted light?(Refractive index of water is 1.33).

(a) Reflected light - 589×10^{-9} m, 5.09×10^{14} Hz, 3×10^{8} ms^{-1}
Refracted light - 4.42×10^{-7} m, 5.09×10^{14} Hz, 2.25×10^{8} ms^{-1}

(b) Reflected light - 475×10^{-9} m, 509×10^{-14} Hz, 2×10^{5} ms^{-1}.
Refracted light - 5×10^{-5} m, 2.09×10^{14}, 3×10^{8} ms^{-1}

(c) Reflected light - 1m, 1ms^{-1}
Refracted light - 1m, 2Hz, 3×10^{6} ms^{-1}

(d) None of the above

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

(a) 5×10^{-7} m

(b) 6×10^{-7} m

(c) 0.05×10^{-7} m

(d) 0.06×10^{-7} m

194. A beam of light consisting of two wavelengths 650 nm and 520 nm is used to obtain interference fringes in a Young's double slit experiment with slit width = 2 mm and distance of screen = 1.2 m.

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

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

(a) 1.17×10^{-3} m, 1.56×10^{-3} m

(b) 2.25×10^{-2} m, 1.25 m

(c) 0.05×10^{-2} m, 1.3×10^{-4} m

(d) None of the above

195. Light of wavelength 5000Å falls on a plane reflecting surface. What are the wavelength and frequency of the reflected light?

For what angle of incidence is the reflected ray normal to the incident ray?

(a) $\lambda = 3000\text{Å}, \nu = 5\times10^{15}$ Hz, $\angle i = 45°$

(b) $\lambda = 5000\text{Å}, \nu = 6\times10^{14}$ Hz, $\angle i = 45°$

(c) $\lambda = 8800\text{Å}, \nu = 5\times10^{15}$ Hz, $\angle i = 60°$

(d) None of the above

196. The 6563 Å H_α sign line emitted by hydrogen in a star is found to be red shifted by 15Å. Estimate the speed with which the star is receding from the earth.

(a) -5.04×10^2 ms^{-1}

(b) -6.86×10^5 ms^{-1}

(c) 5.84×10^2 ms^{-1}

(d) 8.8×10^3 ms^{-1}

197. In Young's double-slit experiment using light of wavelength 600 nm, the angular width of a fringe formed on a distant screen is 0.1°. What is the spacing between the two slits?

(a) 1 m

(b) 1.5×10^{-2} m

(c) 3.44×10^{-4} m

(d) 0.05×10^{-2} m

198. Two towers on top of two hills are 40 km apart. The line joining them passes 50 m above a hill halfway between the towers. What is the longest wavelength of radio waves which can be sent between the towers without appreciable diffraction effects?

(a) 0.125 m (b) 2.5 m (c) 0.05 m (d) 0 m

199. A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1m away. It is observed that the first minimum is at a distance of 2.5 mm from the centre of the screen. Find the width of the slit.

(a) 2 mm (b) 1 mm (c) 0.2 mm (d) 0.1 mm

NCERT Exemplar

200. Consider sunlight incident on a slit of width 10^4 Å. The image seen through the slit shall

(a) be a fine sharp slit white in colour at the centre

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

(c) a bright slit white at the centre diffusing to regions of different colours

(d) only be a diffused slit white in colour

201. Consider a ray of light incident from air onto a slab of glass (refractive index n) of width d, at an angle θ. The phase difference between the ray reflected by the top surface of the glass and the bottom surface is

(a) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}+\pi$ (b) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}$

(c) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}+\frac{\pi}{2}$ (d) $\frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{1/2}+2\pi$

202. 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

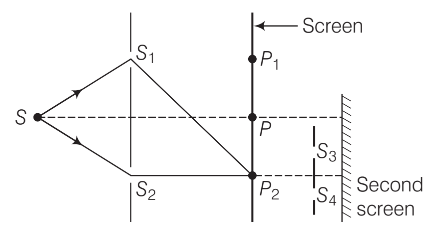
(a) there shall be alternate interference patterns of red and blue

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

(c) there shall be no distinct interference fringes

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

203. Figure shows a standard two slit arrangement with slits S_1, S_2, P_1, P_2 are the two minima points on either side of P as shown in figure.



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

(a) There would be no interference pattern on the second screen but it would be lighted

(b) The second screen would be totally dark

(c) There would be a single bright point on the second screen

(d) There would be a regular two slit pattern on the second screen

204. The human eye has an approximate angular resolution of $\phi = 5.8\times10^{-4}$ rad and a typical photoprinter prints a minimum of 300 dpi (dots per inch, 1 inch = 2.54 cm). At what minimum distance z should a printed page be held so that one does not see the individual dots?

(a) 14.5 cm

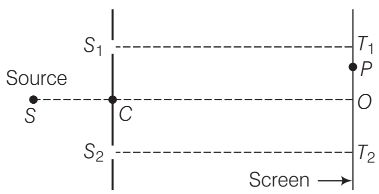
(b) 12.5 cm

(c) 19.8 cm

(d) 10.25 cm

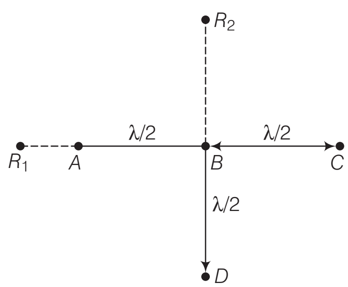
205. Consider a two slits interference arrangements(figure) such that the distance of the screen from the slits is half the distance between the slits.

Obtain the value of D in terms of λ such that the first minima on the screen falls at a distance D from the centre O.



(a) 0.358λ (b) 0.404λ (c) 0.725λ (d) 0.80λ

206. Four identical monochromatic sources A, B, C, D as shown in the figure, produce waves of the same wavelength λ and are coherent. Two receiver R_1 and R_2 are at great but equal distances from B.



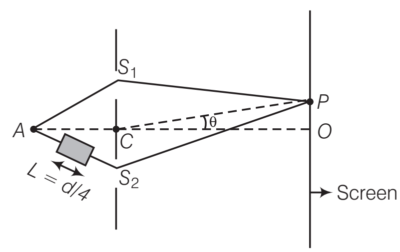
Which of the two receivers picks up the larger signal?

(a) R_1 (b) R_2
(c) R_1 and R_2 (d) None of these

207. To ensure almost 100% transmittivity, photographic lenses are often coated with a thin layer of dielectric material. The refractive index of this material is intermediated between that of air and glass (which makes the optical element of the lens). A typically used dielectric film is MgF_2 (n=1.38). What should the thickness of the film so that at the centre of the visible spectrum (5500Å) there is maximum transmission?

(a) 5000 Å (b) 2800 Å (c) 1000 Å (d) 725 Å

208. A small transparent slab containing material of $\mu = 1.5$ is placed along AS_2 (figure). What will be the distance from O of the principal maxima and of minima on either side of the principal maxima obtained in the absence of the glass slab?



$$AC = CO = D, S_1C = S_2C = d << D$$

(a) $\frac{2D}{\sqrt{247}}$ above point O and $\frac{5}{\sqrt{231}}$ below point O

(b) $3\sqrt{247}$ above point O and $5\sqrt{231}$ below point O

(c) $\frac{5}{\sqrt{465}}$ below point O and $\frac{3D}{\sqrt{247}}$ below point O

(d) None of the above

Answers

1.	(d)	**2.**	(d)	**3.**	(c)	**4.**	(c)	**5.**	(d)	**6.**	(b)	**7.**	(b)	**8.**	(c)	**9.**	(c)	**10.**	(a)	**11.**	(b)	**12.**	(c)	**13.**	(d)	**14.**	(a)	**15.**	(a)
16.	(b)	**17.**	(b)	**18.**	(a)	**19.**	(b)	**20.**	(a)	**21.**	(a)	**22.**	(c)	**23.**	(d)	**24**	(d)	**25.**	(d)	**26.**	(b)	**27.**	(a)	**28.**	(a)	**29.**	(c)	**30.**	(c)
31.	(c)	**32.**	(b)	**33.**	(d)	**34.**	(c)	**35.**	(b)	**36.**	(c)	**37.**	(a)	**38.**	(d)	**39.**	(d)	**40.**	(b)	**41.**	(b)	**42.**	(a)	**43.**	(b)	**44.**	(a)	**45.**	(c)
46.	(d)	**47.**	(c)	**48.**	(b)	**49.**	(b)	**50.**	(a)	**51.**	(b)	**52.**	(b)	**53.**	(c)	**54.**	(a)	**55.**	(d)	**56.**	(d)	**57.**	(c)	**58.**	(a)	**59.**	(c)	**60.**	(b)
61.	(d)	**62.**	(c)	**63.**	(d)	**64.**	(b)	**65.**	(a)	**66.**	(d)	**67.**	(d)	**68.**	(b)	**69.**	(a)	**70.**	(b)	**71.**	(a)	**72.**	(b)	**73.**	(a)	**74.**	(c)	**75.**	(c)
76.	(b)	**77.**	(c)	**78.**	(b)	**79.**	(c)	**80.**	(c)	**81.**	(b)	**82.**	(d)	**83.**	(d)	**84.**	(b)	**85.**	(c)	**86.**	(d)	**87.**	(b)	**88.**	(a)	**89.**	(c)	**90.**	(c)
91.	(b)	**92.**	(c)	**93.**	(c)	**94.**	(d)	**95.**	(a)	**96.**	(c)	**97.**	(a)	**98.**	(d)	**99.**	(b)	**100.**	(b)	**101.**	(b)	**102.**	(a)	**103.**	(a)	**104.**	(a)	**105.**	(a)
106.	(c)	**107.**	(b)	**108.**	(d)	**109.**	(a)	**110.**	(a)	**111.**	(a)	**112.**	(d)	**113.**	(b)	**114.**	(b)	**115.**	(b)	**116.**	(b)	**117.**	(a)	**118.**	(a)	**119.**	(a)	**120.**	(d)
121.	(a)	**122.**	(b)	**123.**	(c)	**124.**	(d)	**125.**	(c)	**126.**	(c)	**127.**	(a)	**128.**	(b)	**129.**	(a)	**130.**	(b)	**131.**	(b)	**132.**	(d)	**133.**	(a)	**134.**	(b)	**135.**	(c)
136.	(a)	**137.**	(a)	**138.**	(a)	**139.**	(b)	**140.**	(b)	**141.**	(c)	**142.**	(a)	**143.**	(c)	**144.**	(c)	**145.**	(a)	**146.**	(c)	**147.**	(a)	**148.**	(c)	**149.**	(b)	**150.**	(a)
151.	(c)	**152.**	(a)	**153.**	(a)	**154.**	(c)	**155.**	(a)	**156.**	(b)	**157.**	(c)	**158.**	(a)	**159.**	(c)	**160.**	(b)	**161.**	(a)	**162.**	(a)	**163.**	(d)	**164.**	(c)	**165.**	(c)
166.	(c)	**167.**	(c)	**168.**	(c)	**169.**	(c)	**170.**	(a)	**171.**	(a)	**172.**	(b)	**173.**	(a)	**174.**	(a)	**175.**	(b)	**176.**	(c)	**177.**	(d)	**178.**	(c)	**179.**	(a)	**180.**	(a)
181.	(b)	**182.**	(a)	**183.**	(d)	**184.**	(c)	**185.**	(b)	**186.**	(c)	**187.**	(b,d)	**188.**	(b,d)	**189.**	(a,b,d)	**190.**	(b,d)	**191.**	(a,b)	**192.**	(a)	**193.**	(b)	**194.**	(a)	**195.**	(b)
196.	(b)	**197.**	(c)	**198.**	(a)	**199.**	(c)	**200.**	(a)	**201.**	(a)	**202.**	(c)	**203.**	(d)	**204.**	(a)	**205.**	(b)	**206.**	(b)	**207.**	(c)	**208.**	(a)				

Hints *and* Explanations

1. (d) In geometrical optics a ray is defined as the path of the energy propagation in the limit of wavelength tending to zero.

2. (d) A ray is defined as the path of energy propagation in the limit of wavelength tending to zero. It travels in a straight line and defined as the path of energy propagation.

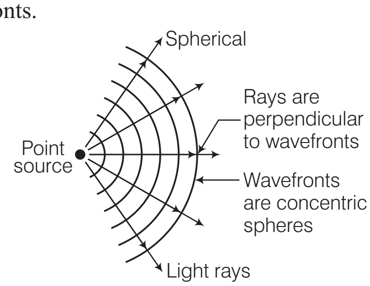
3. (c) The phenomenon of polarisation is based on the fact that the light waves are transverse electromagnetic waves. Diffraction and interference can be explained by wave theory of light.

4. (c) Every point on a given wavefront act as a secondary source of light and emits secondary wavelets which travels in all directions with the speed of light in the medium. A surface touching all these secondary wavelets tangentially in the forward direction, gives new wavefront at that instant of time.

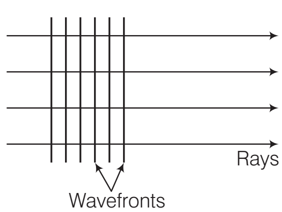
5. (d) Huygens' construction does not explains quantisation of energy and it is not able to explain emission and absorption spectrum.

6. (b) Wavefront is a surface perpendicular to a ray but a wavefront moves in the direction of the light.

7. (b) Wavefronts emitting from a point source are spherical wavefronts.



8. (c) Rays reaching from a source at infinity are parallel and when we draw a surface perpendicular to each ray, we get a plane wavefront.

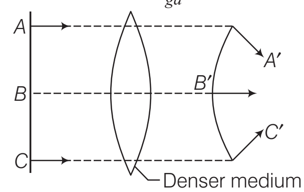


9. (c) In Huygens' wave theory, the locus of all points in the same state of vibration is called a wavefront.

10. (a) According to Huygens' principle, each point of the wavefront is the source of a secondary disturbance and the wavelength emanating from these points spread out in all directions with the speed of the wave.

11. (b) When ABC wavefront passes through glass, its velocity is reduced.

$$v_{\text{glass}} = \frac{v_{\text{air}}}{n_{ga}}$$



As, points A and C remain in glass for a short duration, they move for a larger distance and B covers a small distance as it remains in glass for a longer duration (middle portion of glass is thick) and finally $A'B'C'$ is position of new wavefront. It is concave in shape.

12. (c) Wavelength is dependent on refractive index medium by,

$$\frac{\lambda_1}{\lambda_2} = \frac{\mu_2}{\mu_1}$$

So, in denser medium, $\mu_2 > \mu_1$ so $\lambda_1 > \lambda_2$ (*i.e.* wavelength decreases as the light travels from rarer to denser medium)

$\because \quad c = \nu\lambda$

13. (d) We define an angle i_c by the following equation.

$$\sin i_c = \frac{n_2}{n_1}$$

Thus, if $i = i_c$, then $\sin r = 1$ and $r = 90°$. Obviously for $i > i_c$, there cannot be any refracted wave. The angle i_c is known as the critical angle and for all angles of incidence greater than the critical angle, we will not have any wavefront in medium 2.

14. (a) According to Doppler's effect, wherever there is relative motion between source and observer, the frequency observed is different from that given out by source.

15. (a) When source moves away from the observer, frequency observed is smaller than that emitted from the source and (as if light emitted is yellow but it will be observed as red) this shift is called red shift.

16. (b) For small velocities compared to the speed of light. The fractional change in frequency $\Delta\nu/\nu$ is given by $-v_{\text{radial}}/c$, where, v_{radial} is the component of the source velocity along the line joining the observer to the source relative to the observer, v_{radial} is considered positive when the source moves away from the observer. Thus, the Doppler's shift can be expressed as

$$\frac{\Delta\nu}{\nu} = -\frac{v_{\text{radial}}}{c}$$

17. (b) From Snell's law of refraction

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2}$$

Given, $v_1 = 3\times10^8\ \text{ms}^{-1}$

$$\frac{\mu_2}{\mu_1} = {}^1\mu_2 = 1.5 \quad \Rightarrow \quad v_2 = \frac{v_1}{{}^1\mu_2} = \frac{3\times10^8}{1.5}\ \text{ms}^{-1}$$

$\therefore$ Speed of light, $v_2 = \dfrac{3\times10^8}{3/2} = 2\times10^8\ \text{ms}^{-1}$

18. (*a*) We know from Cauchy's expression,

$$\mu(\lambda) = a + \frac{b}{\lambda^2} + \frac{c}{\lambda_4} + \ldots$$

or $\lambda_{\text{red}} > \lambda_{\text{blue}} > \lambda_{\text{violet}}$

$\mu_{\text{red}} < \mu_{\text{blue}} > \mu_{\text{violet}}$ (for glass prism)

So, refractive index of prism for violet colour is more hence from Eq. (i), the velocity of violet colour in medium $2(v_2)$ will be less than the red colour. Red colour light will travel fastest in glass prism.

19. (*b*) The relation between v, c and λ is $v\lambda = c$

For small changes in v and λ

$$\frac{\Delta v}{v} = \frac{-\Delta\lambda}{\lambda} = \frac{-v_{\text{radial}}}{c}$$

as $\Delta\lambda = 475.6 - 475.0 = +0.6\ \text{nm}$

or $v_{\text{radial}} = c\left(\dfrac{0.6}{475}\right) = \dfrac{0.6}{475}\times3\times10^8$

$= 3.78\times10^5\ \text{ms}^{-1} = 378\ \text{kms}^{-1}$

20. (*a*) Using, $\Delta\lambda = \dfrac{v}{c}\lambda$

Here, $v = 50\text{kms}^{-1} = 50\times10^3\ \text{ms}^{-1}$

$c = 3\times10^8\ \text{ms}^{-1}$

Wavelength, $\Delta\lambda = 0.50\text{Å}$

$\therefore$ Wavelength, $\lambda = \dfrac{c}{v}\,\Delta\lambda = \dfrac{3\times10^8}{50\times10^3}\times0.50 = 3000\text{Å}$

21. (*a*) Here, $\lambda = 400\ \text{nm}$

$\Delta\lambda = 400.1\ \text{nm} - 400\ \text{nm} = 0.1\ \text{nm}$

as $\dfrac{v_s}{c} = \dfrac{\Delta\lambda}{\lambda}$

$$v_s = \frac{\Delta\lambda}{\lambda}\ c = \frac{0.1\ \text{nm}}{400\text{nm}}\times3\times10^8\ \text{ms}^{-1}$$

$= 75\times10^3\ \text{ms}^{-1} = 75\ \text{kms}^{-1}$

22. (*c*) Doppler's shift is given by

$$\frac{\Delta\nu}{\nu} = \frac{v_{\text{radial}}}{c} \quad \Rightarrow \quad \frac{\Delta\nu}{\nu} = \frac{3\times10^3}{3\times10^8} = 10^{-5}$$

23. (*d*) The displacement produced by the source S_1 at the point P is given by $y_1 = a\cos\omega t$

The displacement produced by the sources S_2 (at the point P) is also given by

$$y_2 = a\cos\omega t$$

Thus, the resultant of displacement at P would be given by

$$y = y_1 + y_2 = 2a\cos\omega t$$

Since, the intensity is the proportional to the square of the amplitude, the resultant intensity will be given by

$$I = 4I_0$$

where, I_0 represents the intensity produced by each one of the individual waves.

24. (*d*) Interference is a wave phenomenon. Longitudinal waves like sound, transverse waves like wave on a string or electromagnetic waves like light show interference.

25. (*d*) For constructive interference,

Phase difference $(\Delta\phi) = 2n\pi$ (even multiple of π)

For $n = 0$, $\Delta\phi = 0$

For $n = 1$, $\Delta\phi = 2\pi$

For $n = 2$, $\Delta\phi = 4\pi$ and so on

26. (*b*) Given, path difference $(\Delta x) = 1.5\,\lambda = \dfrac{3}{2}\lambda$

Phase difference $(\Delta\phi)$ and path difference (Δx) are related by the relation,

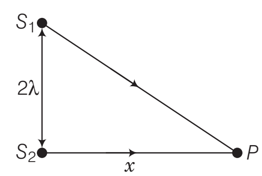
$$\Delta\phi = \frac{2\pi}{\lambda}\times\Delta x$$

$\Rightarrow$ $\Delta\phi = \dfrac{2\pi}{\lambda}\times\dfrac{3}{2}\lambda = 3\pi$

$\Rightarrow$ $\Delta\phi =$ odd multiple of π.

So, destructive interference occurs.

27. (*a*) Given, separation between sources S_1 and $S_2 = 2\lambda$. For minimum intensity at P, destructive interference must take place at P.



So, $S_1P - S_2P = \Delta x$ (path difference)

$= (2n+1)\dfrac{\lambda}{2}$ (for destructive interference)

For minimum distance,

$$S_1P - S_2P = \frac{3\lambda}{2} \neq \frac{\lambda}{2} \qquad \ldots\text{(i)}$$

$\Rightarrow$ $\sqrt{x^2 + (2\lambda)^2} - x = \dfrac{3\lambda}{2} \Rightarrow x^2 + (2\lambda)^2 = \left[x + \left(\dfrac{3\lambda}{2}\right)\right]^2$

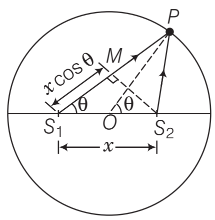
$\Rightarrow$ $x^2 + 4\lambda^2 = x^2 + \dfrac{9\lambda^2}{4} + 2\cdot x\cdot\dfrac{3\lambda}{2}$

$\Rightarrow$ $x\cdot3\lambda = 4\lambda^2 - \dfrac{9\lambda^2}{4} = \dfrac{7\lambda^2}{4} \quad \Rightarrow \quad x = \dfrac{7\lambda}{12}$

Note If we proceed with Eq. (i) taking $S_1P - S_2P = \dfrac{\lambda}{2}$, $x = \dfrac{15\lambda}{4}$ which is more than $\dfrac{7\lambda}{12}$.

28. (*a*) From the figure, path difference $= S_1M = P$

$$P = S_1M = x\cos\theta \qquad (\because x << R)$$



(S_1P and S_2P are assumed approximately parallel)

For maximum intensity, $P = n\lambda$ (where, $n = 0, 1, 2, 3$)

$\Rightarrow \quad x\cos\theta = n\lambda$

$\Rightarrow \quad \cos\theta = \dfrac{n\lambda}{x}$

$\Rightarrow \quad \cos\theta = \dfrac{n\lambda}{5\lambda} \qquad (\because x = 5\lambda)$

$\Rightarrow \quad \cos\theta = \dfrac{n}{5}$

We know, $-1 \le \cos\theta \le 1$

$\Rightarrow \quad -1 \le \dfrac{n}{5} \le 1$

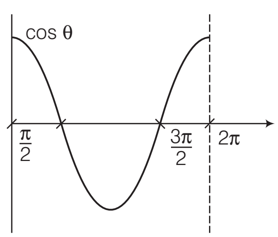
$\Rightarrow \quad -5 \le n \le 5$

Possible values of $n = \{0, \pm 1, \pm 2, \pm 3, \pm 4, \pm 5\}$

Let us analysis each value of n for θ in range.

$$\theta \in (0, 2\pi)$$

For $n = 1, \cos\theta = \dfrac{1}{5}$



Here, negative value of n means the path difference ($S_1P - S_2P$) is negative, *i.e.,* for those points $S_1P < S_2P$.

For $n = 0, \pm 1, \pm 2, \pm 3, \pm 4$,

From the given graph of cosine function, it can be observed that in interval $\theta \in [0, 2\pi]$, for above values of n there are in total 18 points, *i.e.,* 2 points for $n = 0$, 4 points each for $n = \pm 1, \pm 2, \pm 3, \pm 4$.

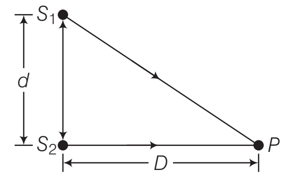
For $n = +5, \cos\theta = +1$,

One value of θ *i.e.,* $\theta = 0°$ is possible as for $\theta = 2\pi$, the points will coincide.

For $n = -5, \cos\theta = -1$, *i.e.,* $\theta = \pi$.

Thus, in total 20 points of maxima's are possible in all 4 quadrants.

29. (*c*) The position of farthest minimum detection occurs when the path difference is least and odd multiple of $\dfrac{\lambda}{2}$, *i.e.,* condition for destructive interference and approaches zero as P moves to infinity.



So, if $\quad S_2P = D$

$S_1P - S_2P = (2n+1)\dfrac{\lambda}{2}$ for destructive interference.

($n = 0, 1, 2, \ldots$). For farthest distance

so $\quad S_1P - S_2P = \dfrac{\lambda}{2}$

$\Rightarrow \quad \sqrt{D^2 + d^2} - D = \dfrac{\lambda}{2}$

$\Rightarrow \quad D^2 + d^2 = \left(D + \dfrac{\lambda}{2}\right)^2$

$\Rightarrow \quad d^2 = D\lambda + \dfrac{\lambda^2}{4}$

$\Rightarrow \quad D = \dfrac{d^2}{\lambda} - \dfrac{\lambda}{4}$

$$= \frac{(1.0 \times 10^{-4}\ \text{m})^2}{(600 \times 10^{-9}\ \text{m})} - 150 \times 10^{-9}\ \text{m}$$

$$= 107\ \text{cm}$$

$\Rightarrow \quad D = 1.07$ m

30. (*c*) Given, $\Delta\phi = 100\pi$

We know, change in phase difference,

i.e., $\quad \Delta\phi = \dfrac{2\pi}{\lambda} \times \Delta x$

where, Δx = path difference

$\Rightarrow \quad \Delta x = \Delta\phi \times \dfrac{\lambda}{2\pi} = 100\pi \times \dfrac{\lambda}{2\pi} = 50\lambda$

31. (*c*) In the phenomenon of interference, energy in conserved but it is redistributed.

32. (*b*) As two distinct sources are incoherent, so phase changes are random, so no fixed pattern of maxima or minima.

33. (*d*) Resultant amplitude

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

Here $\quad A_1 = A_2 = 2\ \text{cm} \Rightarrow \phi = \pi$ rad

$$A = \sqrt{(2)^2 + (2)^2 + 2 \times 2 \times 2 \times \cos\pi}$$

$$A = \sqrt{4 + 4 - 8} \text{ or } A = 0$$

34. (*c*) Resultant intensity is given by $I = 4I_0 \cos^2 \phi/2$.

Now, phase difference $(\phi) = \frac{2\pi}{\lambda} \times \Delta$ (path difference)

As a path difference of one wavelength corresponds to a phase difference of 2π radius.

$$\Rightarrow \quad I = 4I_0 \cos^2\left(\frac{2\pi\Delta}{2\lambda}\right) = 4I_0 \cos^2\left(\frac{\pi\Delta}{\lambda}\right)$$

$$\therefore \quad \frac{I_P}{I_Q} = \cos^2\left(\frac{\pi\Delta_1}{\lambda}\right) \Big/ \cos^2\left(\frac{\pi\Delta_2}{\lambda}\right)$$

35. (*b*) Given, $\frac{I_{max}}{I_{min}} = \frac{4}{1}$

We know, $\frac{I_{max}}{I_{min}} = \left(\frac{r+1}{r-1}\right)^2 = \frac{4}{1}$

$$\Rightarrow \quad \frac{r+1}{r-1} = \frac{2}{1} \Rightarrow r + 1 = 2r - 2 \text{ or } r = 3$$

$\therefore$ The ratio of amplitudes $\frac{A_1}{A_2} = r = 3$

36. (*c*) Given, $I_1 = I$ and $I_2 = 9I$

$$\Rightarrow \quad \frac{I_1}{I_2} = \frac{I}{9I} = \frac{1}{9} \Rightarrow r = \frac{A_1}{A_2} = \frac{\sqrt{I_1}}{\sqrt{I_2}} = \sqrt{\frac{1}{9}} = \frac{1}{3}$$

$$\frac{I_{max}}{I_{min}} = \left(\frac{r+1}{r-1}\right)^2 \qquad \text{...(i)}$$

$$= \left(\frac{\frac{1}{3}+1}{\frac{1}{3}-1}\right)^2 = \frac{16}{4} = 4$$

37. (*a*) Given, Young's double slit experiment, having two slits of width are in the ratio of 1 : 25.

So, ratio of intensity,

$$\frac{I_1}{I_2} = \frac{W_1}{W_2} = \frac{1}{25} \Rightarrow \frac{I_2}{I_1} = \frac{25}{1}$$

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

$$\Rightarrow \quad \left[\frac{5+1}{5-1}\right]^2 = \left(\frac{6}{4}\right)^2 = \frac{36}{16} = \frac{9}{4}$$

Thus, $\frac{I_{max}}{I_{min}} = \frac{9}{4}$

38. (*d*) Given, $\frac{I_1}{I_2} = n \Rightarrow r = \sqrt{\frac{I_1}{I_2}} = \sqrt{n}$

$$\frac{I_{max}}{I_{min}} = \left(\frac{r+1}{r-1}\right)^2 = \left(\frac{\sqrt{n}+1}{\sqrt{n}-1}\right)^2$$

39. (*d*) We know, $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2 = 4I_0'$ (if $I_1 = I_2 = I_0'$)

Here, $4I_0' = I_0$

$$\Rightarrow \quad I_0' = \frac{I_0}{4}$$

For incoherent source, the interference has uniform intensity throughout given by

$$I = I_1 + I_2$$

or $I = 2I_0' = 2 \times \frac{I_0}{4} = \frac{I_0}{2}$

40. (*b*) When the sources are incoherent there is no interference and resultant intensity is $I_1 + I_2$. For sources of same intensity I_0, resultant intensity will be $2I_0$.

41. (*b*) Two identical and independent sodium lamps (*i.e.,* two independent sources of light) can never be coherent. Hence, no coherence between the light emitted by different atoms.

42. (*a*) Let the average intensity be I_{av}.

The amplitude of intensity variation means.

$$I = I_{av} \pm 0.05\, I_{av}$$

$$\Rightarrow \quad I_{max} = I_{av}\,(1 + 0.05) = 1.05\, I_{av}$$

$$\Rightarrow \quad I_{min} = I_{av}\,(1 - 0.05) = 0.95 I_{av}$$

So, $\frac{I_{max}}{I_{min}} = \frac{1.05}{0.95} = \frac{105}{95}$

$$\Rightarrow \quad \left(\frac{r+1}{r-1}\right)^2 = \frac{105}{95}$$

$$\Rightarrow \quad (r^2 + 1 + 2r)\, 95 = 105\,(r^2 + 1 - 2r)$$

$$\Rightarrow \quad 10r^2 + 10 - 200 \cdot 2r = 0$$

$$\Rightarrow \quad 10r^2 - 400r + 10 = 0$$

$$\Rightarrow \quad r^2 - 40r + 1 = 0$$

$$\Rightarrow \quad r = \frac{40 \pm \sqrt{(40)^2 - 4 \times 1 \times 1}}{2}$$

$$\Rightarrow \quad r \approx \frac{40 + 40}{2} = 40$$

$$\therefore \quad \frac{I_1}{I_2} = r^2 = (40)^2 = \frac{1600}{1}$$

or $I_1 : I_2 = 1600 : 1$

43. (*b*) Consider that the source is moved to some new point S' and suppose that Q is the mid-point of S_1 and S_2. If the angle $S'QS$ is ϕ, then the central bright fringe occurs at an angle $-\phi$, on the other side. Thus, if the source S is on the perpendicular bisector, then the central fringe occurs at O, also on the perpendicular bisector.

If S is shifted by an angle ϕ to point S', then the central fringe appears at a point O' at an angle $-\phi$, which means that it is shifted by the same angle on the other side of the bisector.

This also means that the source S', the mid-point Q and the point O' of the central fringe are in a straight line.

44. (*a*) The film appears bright if the path difference is

$$2\mu t = (2n-1)\frac{\lambda}{2}, \text{ where, } n = 1,2,3,...$$

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

$$\lambda = \frac{4\times 1.4\times 10000\times 10^{-10}}{(2n-1)} = \frac{56000}{(2n-1)}\text{Å}$$

$$\therefore \quad \lambda = 56000\text{ Å}, 18666\text{ Å}, 11200\text{ Å}, 8000\text{ Å}, 6222\text{ Å}, 5091\text{ Å}, 4308\text{ Å}, 3733\text{ Å}$$

The wavelengths which are not within specified ranges produce minima.

45. (*c*) Path difference $= QX - PX = (n+2)\lambda - n\lambda = 2\lambda$ ...(i)

For constructive interference or bright band,

Path difference $= \Delta x = n\lambda$ (where, $n = 1, 2, ...$)

From Eq. (i), it is obvious that second bright band is formed as $n = 2$.

46. (*d*) We know,

Intensity of bright band, $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2$ ...(i)

Intensity of dark band, $I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$ ...(ii)

Case I When there is no glass slab

$\Rightarrow \quad I_1 = I_2 = I_0$

or $\quad I_{max} = 4I_0$ (Complete brightness)

and $\quad I_{min} = 0$ (Complete darkness)

Case II When glass slab is inserted,

$\Rightarrow \quad I_1 < I_2$ or $I_1 = \frac{I_0}{2}$ and $I_2 = I_0$ (given)

or $\quad I_{max} < 4I_0$ [from Eq. (i)]

and $\quad I_{min} > 0$ [from Eq. (ii)]

Hence, the bright band becomes less bright and dark band becomes less dark.

47. (*c*) Using relation, $I = I_{max}\cos^2\left(\frac{\Delta\phi}{2}\right)$,

where, $\Delta\phi$ = total phase difference

Given, $\quad I = \frac{I_{max}}{4}$ at certain point

$$\Rightarrow \quad \frac{I_{max}}{4} = I_{max}\cos^2\left(\frac{\Delta\phi}{2}\right) \quad \text{or} \quad \frac{1}{4} = \cos^2\left(\frac{\Delta\phi}{2}\right)$$

$$\Rightarrow \quad \cos\left(\frac{\Delta\phi}{2}\right) = \cos\left(\frac{\pi}{3}\right) \quad \text{or} \quad \Delta\phi = \left(\frac{2\pi}{3}\right)$$

Path difference, $\Delta x = \frac{\lambda}{2\pi}\times\Delta\phi = \frac{\lambda}{2\pi}\times\frac{2\pi}{3} = \frac{\lambda}{3}$ ...(i)

For Young's double slit experiment we know, path difference $= d\sin\theta$ ...(ii)

where, θ = angular separation of the point

Using Eqs. (i) and (ii), we get

$$\frac{\lambda}{3} = d\sin\theta \Rightarrow \sin\theta = \frac{\lambda}{3d}$$

$$\Rightarrow \quad \theta = \sin^{-1}\left(\frac{\lambda}{3d}\right)$$

48. (*b*) Shift produced due to insertion of slab

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

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

Thus, the central maximum is obtained at a distance 4.33 mm below point O on the screen as the slab is placed in the path of lower slit.

49. (*b*) At O, path difference, $P = \left(\frac{\mu_g}{\mu_m} - 1\right)t$

For maximum intensity at O

$$P = n\lambda \ (n = 1, 2, 3, \cdots)$$

$$\therefore \quad \lambda = \left[\frac{P}{n}\right]$$

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

$$\lambda = \frac{1300\text{ nm}}{n}$$

For $n = 1$, $\quad \lambda = 1300$ nm

For $n = 2$, $\quad \lambda = 650$ nm

For $n = 3$, $\quad \lambda = 433.33$ nm

Thus, the wavelength in the range 400 to 700 nm are 650 nm and 433.33 nm.

50. (*a*) The condition for minimum thickness corresponding to a dark band in reflection

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

$$\therefore \quad t = \frac{\lambda}{2\mu\cos r} = \frac{6000\times 10^{-10}}{2\times 1.5\times\cos 60^\circ} = 4000\text{ Å}$$

51. (*b*) The resultant internsity

$$I = I_0\cos^2\frac{\phi}{2}$$

Here, I_0 is the maximum intensity and $\phi = \frac{\pi}{2}$

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

$$I = \frac{I_0}{2}$$

52. (*b*) Here, $A_1 = 2A, A_2 = 2A, \phi = 60^\circ$

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

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

$$= A\sqrt{12}$$

as intensity $\propto$ (Amplitude)^2

Therefore, $\quad I \propto 12A^2$

54. (*a*) Fringe spacing

$$\beta = \frac{D\lambda}{d} = \frac{1\times 5\times 10^{-7}}{1\times 10^{-3}}\text{ m} \ (1\text{ nm} = 10^{-9}\text{ m})$$

$$= 5\times 10^{-4}\text{ m} = 0.5\text{ mm}$$

55. (*d*) Position of *n*th bright fringe from central maxima is $\frac{n\lambda D}{d}$.

$$\therefore \quad \frac{8\lambda_1 D}{d} = \frac{9\lambda_2 D}{d}$$

$$\Rightarrow \quad \frac{\lambda_1}{\lambda_2} = \frac{9}{8}$$

Hence, the possible wavelengths of visible light is of the ratio of 9 : 8.

56. (*d*) $\lambda_1 = 6000$ Å, $n_1 = 16$ fringes and $n_2 = 24$ fringes

Position of *n*th fringe, $\frac{nD\lambda}{d} \Rightarrow n_1\lambda_1 = n_2\lambda_2$

$$\Rightarrow \quad \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1} \Rightarrow \frac{6000}{\lambda_2} = \frac{24}{16}$$

$$\Rightarrow \quad \lambda_2 = \frac{6000 \times 16}{24} = \frac{96000}{24} = 4000 \text{ Å}$$

57. (*c*) Suppose slit width are equal, so they produces wave of equal intensity say I'. Resultant intensity at any point $I_R = 4I' \cos^2 \phi$, where ϕ is the phase difference between the moves at the point of observation. For maximum intensity.

$$\phi = 0 \Rightarrow I_{max} = 4I' = I \quad \ldots\text{(i)}$$

Also, when one slit is closed

$$I' = I_0 \quad \ldots\text{(ii)}$$

From Eqs. (i) and (ii), we get $4I_0 = I$

58. (*a*) Position of 10th bright fringe $= \frac{10\lambda D}{d}$

Also, $\frac{10\lambda D}{d} = 12$

$$\Rightarrow \quad d = \frac{10\lambda D}{12}$$

The separation between the slits

$$= \frac{10 \times 589.3 \times 10^{-9} \times 1}{12 \times 10^{-3}}$$

$$= 4.9 \times 10^{-4} \text{ m} = 0.49 \text{ mm}$$

59. (*c*) $\mu = \frac{\lambda_{air}}{\lambda_{water}}$

Using Eq. (iii), we get

$$\frac{\omega_1}{\omega_2} = \frac{\mu_{water}}{\mu_{air}} = \frac{4}{3}$$

60. (*b*) Here, $\lambda = 500$ nm, $d = 1$ mm, $D = 1$ m

Distance of 3rd minima *i.e.*, $x_n = \left(n + \frac{1}{2}\right)\frac{\lambda D}{d}$

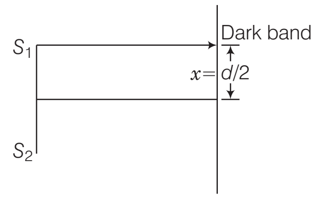
$$x_3 = \left(2 + \frac{1}{2}\right)\frac{\lambda D}{d}$$

$$\Rightarrow \quad x = \frac{5\lambda D}{2d}$$

$$= \frac{5 \times 500 \times 10^{-9} \times 1}{2 \times 1 \times 10^{-3}}$$

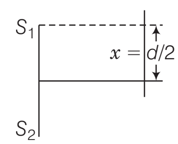
$$= 12.5 \times 10^{-4} \text{ m} = 1.25 \text{ mm}$$

61. (*d*) Since, dark fringe is directly opposite to one of the slits,



$\therefore$ Distance of the dark fringe from central maxima $= \frac{d}{2}$

Position of *n*th dark fringe $= \frac{\lambda D}{2d}(2n - 1)$



$$\text{or} \quad \frac{d}{2} = (2n - 1)\frac{\lambda D}{2d}$$

$$\Rightarrow \quad \lambda = \frac{d^2}{D(2n - 1)}$$

$\Rightarrow$ For $n = 1$, $\lambda = \frac{d^2}{D}$

62. (*c*) Position of *n*th maximum from central maxima

$$= \frac{n\lambda D}{d} \Rightarrow x_n \propto \lambda$$

So, x(blue) < x (green) as

$$\lambda_{blue} < \lambda_{green}$$

63. (*d*) Given, $d = 0.90$ mm $= 0.90 \times 10^{-3}$, $D = 1$ m

Position of 2nd dark fringe from central fringe

$$= \frac{3\lambda D}{2d} = 1 \times 10^{-3} \text{ m}$$

$$\Rightarrow \quad 1 \times 10^{-3} = \frac{3 \times \lambda \times 1}{2 \times 0.90 \times 10^{-3}}$$

$$\therefore \quad \lambda = \frac{1.8 \times 10^{-6}}{3} = 0.6 \times 10^{-6} \text{ m} = 6 \times 10^{-5} \text{ cm}$$

64. (*b*) Given, $\lambda_1 = 12000$ Å and $\lambda_2 = 10000$ Å,

$D = 2$ cm and $d = 2$ mm $= 2 \times 10^{-3}$ cm.

We have $\frac{\lambda_1}{\lambda_2} = \frac{12000}{10000} = \frac{6}{5} = \frac{n_2}{n_1}$

$$\text{as} \quad x = \frac{n_1\lambda_1 D}{d} = \frac{5 \times 12000 \times 10^{-10} \times 2}{2 \times 10^{-3}}$$

$$= 5 \times 1.2 \times 10^4 \times 10^{-10} \times 10^3 = 6 \text{ mm}$$

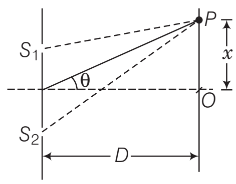
65. (*a*) The fringe width *i.e.*, $\beta_1 = \frac{\lambda D_1}{d}$ and $\beta_2 = \frac{\lambda D_2}{d}$

So, $\beta_1 - \beta_2 = \frac{\lambda}{d}(D_1 - D_2)$

$$\Rightarrow \quad 3 \times 10^{-5} = \frac{\lambda}{10^{-3}}(5 \times 10^{-2})(\because D_1 - D_2 = 5 \times 10^{-2} \text{ m})$$

$$\Rightarrow \quad \lambda = \frac{3}{5} \times \frac{10^{-8}}{10^{-2}} = 0.6 \times 10^{-6} \text{ m} = 6000 \text{ Å}$$

66. (*d*)



Angular position of first dark fringe $= \tan\theta \approx \theta = \dfrac{x}{D}$

$$\Rightarrow \quad \theta = \frac{\lambda}{2d} = \frac{5460\times10^{-10}}{0.1\times10^{-3}} \qquad \left(\because x = \frac{\lambda D}{2d}\right)$$

$$= 54600\times10^{-7}\ \text{rad}$$

As, we know, $\theta\ (\text{in degree}) = \dfrac{180}{\pi}\times 546\times10^{-5}$

$$= \frac{180}{22}\times 7\times 546\times10^{-5} \approx \frac{0.32}{2} = 0.16^\circ$$

67. (*d*) $\quad \beta = \dfrac{\lambda D}{d}$

$$\therefore \quad \frac{\beta_2}{\beta_1} = \frac{\lambda_2\, D_2\, d_1}{\lambda_1\, D_1\, d_2}$$

$$\Rightarrow \quad \beta_2 = \frac{\beta_1\times\lambda_2\times 2D_1\times d_1}{\lambda_1\times D_1\times d_1/2}$$

$$\Rightarrow \quad \beta_2 = \beta\times\frac{\lambda_2}{\lambda_1}\times 4$$

$$\Rightarrow \quad \beta_2 = 2.5\times10^{-4}\ \text{m}$$

68. (*b*) Resultant intensity, $I_R = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\Delta\phi$

Case I (at A) $\Delta\phi = \pi/2$

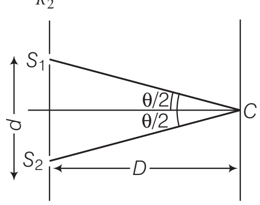
$$I_{R_1} = I_1 + I_2 = I + 4I = 5I$$

Case II (at B) $\Delta\phi = \pi$

$$I_{R_2} = I_1 + I_2 - 2\sqrt{I_1 I_2} = 5I - 2\times 2I = I$$

$$\therefore \quad I_{R_1} - I_{R_2} = 5I - I = 4I$$

69. (*a*)



So, distance between two slits *i.e.,* S_1 and S_2

$$d = (2\tan\theta/2)\,D$$

For small angles θ, $\tan\theta \approx \theta$

$$\Rightarrow \quad d = 2\times\frac{\theta}{2}\times D = D\theta \quad \text{or} \quad \frac{D}{d} = \frac{1}{\theta}$$

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

70. (*b*) Length of segment = constant

$$\Rightarrow \quad n_1\omega_1 = n_2\omega_2 \quad \Rightarrow \quad n_1\lambda_1 = n_2\lambda_2$$

$$\text{or} \quad n_2 = n_1\frac{\lambda_1}{\lambda_2} = 12\times\frac{600}{400} = 18$$

71. (*a*) In liquid position of 10th bright fringe, $x_n = \dfrac{n\lambda_l D}{d}$

$$\Rightarrow \quad x = \frac{10\lambda_l D}{d}$$

where, λ_l = wavelength in liquid.

$\because$ Position of dark fringe $= (2n-1)\dfrac{\lambda D}{2d}$ ...(i)

In vacuum position of 6th dark fringe $= \dfrac{11\lambda_{\text{air}} D}{2d}$

[put $n = 6$ in Eq (i)]

Since, 10th bright fringe in liquid is located at 6th dark fringe in air,

$$\Rightarrow \quad \frac{10\lambda_l D}{d} = \frac{11\cdot\lambda_{\text{air}} D}{2d} \quad \Rightarrow \quad \frac{\lambda_l}{\lambda_{\text{air}}} = \frac{5.5}{10}$$

$$\text{Also,} \quad \frac{\lambda_l}{\lambda_{\text{air}}} = \frac{\mu_{\text{air}}}{\mu_l} \quad \Rightarrow \quad \frac{1}{\mu_l} = \frac{5.5}{10}$$

$$\text{or} \quad \mu_l = \frac{10}{5.5} = \frac{20}{11} = 1.8$$

72. (*b*)

$$I = I_{\max}\cos^2\frac{\phi}{2} \qquad \text{...(i)}$$

$$\text{Given,} \quad I = \frac{I_{\max}}{2} \qquad \text{...(ii)}$$

$\therefore$ From Eqs. (i) and (ii), we have, $\phi = \dfrac{\pi}{2}, \dfrac{3\pi}{2}, \dfrac{5\pi}{2}$

Or path difference, $\Delta x = \left(\dfrac{\lambda}{2\pi}\right)\cdot\phi$

$$\therefore \quad \Delta x = \frac{\lambda}{4}, \frac{3\lambda}{4}, \frac{5\lambda}{4}\ldots\left(\frac{2n+1}{4}\right)\lambda$$

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

73. (*a*) Fringe width

$$\textit{i.e.,} \quad \beta = \frac{\lambda D}{d} = \frac{600\times10^{-9}\times 2}{2\times10^{-3}} = 6\times10^{-4}\ \text{m}$$

$$\text{Using,} \quad I = I_{\max}\cos^2\frac{\pi x}{\beta}$$

$$\Rightarrow \quad I = 0.20\cos^2\left(\frac{\pi\ 0.5\times10^{-2}}{6\times10^{-4}}\right)$$

$$\Rightarrow \quad I = 0.20\cos^2\left(\frac{100\pi}{12}\right) = 0.20\cos^2\frac{25\pi}{3}$$

$$\text{or} \quad I = 0.20\cos^2\left(8\pi + \frac{\pi}{3}\right)$$

$$\Rightarrow \quad I = 0.20\cos^2\frac{\pi}{3} = 0.20\times\frac{1}{4} = 0.05\ \text{Wm}^{-2}$$

74. (*c*) As we know, fringe width $\beta_1 = \dfrac{\lambda D}{d}$

$$\beta_2 = \lambda\left(\frac{2D}{2d}\right) = \frac{\lambda D}{d}$$

$$\Rightarrow \quad \beta_1 = \beta_2$$

75. (c) Let nth fringe of 1500 Å coincide with $(n-2)$th fringe of 2500 Å

$\therefore \quad 1500 \times n = 2500 \times (n-2)$

$$3n = 5(n-2)$$
$$3n = 5n - 10$$
$$2n = 10$$
$$\Rightarrow \quad n = 5$$
$$(n-2) = 3$$

$\therefore$ 5th order of 1st and 3rd order of 2nd.

76. (b) In YDSE, as we know

Intensity, $\quad I = I_{max} \cos^2 \frac{\Delta\phi}{2}$

$$\Rightarrow \quad \frac{I_{max}}{2} = I_{max} \cos^2 \frac{\Delta\phi}{2}$$

$$\cos^2 \frac{\Delta\phi}{2} = \frac{1}{2} \Rightarrow \frac{\Delta\phi}{2} = \left(\frac{2n+1}{4}\right)\pi, \qquad n = 0, 1, 2, \ldots$$

$$\Delta\phi = \left(\frac{2n+1}{2}\right)\pi$$

$$\Rightarrow \quad \Delta x = \frac{\Delta\phi}{2\pi} \times \lambda \qquad \text{(Here, } \Delta x \text{ is path difference)}$$

$$= \left(\frac{2n+1}{2}\right)\pi \times \frac{\lambda}{2\pi} = \left(\frac{2n+1}{4}\right)\lambda$$

77. (c) Fringe width, $\beta = \frac{\lambda D}{d}$ ...(i)

According to the question,

$$D' = \frac{D}{2} \text{ and } d' = 5d$$

$$\therefore \quad \beta' = \frac{D'\lambda}{d'} = \frac{\left(\frac{D}{2}\right)\lambda}{5d} = \frac{1}{10}\frac{D\lambda}{d}$$

$$\beta' = \frac{\beta}{10} \qquad \text{[from Eq. (i)]}$$

78. (b) Here, $\beta_1 = 3.2 \times 10^{-4}$ m

$$\lambda_1 = 5600 \text{Å}, \ \lambda_2 = 4200 \text{Å}$$
$$\frac{\beta_2}{\beta_1} = \frac{\lambda_2}{\lambda_1} = \frac{4200}{5600}$$

or $\quad \beta_2 = \frac{6}{8} \times \beta_1$

$$= \frac{6}{8} \times 3.2 \times 10^{-4} = 2.4 \times 10^{-4} \text{ m}$$

Decrease in fringe width,

$$\Delta\beta = \beta_1 - \beta_2$$
$$= (3.2 - 2.4) \times 10^{-4} = 0.8 \times 10^{-4} \text{ m}$$

79. (c) For net intensity, $\quad I = 4I_0 \cos^2 \frac{\phi}{2} \left(\phi = \frac{2\pi}{\lambda} \times \lambda\right)$

For the first case,

$$K = 4I_0 \cos^2 (\pi)$$
$$K = 4I_0 \qquad \ldots\text{(i)}$$

For the second case,

$$K' = 4I_0 \cos^2 \left(\frac{\pi/2}{2}\right)\left(\phi = \frac{2\pi}{\lambda} \times \frac{\lambda}{4}\right)$$
$$= 4I_0 \cos^2 (\pi/4)$$
$$K' = 2I_0 \qquad \ldots\text{(ii)}$$

Comparing Eqs. (i) and (ii),

$$K' = K/2$$

80. (c) The contrast interference will occur when there is absolute darkness at the dark band due to destructive interference $i.e.$, $I_R = I_{min} = 0$ and there is complete (max.) brightness at the bright band due to constructive interference $i.e.$, $I_R = I_{max} = 4I_0$, which is possible only when individual intensities are same,

So, $\quad I_1 = I_2 = I_0$

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

82. (d) By using white light, the central maxima will be white while the fringes closest on either side of central fringe is red and farthest will appear blue.

83. (d) Diffraction is observed when slit width is of the order of wavelength of light (or any electromagnetic wave) used.

$\therefore \quad \lambda_{\text{X-rays}}$ (1 – 100Å) << slit width (0.6 mm)

$\Rightarrow$ So, no pattern of diffraction will be observed.

84. (b) As, the path difference $a\theta$ is λ,

then $\quad \theta = \frac{\lambda}{a}$

$$\Rightarrow \quad \frac{10\lambda}{d} = \frac{2\lambda}{a} \Rightarrow a = \frac{d}{5} = \frac{10}{5} = 0.2 \text{ mm}$$

So, the width of each slit is 0.2 mm.

85. (c) The direction in which the first minima occurs is θ (say).

Then, $\quad e\sin\theta = \lambda$ or $e\theta = \lambda$ or $\theta = \frac{\lambda}{e}$

($\because \theta = \sin\theta$, when θ is small)

Width of the central maxima $= 2b\theta + e = \frac{2\lambda b}{e} \pm e$

86. (d) Given, $\lambda = 6000$ Å $= 6000 \times 10^{-10}$ m, $d = 0.3$ mm

For minima, $\quad d\sin\theta = m\lambda$

First minima means $(m = 1)$,

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

Angular position of 1st minima,

$$\sin\theta = \theta = \frac{\lambda}{d} = \frac{6000 \times 10^{-10}}{0.3 \times 10^{-3}} = 2 \times 10^{-3} \text{ rad}$$

So, angular position of first minima is 2×10^{-3} rad.

87. (b) Given, $\lambda = 589$ nm $= 589 \times 10^{-9}$ m, $D = 1.0$ m

Slit width $= d = ?$

Here, given the distance between two dark fringes ($i.e.$, dark fringes for $m = \pm 1$)

$$= \text{ width of central maximum} = 2y = 2.2 \text{ mm}$$

or $\quad y = 1.1 \text{ mm} = 1.1 \times 10^{-3}$ m

Using, for zero intensities path difference = $m\lambda$,

we have $\frac{dy}{D} = m\lambda$

Slit width *i.e.*, $d = \frac{m\lambda D}{y} = \frac{(1)(589\times 10^{-9}\text{ m})\times(1.0\text{ m})}{1.1\times 10^{-3}\text{ m}}$

$= 0.54$ mm

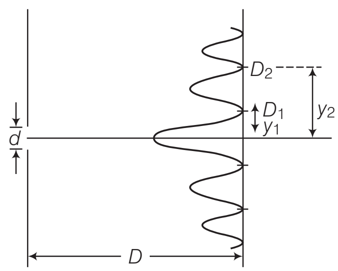
88. (*a*) Width of central maximum

$$(\Delta y_0) = 2y = \frac{2\lambda D}{d} \quad \ldots(i)$$

Width of 1st order secondary maxima

= Distance between D_1 and D_2 (consecutive dark bands)

$= y_2 - y_1$



For secondary minima (or dark band) path difference

$= d\sin\theta = m\lambda$ (where, $m = 1, 2, 3, \ldots$)

Position of 1st dark band

Path difference $= \frac{y_1 d}{D} = \lambda$ or $y_1 = \frac{\lambda D}{d}$

Position of 2nd dark band

Path difference $= \frac{y_2 d}{D} = 2\lambda \Rightarrow y_2 = \frac{2\lambda D}{d}$

$\therefore$ Width of secondary maxima (Δy_1)

$\Rightarrow \Delta y_1 = y_2 - y_1$ or $\Delta y_1 = \frac{\lambda D}{d} = y$

Thus, width of other secondary maxima is half that of central maxima.

or $\frac{\Delta y_0}{\Delta y_1} = \frac{2}{1}$

89. (*c*) Phase difference $= \Delta\phi = \frac{2\pi}{\lambda}\times(d\sin\theta)$

(for two end of slit)

For first order diffraction maximum,

$d\sin\theta = (2m+1)\frac{\lambda}{2}$,

where $m = 1 = \frac{3\lambda}{2} \Rightarrow \Delta\phi = \frac{2\pi}{\lambda}\times\frac{3\lambda}{2} = 3\pi$

90. (*c*) For minima,

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

$\Rightarrow a\sin 30° = (1)\lambda \quad (n = 1)$

$\Rightarrow a = 2\lambda \quad \left\{\because \sin 30° = \frac{1}{2}\right\} \quad \ldots(i)$

For 1st secondary maxima

$\Rightarrow a\sin\theta_1 = \frac{3\lambda}{2} \Rightarrow \sin\theta_1 = \frac{3\lambda}{2a} \quad \ldots(ii)$

Substitute value of a from Eq. (i) to Eq. (ii), we get

$$\sin\theta_1 = \frac{3\lambda}{4\lambda} \Rightarrow \sin\theta_1 = \frac{3}{4}$$

$$\theta_1 = \sin^{-1}\frac{3}{4}$$

92. (*c*) For 2nd secondary maxima using red light

$$d\sin\theta_1 = \frac{(2m+1)\lambda_1}{2}, \text{ where } m = 2$$

$$d\sin\theta_1 = \frac{5\lambda_1}{2} \Rightarrow \sin\theta_1 = \frac{5\lambda_1}{2d} \quad \ldots(i)$$

When white light is used, for position of 3rd secondary maxima ($m = 3$)

$$d\sin\theta_2 = \frac{7\lambda_2}{2} \Rightarrow \sin\theta_2 = \frac{7\lambda_2}{2d} \quad \ldots(ii)$$

Since, the position coincide with each other for white and red light

$$\sin\theta_1 = \sin\theta_2 \Rightarrow \frac{5\lambda_1}{2d} = \frac{7\lambda_2}{2d}$$

$\Rightarrow \lambda_2 = \frac{5}{7}\lambda_1 = \frac{5}{7}\times 6500$ Å

Wavelength of white light, $\lambda_2 = 4642.85$ Å

93. (*c*) Using violet light

Slit width = d, $\lambda_1 = 400\times 10^{-9}$ m

Width of diffraction pattern (central maxima)

$$= 2y = \frac{2\lambda_1 D}{d} \quad \ldots(i)$$

Slit width $= \frac{d}{2}$ (as half covered)

$$\lambda_2 = 600\times 10^{-9}\text{ m}$$

Width of diffraction pattern(Central maxima)

$$= 2y' = \frac{2\lambda_2 D}{(d/2)} \quad \ldots(ii)$$

From Eqs. (i) and (ii), $\frac{y}{y'} = \frac{\lambda_1}{2\lambda_2}$

$\Rightarrow \frac{y}{y'} = \frac{400}{600\times 2} = \frac{2}{3\times 2} = \frac{1}{3} \Rightarrow y' = 3y$

94. (*d*) Distance between the first dark fringes on either side of the central bright fringe = Width of central maxima

$$2y = \frac{2\lambda D}{d} = \frac{2\times 600\times 10^{-9}\times 2}{1\times 10^{-3}}$$

$$= 24\times 10^{-4}\text{ m} = 2.4\text{ mm}$$

95. (*a*) Angular width of central maxima $(2\theta) = \frac{2\lambda}{d} = \frac{2\lambda}{e}$

$\Rightarrow 2\theta \propto \frac{\lambda}{e} \Rightarrow \theta \propto \frac{1}{e}$ (for λ = constant)

Thus, on decreasing slit width (e), then θ will increases.

96. (*c*) Angular width of central maxima $= 2\theta = \frac{2\lambda}{d}$.

Thus, θ does not depend on D *i.e.*, distance between the slits and the screen.

97. (*a*) Here, $\lambda = 4000\,\text{Å} = 4000 \times 10^{-10}\ \text{m} = 4 \times 10^{-7}\ \text{m}$

$$a = 0.2\ \text{mm} = 0.2 \times 10^{-3}\ \text{m} = 2 \times 10^{-4}\ \text{m}$$

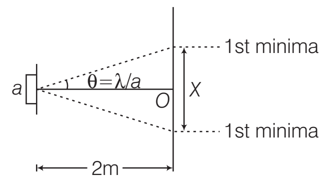
$$\sin\theta = \frac{\lambda}{a} = \frac{4 \times 10^{-7}\text{m}}{2 \times 10^{-4}\text{m}} = 2 \times 10^{-3}$$

As $\sin\theta$ is very small

$$\therefore \quad \theta \cong \sin\theta = 2 \times 10^{-3}\ \text{rad}$$

98. (*d*) From the figure, $\tan\theta = \frac{x/2}{2}$

For small θ and when θ is counted in rad, $\tan\theta \simeq \theta$



Width of central maximum $= \frac{2\lambda D}{d} = 2.4$ mm

So, $$\theta \simeq \frac{x/2}{2} \Rightarrow \frac{\lambda}{9} \simeq \frac{x}{4}$$

$$x \simeq \frac{4\lambda}{a} \simeq \frac{4 \times 600 \times 10^{-9}}{10^{-3}}$$

$$\simeq 24 \times 10^{-4}\ \text{m} \simeq 2.4 \times 10^{-3}\ \text{m}$$

$$\Rightarrow \quad \simeq 2.4\ \text{mm}$$

99. (*b*) Angular width, $\theta = \frac{\lambda}{d}$

$$\therefore \quad \frac{\theta_1}{\theta_2} = \frac{\lambda_1}{\lambda_2} \Rightarrow \frac{\theta_1}{\theta_2} = \frac{\lambda_1}{\lambda_1/\mu}$$

$$\Rightarrow \quad \frac{\theta_1}{\theta_2} = \mu \qquad \text{(refractive index)}$$

$$\therefore \quad \theta_2 = \frac{\theta_1}{\mu} = \frac{3}{4} \times 0.2 = 0.15°$$

100. (*b*) In water angular width $\theta_w = 0.2°$ (given)

We know, $$\theta_w = \frac{\lambda_{\text{water}}}{d} \qquad \ldots\text{(i)}$$

Let μ_{water} = refractive index of water

In air,

$$\theta_{\text{air}} = \frac{\lambda_{\text{air}}}{d} \qquad \ldots\text{(ii)}$$

On dividing Eq. (i) from Eq. (ii), we get

$$\frac{\theta_w}{\theta_{\text{air}}} = \frac{\lambda_{\text{water}}}{\lambda_{\text{air}}}$$

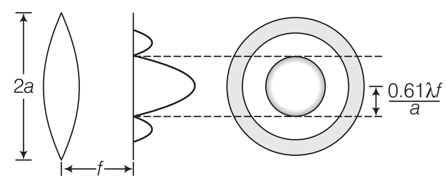
or $$\frac{\theta_w}{\theta_{\text{air}}} = \frac{\mu_{\text{air}}}{\mu_{\text{water}}} = \frac{1}{\mu_{\text{water}}} \qquad \left(\because \frac{\lambda_{\text{air}}}{\lambda_{\text{water}}} = \frac{\mu_{\text{water}}}{\mu_{\text{air}}}\right)$$

$$\Rightarrow \quad \theta_{\text{air}} = \mu_{\text{water}}\theta_w = \frac{4}{3} \times 0.2° \approx 0.28°$$

101. (*b*) The angular resolution of the telescope is determined by the objective of the telescope.

102. (*a*) Radius of the central bright region is approximately given by

$$r_0 \approx \frac{1.22\lambda f}{2a} = \frac{0.61\lambda f}{a}$$



103. (*a*) Thus, $\Delta\theta$ will be small if the diameter of the objective is large. This implies that the telescope will have better resolving power, if a is large. It is for this reason that for better resolution, a telescope must have a large diameter objective.

104. (*a*) Resolving power of telescope (RP) $= \frac{1}{\Delta\theta} = \frac{D}{1.22\,\lambda}$

where, D = diameter of objective, λ = wavelength of light

Given, $D = 6\,\text{cm} = 6 \times 10^{-2}$ m, $\lambda = 540\ \text{nm} = 540 \times 10^{-9}$ m

$$\Rightarrow \quad \text{RP} = \frac{6 \times 10^{-2}}{1.22 \times 540 \times 10^{-9}}\,\text{rad}^{-1}$$

$$= \frac{6000 \times 10^4}{540 \times 1.22}\,\text{rad}^{-1} = 9.1 \times 10^4\ \text{rad}^{-1}$$

105. (*a*) Aperture of the telescope

$$D = \frac{1.22\,\lambda}{d\theta}$$

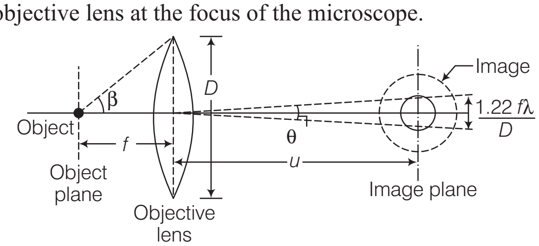
Here $\lambda = 5600\,\text{Å} = 5600 \times 10^{-10}$ m, $d\theta = 3.2 \times 10^{-6}$ rad

$$\therefore \quad D = \frac{1.22 \times 5600 \times 10^{-10}}{3.2 \times 10^{-6}} \Rightarrow D = 0.2135\ \text{m}$$

106. (*c*) The objective lens of a microscope, the object is placed slightly beyond f, so that a real image is formed at a distance v [figure]. The magnification ratio of image size to object size is given by $m \approx v/f$. It can be seen from figure that

$$D/f \approx 2\tan\beta \qquad \ldots\text{(i)}$$

where, 2β is the angle subtended by the diameter of the objective lens at the focus of the microscope.



107. (*b*) If the medium between the object and the objective lens is not air but a medium of refractive index n,

$$d_{\min} = \frac{1.22\,\lambda}{2n\sin\beta}$$

108. (*d*) For compound microscope,

Resolving power

i.e., $$\text{RP} = \frac{2\mu\,\sin\beta}{1.22\,\lambda}$$

(i) $\because$ RP $\propto \mu$

If the refractive index (μ) of the medium between the object and the objective lens increases, the resolving power increases.

(ii) $\because$ RP $\propto \dfrac{1}{\lambda}$

On increasing the wavelength of light used, the resolving power of microscope decreases and *vice-versa.*

109. (*a*) In Fresnel biprism experiment, the actual distance of separation between the two slits,

$$d = \sqrt{d_1 d_2} = \sqrt{25 \times 16} = 20\,\text{cm}$$

110. (*a*) According to Fresnel distance, Z_F *i.e.,* $Z_F = \dfrac{a^2}{\lambda}$

$$= \frac{(3\times 10^{-3})^2}{5\times 10^{-7}} = \frac{9\times 10^{-6}}{5\times 10^{-7}} = 18\text{ m}$$

112. (*d*) Light waves are transverse in nature; *i.e.*, the electric field associated with a propagating light wave is always at right angles to the direction of propagation of the wave. We can say light waves are transverse electromagnetic waves.

113. (*b*) Polaroids can be used to control the intensity in sunglasses windowpanes, etc. The intensity can be further controlled from 50% to zero of the incident intensity by adjusting the angle between the pass-axes of two polaroids.

114. (*b*) The phenomenon of polarisation is based on the fact that light waves are transverse electromagnetic waves.

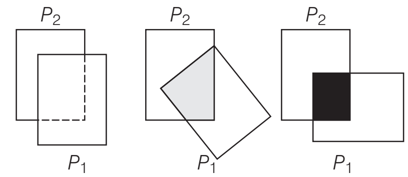
Light waves are transverse in nature *i.e.*, the electric field associated with a propagating light wave is always at right angles to the direction of propagation of the wave.

115. (*b*) Ultrasonic waves being sound waves are longitudinal and hence cannot be polarised.

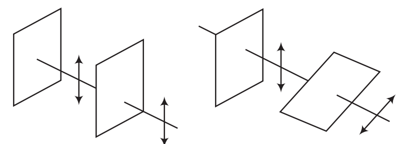
116. (*b*) Some crystals such as tourmaline and sheets of iodosulphate of quinine have the property of strongly absorbing the light with vibrations perpendicular to a specific direction (called pass axis), transmitting the light with vibration parallel to it. This selective absorption of light called dichroism.

117. (*a*) Plane of vibration is perpendicular to the direction of propagation and also perpendicular to plane of polarisation. Thus, the angle between plane of polarisation and direction of vibration is 0° *i.e*, they are parallel.

118. (*a*) If an identical piece of polaroid P_2 be placed before P_1. As expected, the light from the lamp is reduced in intensity on passing through P_2 alone. But now rotating P_1 has a dramatic effect on the light coming from P_2. In one position, the intensity transmitted by P_2 followed by P_1 is nearly zero. When turned by 90° from this position, P_1 transmits nearly the full intensity emerging from P_2 as shown figure.



(a)



(b)

119. (*a*) Suppose I_0 be the intensity of polarised light after passing through the first polariser P_1. Then, the intensity of light after passing through second polariser will be

$$I = I_0 \cos^2\theta$$

where, θ is the angle between pass axes of P_1 and P_2. Since, P_1 and P_3 are crossed the angle between the pass axes of P_2 and P_3 will be $\left(\dfrac{\pi}{2} - \theta\right)$.

Hence, the intensity of light emerging from P_3 will be

$$I = I_0 \cos^2\theta \cos^2\left(\frac{\pi}{2} - \theta\right)$$

$$= I_0 \cos^2\theta \cdot \sin^2\theta = \left(\frac{I_0}{4}\right)\sin^2 2\theta$$

Therefore, the transmitted intensity will be maximum when $\theta = \pi/4$.

120. (*d*) Given, $i + r = \pi / 2$

According to Brewster's law, we get

$$\tan i_B = \mu = 1.5$$

So, $$i_B = \tan^{-1}(1.5) \Rightarrow i_B = 57°$$

i.e., this is the Brewster's angle for air to glass interface.

121. (*a*) In unpolarised beam, vibrations are probable in all directions in a plane perpendicular to the direction of propagation. Therefore, θ can have any value from 0 to 2π.

$$[\cos^2\theta]_{\text{av}} = \frac{1}{2\pi}\int_0^{2\pi} \cos^2\theta\, d\theta = \frac{1}{2\pi}\int_0^{2\pi}\left(\frac{1+\cos 2\theta}{2}\right)d\theta = \frac{1}{2}$$

So, using law of Malus, $I = I_0 \cos^2\theta \Rightarrow I_0 = I_0 \times \dfrac{1}{2} = \dfrac{I_0}{2}$

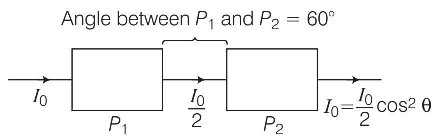
122. (*b*) When an unpolarised beam of light is incident at the Brewster's angle on an interface of two media, only part of light with electric field vector perpendicular to the plane of incidence will be reflected. Now, by using a good polariser, if we completely remove all the light with its electric vector perpendicular to the plane of incidence and let this light be incident on the surface of the prism at Brewster's angle, we will observe no reflection and there will be total transmission of light.

123. (*c*) In the special situation, one of the two perpendicular components of the electric field is zero. At other angles, both components are present but one is stronger than the other.

There is no stable phase relationship between the two perpendicular components, since these are derived from two perpendicular components of an unpolarised beam.

When such light is viewed through a rotating analyser, one sees a maximum and a minimum of intensity but not complete darkness. This kind of light is called partially polarised.

124. (*d*)

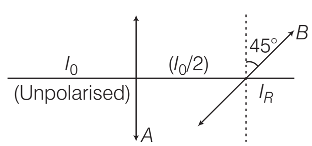


Intensity of light emerging from P_2 is $I = \frac{I_0}{2}\cos^2\theta$

where, $\theta = \angle$angle between P_1 and P_2

so, $I = \frac{I_0}{2}\cos^2 60° = \frac{I_0}{8}$

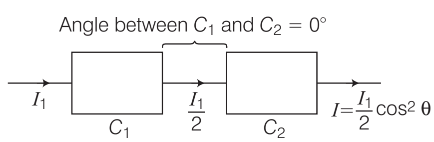
125. (*c*)



According to Malus law,

$$I_R = \left(\frac{I_0}{2}\right)\cos^2(45°) = \frac{I_0}{2} \times \frac{1}{2} = \frac{I_0}{4}$$

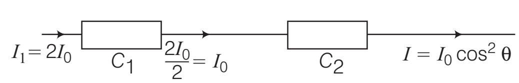
126. (*c*) **Case I** Since, ray emergent from C_2 has intensity.



$$I = \frac{I_1}{2}\cos^2\theta = \frac{I_1}{2}\cos^2 0° = \frac{I_1}{2}$$

or $\frac{I_1}{2} = I_0 \Rightarrow I_1 = 2I_0$

Case II Angle between C_1 and C_2 = 60°



Intensity of emergent ray $= I_0\cos^2 60° = I_0\left(\frac{1}{2}\right)^2 = \frac{I_0}{4}$

127. (*a*) If unpolarised light is incident at polarising angle, then reflected light is completely *i.e.*, 100% polarised perpendicular to the plane of incidence.

128. (*b*) $\tan i_B = \mu$, where i_B = polarising or Brewster's angle

$\Rightarrow \quad i_B = \tan^{-1}(\mu) = \tan^{-1}(\sqrt{3}) = 60°$

129. (*a*) Here, Critical angle, $i_c = \sin^{-1}\left(\frac{4}{5}\right)$

$\therefore \quad \sin i_c = \frac{4}{5}$

As $\quad \mu = \frac{1}{\sin i_c} = \frac{5}{4}$

According to Brewster's law,

$\tan i_p = \mu$

where, i_p is the polarising angle

$\therefore \quad \tan i_p = \frac{5}{4} \Rightarrow i_p = \tan^{-1}\left(\frac{5}{4}\right)$

130. (*b*) As reflected light is completely polarised, therefore

$i_p = 45°$

$\mu = \tan i_p = \tan 45° = 1$

As $\quad \mu = \frac{c}{v}$

$\Rightarrow \quad v = \frac{c}{\mu} = \frac{3 \times 10^8}{1} \Rightarrow v = 3 \times 10^8 \text{ ms}^{-1}$

131. (*b*) Using $\tan i_p = \mu$

$\tan i_p = 1$

$i_p = \tan^{-1}(1) = 45°$

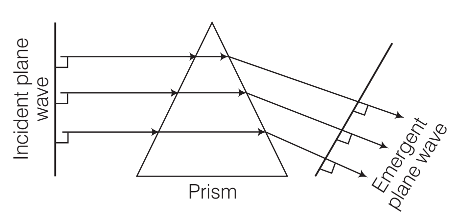
As $\quad r = 90° - i_p = 90° - 45° \Rightarrow r = 45°$

132. (*d*) Using, $\tan i_p = \mu = 1.5 \Rightarrow i_p = \tan^{-1}(1.5) = 56.3°$

133. (*a*) The branch of optics in which one completely neglects the finiteness of the wavelength is called geometrical optics. The wavelength of light is very small as compared to the dimensions of objects (such as mirror, lenses etc.) and hence, it can be neglected and assumed to travel in a straight line.

134. (*b*) Reflection and refraction arise through interaction of incident light with constituents of matter. Atoms may be viewed as oscillators, which take up the frequency of the external agency (light) causing forced oscillations. The frequency of light emitted by a charged oscillator equals its frequency of oscillation. Thus, the frequency of scattered light equals the frequency of incident light.

135. (*c*) Since, the speed of light waves is less in glass, the lower portion of the incoming wavefront (which travels through the greatest thickness of glass) will get delayed resulting in a tilt in the emerging wavefront.



136. (*a*) According to Huygens' principle each point of the wavefront is the source of a secondary disturbance and the wavelets emanating from these point spread out in all directions with the space of wave.

These wavelets emanating from the wavefront are usually referred to as secondary wavelets and if we draw a common tangent to all these spheres, we obtain the new position of the wavefront at a later time.

137. (*a*) Increase in wavelength of light when the source move away from the observer due to Doppler's effect is called red shift. The visible regions shifts towards red end of electromagnetic spectrum and hence called red shift.

138. (*a*) As, we know, fringe width β *i.e.*,$= \dfrac{\lambda D}{d}$

So, smaller the distance between the slits (d), then larger will be fringe width (β).

Hence, single fringe will cover whole screen and pattern will not be visible.

139. (*b*) Given, initial phase difference $= \phi_{S_1} - \phi_{S_2} = \pi$

At central maximum, $\Delta x = 0$ (path difference $= \Delta x$)

$\Rightarrow$ Total phase difference $= \phi_{S_1} - \phi_{S_2} + \dfrac{2\pi}{\lambda}\Delta x$

At central maximum,

$$\Delta\phi = \pi + \frac{2\pi}{\lambda} \times \Delta x = \pi + 0$$

or $\Delta\phi = \pi =$ odd multiple of π.

Hence, at central maximum dark band is obtained.

140. (*b*)

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

141. (*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 interferring beam have different intensities or amplitudes.

Hence, intensity at minima will not be zero and fringes will become indistinct.

142. (*a*) For reflecting system of the film, the condition for maxima or constructive interference is

$2\mu t \cos r = \dfrac{(2n-1)}{2}\lambda$, 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.

143. (*c*) In Young's double slit experiment fringe width for dark and white fringes are same while in the same experiment, when a white light as source is used, the central fringe is white around while few coloured fringes are observed on either side.

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

145. (*a*) For diffraction to occur, the size of an obstacle/aperture is comparable to the wavelength of light wave. The order of wavelength of light wave is 10^{-7}, so diffraction occurs.

146. (*c*) Maxwell proposed that light must be an electromagnetic wave. Thus, according to Maxwell, light waves are associated with changing electric and magnetic fields. The changing electric and magnetic field result in the propagation of electromagnetic waves (or light waves) even in vacuum.

147. (*a*) The frequency of light emitted by a charged oscillator equal to its frequency of oscillation. So, the frequency of scattered light equals to the frequency of incident light.

148. (*c*) Red colour travels faster than violet in glass. Speed of light is independent of its colour only in vacuum.

For light travelling from medium 1 to medium 2,

$$\frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} = \frac{\mu_2}{\mu_1}$$

149. (*b*) $\mu = \dfrac{c}{v}$

Hence, the speed of light decreases in denser medium.

Energy carried by a wave depends on the amplitude of the wave, not on the speed of wave propagation. Energy remains same.

Also, intensity of wave $\propto$ (amplitude)^2 or $I \propto A^2$

150. (*a*) Only transverse waves can be polarised. Sound waves are longitudinal waves, so these waves cannot be polarised.

151. (*c*) $I_{max} = (\sqrt{I_1} + \sqrt{I_2})^2 = (2\sqrt{I_0})^2 = 4I_0$

The minimum intensity observed at dark band is given by

$$I_{min} = [\sqrt{I_1} - \sqrt{I_2}]^2$$

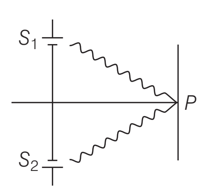
If $I_1 = I_2 = I_0, I_{min} = 0$

If $I_1 \neq I_2; I_{min} \neq 0$

152. (*a*) For centre of screen,

$S_1P - S_2P = 0 \Rightarrow \Delta L = 0$

$\Rightarrow \quad \Delta\phi = \dfrac{2\pi}{\lambda} \times \Delta L = 0$



So, waves meet in phase and results in intensity maxima or bright fringe due to constructive interference.

153. (*a*) Intensity is the amount of light energy falling per unit area per unit time. So, when a slit width is increased, area over which light falls increases and hence, more light energy falls and hence, intensity increases.

(Intensity from slit) $\propto$ slit width of each slit

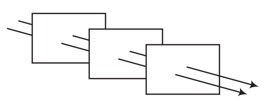
$\Rightarrow \quad I_{\text{max}} = (\sqrt{I_1} + \sqrt{I_2})^2 \quad \Rightarrow \quad I_{\text{min}} = (\sqrt{I_1} - \sqrt{I_2})^2$

So, maximum and minimum intensities both increase.

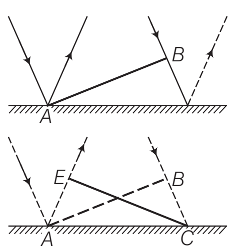
154. (*c*) Diffraction determines the limitations of the concept of light rays. A beam of width a travels a distance $\frac{a^2}{\lambda}$, called the fresnal distance, before it starts to spread out due to diffraction.

155. (*a*) Except photoelectric effect, all others phenomenon such as propagation of light in vacuum, interference and polarisation of light can be explained by wave theory of light. In photoelectric effect light behaves as it is made up of particles.

156. (*b*) For a point emitting waves uniformly in all to direction, the locus of points which have the same amplitude and vibrate in the same phase are spheres. But at a large distance from the source, the small portion of the sphere can be considered as plane wave as shown in Figure



157. (*c*) Figure shows AB as incident wavefront, so A and B are in same phase.



By the time B reaches C, secondary wavelet from A reaches E. So, points C and E are same time intervals apart as they are in same phase.

158. (*a*) When incident wave fronts passes through a prism, then lower portion of wavefront (B) is delayed resulting in a tilt. So, time taken by light to reach A' from A is equal to the time taken to reach B' from B.

159. (*c*) Frequency does not changes in reflection,

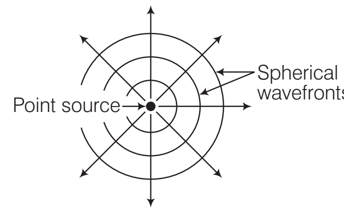
According to Snell's law of refraction, we get

$$\eta_w = \frac{v_{\text{air}}}{v_{\text{water}}} = \frac{\lambda_{\text{air}}}{\lambda_{\text{water}}}$$

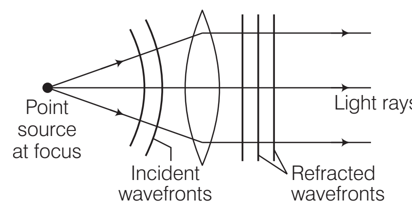
$\Rightarrow$ As wavelength *i.e.*, $\lambda_{\text{water}} = \frac{\lambda_{\text{air}}}{\eta_w} = \frac{\lambda_{\text{air}}}{4/3} = \frac{3}{4} \lambda_{\text{air}}$

So, wavelength of reflected light is more than that of refracted light.

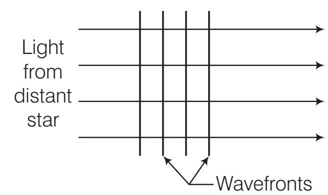
160. (*b*) **Case I** A light rays diverging from a point source.



Case II A light ray emerging out of convex lens when a point source is placed at its focus.



Case III A portion of the wavefront of light from a distant star intercepted by the earth.

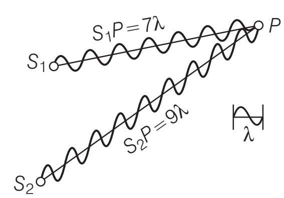


161. (*a*) It is given that $S_1P = 7\lambda$ and $S_2P = 9\lambda$

We have, $S_2P - S_1P = 9\lambda - 7\lambda$

$\Rightarrow \quad S_2P - S_1P = 2\lambda$

The waves emanating from S_1 will arrive exactly two cycles earlier than the waves from S_2 and will again be in phase.



162. (*a*) When interferring sources have same frequency and their phase difference remains constant with time, interference is sustained (stayed for a finite time interval). If amplitudes are of nearby values, then contrast will be more pronounced.

163. (*d*) Light sources which emit light waves of same wavelength (or frequency) having either zero or a constant originating phase difference are called coherent sources of light.

164. (*c*) For a single slit of width a, the first null of the interference pattern occurs at an angle of λ/a. At the same angle of λ/a, we get a maximum (not a null) for two narrow slits separated by a distance a.

165. (*c*)

I. For diffraction pattern, the size of slit should be comparable to the wavelength of wave used.

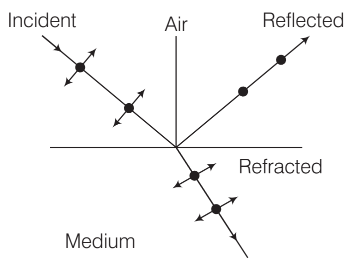
II. Diffraction phenomenon is commonly observed in our daily routine in case of sound waves (which is a longitudinal wave) because wavelength of sound waves is large (0.1-1 m). However, as wavelength of light waves is extremely small (10^{-6}-10^{-7} m), we do not observe diffraction of light in daily routine.

III. Diffraction is a wave phenomenon. It is observed in electromagnetic and longitudinal waves as well.

166. (*c*) Figure shows light reflected from a transparent medium, say, water. As before, the dots and arrows indicate that both polarisations (E) are present in the incident and refracted waves.

As the figure shows, the reflected light is therefore, linearly polarised perpendicular to the plane of the figure (represented by dots). This can be checked by looking at the reflected light through an analyser.

The transmitted intensity will be zero when the axis of the analyser is in the plane of the figure, *i.e.*, the plane of incidence

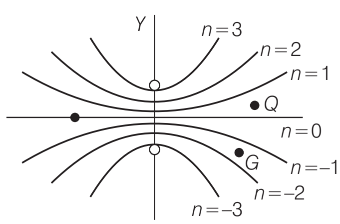


167. (*c*) Since, light wave travels along the direction perpendicular to its wavefront, for rays travelling along X-axis,

i.e., plane, $X = C$ is the perpendicular plane.

Similarly, for rays along Y and Z-axes plane wavefronts $Y = C$ and $Z = C$ represent the wavefront, respectively.

168. (*c*) A constructive interference is produced when waves overlaps such that a crest meets a crest and waves are in phase.



For maxima,

$$S_1P \sim S_2P = n\lambda \, (n = 0, 1, 2, 3, \dots)$$

For minima,

$$S_1P \sim S_2P = \left(n + \frac{1}{2}\right)\lambda \;\; (n = 0, 1, 2, 3, \cdots)$$

we will have destructive interference and the resultant intensity will be zero.

169. (*c*)

A. Angular separation of the fringes remains constant $(= \lambda/d)$. The actual separation of the fringes increases in proportion to the distance of the screen from the plane of the two slits.

B. The separation of the fringes (and also angular separation) decreases.

C. When medium is water, $\lambda' = \dfrac{\lambda_{air}}{4/3} = \dfrac{3}{4}\lambda_{air}$

$$\therefore \quad \beta' = \frac{\lambda' D}{d} = \frac{3}{4}\left(\frac{\lambda D}{d}\right) = \frac{3}{4}\beta$$

As we know , fringe width $\beta = \dfrac{D\lambda}{d}$

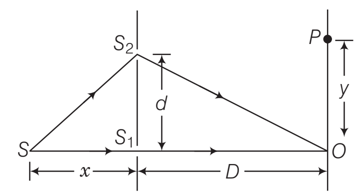
D. When d is reduced, $\beta \propto \dfrac{1}{d}$

So, β is increased.

170. (*a*) Path difference, $P = (S\,S_2 + S_2O) - (S\,S_1 + S_1O)$

$$S\,S_2 = \sqrt{x^2 + d^2} = x\left(1 + \frac{d^2}{x^2}\right)^{1/2} = x\left(1 + \frac{d^2}{2x^2}\right)$$

$(\because d <<< x)$



Similarly, $S_2O = \sqrt{(D^2 + d^2)} = D\left(1 + \dfrac{d^2}{2D^2}\right) \quad (\because d << D)$

Also, $S\,S_1\,O = x + D$

$$\therefore \quad P = x\left(1 + \frac{d^2}{2x^2}\right) + D\left(1 + \frac{d^2}{2D^2}\right) - (x + D)$$

$$= x + \frac{d^2}{2x} + D + \frac{d^2}{2D} - x - D \text{ or } P = \frac{d^2}{2}\left(\frac{1}{x} + \frac{1}{D}\right)$$

For dark fringe, $P = \dfrac{\lambda}{2}$

[for minimum d, $P = \dfrac{(2n-1)\lambda}{2}$; $n = 1$]

$$\Rightarrow \quad \frac{\lambda}{2} = \frac{d^2}{2}\left(\frac{1}{x} + \frac{1}{D}\right) \text{ or } d = \sqrt{\frac{\lambda x D}{(x + D)}}$$

Put $x = D, d = \sqrt{\dfrac{\lambda D}{2}}$ $\Rightarrow$ Put $x = D/2, d = \sqrt{\dfrac{\lambda D}{3}}$

$$\text{Fringe width} = \beta = \frac{\lambda D}{d} = \frac{\lambda D}{\sqrt{\lambda D/2}} = 2d$$

Distance of next bright fringe from O.

Distance of consecutive bright and dark band

$$= \frac{\text{Fringe width}}{2} = d$$

171. (*a*) Fringe width, $W = \dfrac{D\lambda}{d}$

where, D = distance between slits and screen

d = distance between slits and

λ = wavelength of light

A. λ increase so W also increase ($\therefore A \to 4$)

B. White light produces coloured fringes ($\because B \to 1$)

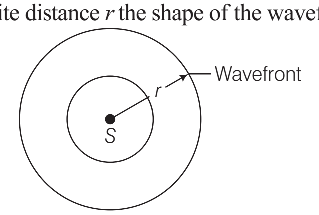
C. If D is doubled and d is halved, then W becomes four times ($\because C \to 2$)

D. If intensity of either slit is reduced, the bright fringes became less bright. ($\because D \to 3$)

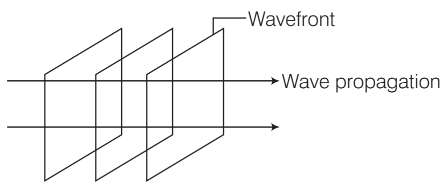
172. (*b*) A wavefront is locus of points, which oscillate in phase *i.e.*, it is a surface of constant phase.

173. (*a*) If we have a point source emitting waves uniformly in all directions, then the locus of points which have the same amplitude and vibrate in same phase are spheres.

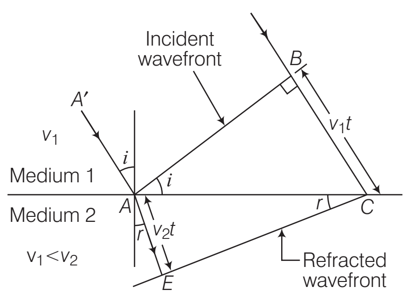
174. (*a*) At a finite distance r the shape of the wavefront is spherical.



175. (*b*) At a large distance from the source, a small portion of the spherical wave can be approximated by a plane wave.



176. (*c*)



$$\sin i = \frac{BC}{AC} = \frac{v_1\tau}{AC}$$

and $$\sin r = \frac{AE}{AC} = \frac{v_2\tau}{AC}$$

where, i and r are the angles of incidence and refraction, respectively.

$$\frac{\sin i}{\sin r} = \frac{BC/AC}{AE/AC} = \frac{BC}{AE}$$

177. (*d*) According to Snell's law of refraction, we have

$$\frac{\sin i}{\sin r} = \frac{v_1\tau / AC}{v_2\tau / AC} = \frac{v_1}{v_2}$$

$$\frac{v_1}{v_2} = \frac{f\lambda_1}{f\lambda_2} = \frac{\lambda_1}{\lambda_2} \text{ or } \frac{v_1}{\lambda_1} = \frac{v_2}{\lambda_2}$$

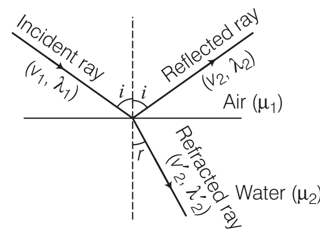
178. (*c*) In refraction, speed and wavelength changes but frequency remains constant. As part of light is always reflected (and also absorbed,) there is change in intensity of light also.

179. (*a*) On reflection and refraction, frequency of light remains the same.

$$\Rightarrow \qquad \frac{\nu_2}{\nu_2'} = 1$$

180. (*a*) According to Snell's law of refraction,

$$\frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} = \frac{v_1}{v_2'} = \frac{\lambda_1}{\lambda_2'} \qquad \ldots\text{(i)}$$



Given, wavelength of incident light, $\lambda_1 = 589$ nm

For reflection, $\lambda_2 = \lambda_1 = 589$ nm …(A)

Also, $v_2 = v_1 = 3\times10^8 \text{ ms}^{-1} = 300\times10^6 \text{ ms}^{-1}$ …(C)

For refraction, using Eq. (i)

$$\frac{\mu_2}{\mu_1} = \frac{\lambda_1}{\lambda_2'} = \frac{v_1}{v_2'} \Rightarrow \lambda_2' = \frac{\lambda_1}{{}^1\mu_2} = \frac{589 \text{ nm}}{4/3}$$

$$= 441.7 \text{ nm} \approx 442 \text{ nm} \qquad \ldots\text{(B)}$$

Also, $$v_2' = \frac{v_1}{{}^1\mu_2} = \frac{3\times10^8 \text{ ms}^{-1}}{4/3} = 2.25\times10^8 \text{ ms}^{-1}$$

$$= 2.25\times10^6 \text{ ms}^{-1} \qquad \ldots\text{(D)}$$

181. (*b*) In Doppler's shift given by, $\dfrac{\Delta\nu}{\nu} = \dfrac{v_{\text{radial}}}{c}$

$\dfrac{\Delta\nu}{\nu}$ = fractional change in frequency

v_{radial} = the component of the source velocity along the line joining the observer to the source relative to the observer

c = speed of light in vacuum = $3\times10^8 \text{ ms}^{-1}$.

182. (*a*)

I. The Doppler's shift is valid only when the speed of source is small compared to that of light. When speeds are close to that of light, the concept of Einstein's special theory of relativity is used.

II. Doppler's effect finds application in estimation of the velocity of aeroplanes, rockets, submarines etc.

183. (*d*) In transverse wave the displacement is in the y-direction, it is often referred to as a y-polarised wave. Since, each point on the string moves on a straight line, the wave is also referred to as a linearly polarised wave. Further, the string always remains confined to the XY-plane and therefore, it is also referred to as a plane polarised wave.

184. (*c*) If the plane of vibration of the string is changed randomly in very short intervals of time, then we have what is known as an unpolarised wave. Thus for an unpolarised wave the displacement will be randomly changing with time though it will always be perpendicular to the direction of propagation.

185. (*b*) By law of Malus, intensity of emergent light from P_2 is

$I = I_0 \cos^2 \theta$, where θ = angle between P_1 and P_2 pass axis.

$$\Rightarrow \qquad I = 0 \text{ when } \theta = 90°$$

186. (*c*) Let P_3 be the new polaroid inserted.

β = angle between the pass axis of P_1 and P_3 (given)

I_0 = Intensity of light on polaroid P_1 (given)

Let α be the angle between P_3 and P_2 pass axis.

Intensity of light from $P_1 = \dfrac{I_0}{2}$

Intensity of light from $P_3 = \dfrac{I_0}{2}\cos^2\beta$

Intensity of light from $P_2 = \dfrac{I_0}{2}\cos^2\beta\cos^2\alpha$

$$\because \qquad \alpha = \frac{\pi}{2} - \beta \qquad \text{(as } P_1 \text{ and } P_2 \text{ are perpendicular)}$$

$$I = \frac{I_0}{2}\cos^2\beta\cos^2(\pi/2 - \beta)$$

$$= \frac{I_0}{2}\cos^2\beta\sin^2\beta$$

$$I = \frac{I_0}{8}\sin^2 2\beta \qquad (\because \sin 2\theta = 2\sin\theta\cos\theta)$$

$$\text{Also,} \qquad I = \frac{I_0}{8} \qquad \text{(given)}$$

$$\Rightarrow \qquad \frac{I_0}{8} = \frac{I_0}{8}\sin^2 2\beta \text{ or } \sin^2 2\beta = 1 \Rightarrow \beta = \pi/4 = 45°$$

187. (*b, d*) $\dfrac{I_{\max}}{I_{\min}} = 9 \Rightarrow \left(\dfrac{a_1 + a_2}{a_1 - a_2}\right)^2$

$$\frac{a_1 + a_2}{a_1 - a_2} = \sqrt{9} = 3 \Rightarrow \frac{a_1}{a_2} = \frac{3+1}{3-1} = \frac{4}{2} \Rightarrow \frac{a_1}{a_2} = 2$$

Therefore $I_1 : I_2 = 4:1$

188. (*b,d*) We have, for minima is reflection

$$2\mu_1 t = n\lambda \quad \Rightarrow \quad t = \frac{n\lambda}{2\mu_1} = n\frac{640 \times 3}{2 \times 4} = 240 \text{ nm}$$

$$t = 240 \text{ nm}, 480 \text{ nm}, \ldots$$

189. (*a, b, d*) Consider the pattern of the intensity shown in the figure of question.

(i) As intensities of all successive minima is zero, hence we can say that two sources S_1 and S_2 are having same intensities.

(ii) Regular pattern shows constant phase difference.

(iii) We are using monochromatic light in YDSE to avoid overlapping and to have very clear pattern on the screen.

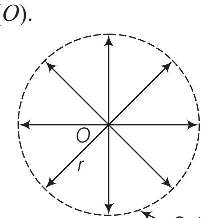
190. (*b, d*) Given, width of pinhole = 10^3 Å = 1000 Å

We know that wavelength of sunlight ranges from 4000 Å to 8000 Å.

Clearly, wavelength λ < width of the slit.

Hence, light is diffracted from the hole. Due to diffraction from the sunlight the image formed on the screen will be different from the geometrical image and overlaping of colour v.

191. (*a, b*) Consider the diagram in which light diverges from a point source (O).



Due to the point source light propagates in all directions symmetrically and hence, wavefront will be spherical as shown in the diagram.

If power of the source is P, then intensity of the source will be

$$I = \frac{P}{4\pi r^2}$$

where, r is radius of the wavefront at any time.

192. (*a*) Given, wavelength of light, $\lambda = 589 \text{ nm} = 589 \times 10^{-9}$ m

Refractive index of water $\mu_w = 1.33$

(i) For reflected light

(a) Wavelength of reflected light, $\lambda = 589 \times 10^{-9}$ m

(b) Frequency of reflected of light, $\nu = \dfrac{c}{\lambda} = \dfrac{3 \times 10^8}{589 \times 10^{-9}}$

where c is velocity of light

$(\because$ Speed of light, $c = 3 \times 10^8 \text{ ms}^{-1})$

$$v = 5.09 \times 10^{14} \text{ Hz}$$

(c) As the reflection takes place in the same medium so Speed of reflected light $c = 3 \times 10^8 \text{ ms}^{-1}$

(ii) For refracted light (In this process wavelength and speed changes but frequency remains the same)

Wavelength of refracted light

$$\lambda' = \frac{\lambda}{\mu} = \frac{589 \times 10^{-9}}{1.33} = 4.42 \times 10^{-7} \text{ m}$$

$$\therefore \text{ Velocity of refracted li, } v = \frac{c}{\mu} = \frac{3 \times 10^8}{1.33} = 2.25 \times 10^8 \text{ms}^{-1}$$

193. (*b*) Given, separation between slits

$$d = 0.28 \text{ mm} = 0.28 \times 10^{-3} \text{ m}$$

Distance between screen and slit $D = 1.4$ m

Distance between central bright and fourth fringe

$$x = 1.2 \text{ cm} = 1.2\times10^{-2}\text{m}$$

Number of fringes $n = 4$

For constructive interference $x = n\dfrac{D\lambda}{d}$

$$1.2\times10^{-2} = \frac{4\times1.4\times\lambda}{0.28\times10^{-3}}$$

Wavelength, $\lambda = \dfrac{1.2\times10^{-2}\times0.28\times10^{-3}}{4\times1.4} \Rightarrow \lambda = 6\times10^{-7}\text{ m}$

194. (*a*) Given, wavelength $\lambda_1 = 650\text{ nm} = 650\times10^{-9}\text{m}$

and $\lambda_2 = 520\text{ nm} = 520\times10^{-9}\text{m}$, $d = 2\times10^{-3}\text{m}$

(i) For third bright fringe, $n=3, D = 1.2$ m

The distance of third bright fringe from central maximum.

$$x = \frac{n\lambda D}{d} = 3\times650\times10^{-9}\times\frac{D}{d}\text{m}$$

$$= \frac{3\times650\times10^{-9}\times1.2}{2\times10^{-3}} = 1.17\times10^{-3}\text{ m}$$

(ii) Let nth bright fringe due to wavelength $\lambda_2 = 520$ nm, coincide with $(n+1)$ th bright fringe due to wavelength $\lambda_1 = 650$ nm.

i.e., $$n\lambda_2\frac{D}{d} = (n-1)\lambda_1\frac{D}{d}$$

$$n\times520\times10^{-9} = (n-1)\,650\times10^{-9}$$

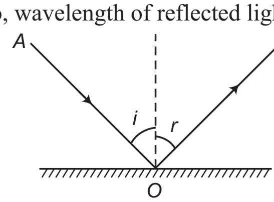
or $$4n = 5n-5 \quad\text{or}\quad n=5$$

Thus, the least distance, $x = n\lambda_2\dfrac{D}{d} = 5\times520\times10^{-9}\dfrac{D}{d}$

$$x = 2600\frac{D}{d}\times10^{-9}\text{ m} = 2600\times\frac{1.2\times10^{-9}}{2\times10^{-3}}\text{ m} = 1.56\times10^{-3}\text{ m}$$

195. (*b*) Given, wavelength of light $\lambda = 5000\text{Å} = 5000\times10^{-10}$ m

On the reflection there is no change in wavelength and frequency. So, wavelength of reflected light will be 5000Å.



Frequency of the incident light

$$\nu = \frac{c}{\lambda} = \frac{3\times10^8}{5\times10^{-7}} = 6\times10^{14}\text{ Hz}$$

When reflected ray is normal to the incident ray.

AO and *BO* are the incident and reflected rays.

$$BO \perp AO$$

$\therefore$ $$\angle i + \angle r = 90^\circ$$

For reflection, $$\angle i = \angle r$$

$\therefore$ $$2\angle i = 45^\circ$$

$$\angle i = 45^\circ$$

Thus, the angle of incidence is 45°.

196. (*b*) Given, wavelength of H_α, $\lambda = 6563\text{Å} = 6563\times10^{-10}$ m

Red shift $\Delta\lambda = 15\text{Å}$

Since, the star is found to be red-shifed, hence star is receding away from earth and Doppler's shift is negative.

$$\Delta\lambda = -\frac{v\lambda}{c} \Rightarrow v = -\frac{\Delta\lambda\cdot c}{\lambda} = -\frac{15\times3\times10^8}{6563}$$

$$v = -6.86\times10^5\text{ ms}^{-1}$$

Negative sign shows that the star is receding away from earth.

197. (*c*) Given, wavelength of light, $\lambda = 600\text{nm} = 600\times10^{-9}$ m

Angular width of fringe, $\theta = 0.1^\circ = \dfrac{0.1\pi}{180}$ rad

Using the formula, $\theta = \dfrac{\lambda}{d}$

Spacing between the slits, $d = \dfrac{\lambda}{\theta} = \dfrac{600\times10^{-9}\times180}{0.1\times\pi}$

$$d = 3.44\times10^{-4}\text{ m}$$

Thus, the spacing between the two slits is 3.44×10^{-4} m.

198. (*a*) There is no obstruction by the hill to spreading the radio beams, the radial spread of the beam over the hill 20 km away must not exceed 50 m.

i.e., Z_F (Fresnel's distance) $= 20\text{ km} = 20\times10^{-3}\text{ m} \Rightarrow a = 50\text{ m}$

$$Z_F = \frac{a^2}{\lambda} \Rightarrow \lambda = \frac{a^2}{Z_F} = \frac{50\times50}{20\times10^3} = 1250\times10^{-4}\text{ m}$$

Thus, the longest wavelength of radio waves is 0.125 m.

199. (*c*) Given, wavelength of light $\lambda = 500\text{ nm} = 500\times10^{-9}$ m

$D = 1\text{ m}, n = 1, x = 2.5\text{ mm} = 2.5\times10^{-3}$ m

Distance of n^{th} minimum from the centre, $x = \dfrac{nD\lambda}{d}$

$$d = \frac{nD\lambda}{x} = \frac{1\times1\times500\times10^{-9}}{2.5\times10^{-3}} = 2\times10^{-4}\text{ m} \Rightarrow d = 0.2\text{ mm}$$

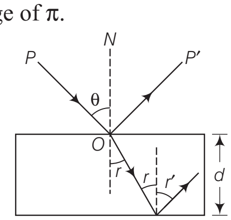
Thus, the width of slit of 0.2 mm.

200. (*a*) Given, width of the slit $= 10^4$ Å

$$= 10^4\times10^{-10}\text{ m} = 10^{-6}\text{ m} = 1\mu\text{m}$$

Wavelength of (visible) sunlight varies from 4000 Å to 8000 Å. As the width of slit is comparable to that of wavelength, hence diffraction occurs with maxima at centre. So, at the centre all colours appear i.e., mixing of colours form white patch at the centre.

201. (*a*) Consider the diagram, the ray (P) is incident at an angle θ and gets reflected in the direction P' and refracted in the direction P''. Due to reflection from the glass medium, there is a phase change of π.



Time taken to travel along OP''

$$\Delta t = \frac{OP''}{v} = \frac{d/\cos r}{c/n} = \frac{nd}{c\cos r}$$

From Snell's law, $n = \dfrac{\sin\theta}{\sin r}$

$$\Rightarrow \quad \sin r = \frac{\sin\theta}{n}$$

$$\cos r = \sqrt{1-\sin^2 r} = \sqrt{1-\frac{\sin^2\theta}{n^2}}$$

$$\therefore \quad \Delta t = \frac{nd}{c\left(1-\frac{\sin^2\theta}{n^2}\right)^{1/2}} = \frac{n^2 d}{c}\left(1-\frac{\sin^2\theta}{n^2}\right)^{-1/2}$$

$$\text{Phase difference} = \Delta\phi = \frac{2\pi}{\lambda}\times\Delta t = \frac{2\pi\, nd}{\lambda}\left(1-\frac{\sin^2\theta}{n^2}\right)^{-1/2}$$

So, net phase difference $= \Delta\phi + \pi$

$$= \frac{4\pi d}{\lambda}\left(1-\frac{1}{n^2}\sin^2\theta\right)^{-1/2} + \pi$$

202. (*c*) In a Young's double slit experiment, when one of the holes is covered by a red filter and another by a blue filter. In this case due to filteration only red and blue lights are present. In Young's double slit monochromatic light is used for the formation of fringes on the screen. Hence, in this case there shall be no interference fringes.

203. (*d*) There is a hole at point P_2 (minima). The hole will act as a source of fresh light for the slits S_3 and S_4. Therefore, there will be a regular two slit pattern on the second screen.

204. (*a*) Given, angular resolution of human eye, $\phi = 5.8\times10^{-4}$ rad. and printer prints 300 dots per inch.

The linear distance between two dots is

$$l = \frac{2.54}{300} = 0.84\times10^{-2} \text{ cm.}$$

At a distance of z cm, this subtends an angle, $\phi = \dfrac{l}{z}$

$$\therefore \quad z = \frac{l}{\phi} = \frac{0.84\times10^{-2}\text{ cm}}{5.8\times10^{-4}} = 14.5 \text{ cm.}$$

205. (*b*) For *n*th minima to be formed on the screen path difference between the rays coming from S_1 and S_2 must be $(2n-1)\dfrac{\lambda}{2}$.

From the given figure of two slit interference arrangements, we can write

$$T_2P = T_2O + OP = D + x$$

and $\quad T_1P = T_1O - OP = D - x$

$$S_1P = \sqrt{(S_1T_1)^2 + (PT_1)^2} = \sqrt{D^2 + (D-x)^2}$$

and $\quad S_2P = \sqrt{(S_2T_2)^2 + (T_2P)^2} = \sqrt{D^2 + (D+x)^2}$

The minima will occur when $S_2P - S_1P = (2n-1)\dfrac{\lambda}{2}$

i.e., $\quad [D^2 + (D+x)^2]^{1/2} - [D^2 + (D-x)^2]^{1/2} = \dfrac{\lambda}{2}$

(for first minima $n = 1$)

If $\quad x = D$

we can write $[D^2 + 4D^2]^{1/2} - [D^2 + 0]^{1/2} = \dfrac{\lambda}{2}$

$$\Rightarrow \quad [5D^2]^{1/2} - [D^2]^{1/2} = \frac{\lambda}{2}$$

$$\Rightarrow \quad \sqrt{5}D - D = \frac{\lambda}{2}$$

$$\Rightarrow \quad D(\sqrt{5}-1) = \lambda/2 \quad \text{or} \quad D = \frac{\lambda}{2(\sqrt{5}-1)}$$

Putting $\quad \sqrt{5} = 2.236$

$$\Rightarrow \quad \sqrt{5} - 1 = 2.236 - 1 = 1.236$$

$$D = \frac{\lambda}{2(1.236)} = 0.404\,\lambda$$

206. (*b*) The resultant disturbance at a point will be calculated by sun of disturbances due to individual sources.

Consider the disturbances at the receiver R_1 which is at a distance d from B.

Let the wave at R_1 because of A be $Y_A = a\cos\omega t$. The path difference of the signal from A with that from B is $\lambda/2$ and hence, the phase difference is π.

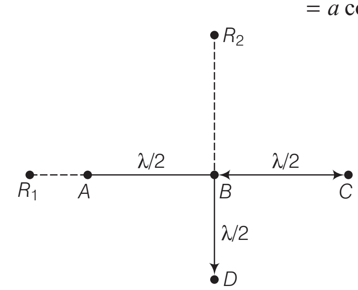
Thus, the wave at R_1 because of B is

$$y_B = a\cos(\omega t - \pi) = -a\cos\omega t.$$

The path difference of the signal from C with that from A is λ and hence the phase difference is 2π.

Thus, the wave at R_1 because of C is $Y_C = a\cos(\omega t - 2\pi)$

$$= a\cos\omega t$$



The path difference between the signal from D with that of A is

$$\sqrt{d^2 + \left(\frac{\lambda}{2}\right)^2} - (d - \lambda/2) = d\left(1 + \frac{\lambda}{4d^2}\right)^{1/2} - d + \frac{\lambda}{2}$$

$$= d\left(1 + \frac{\lambda^2}{8d^2}\right)^{1/2} - d + \frac{\lambda}{2} \approx \frac{\lambda}{2} \qquad (\because d >> \lambda)$$

Therefore, phase difference is π.

$$\therefore \quad Y_D = a\cos(\omega t - \pi) = -a\cos\omega t$$

Thus, the signal picked up at R_1 from all the four sources is

$Y_{R_1} = y_A + y_B + y_C + y_D$

$= a\cos\omega t - a\cos\omega t + a\cos\omega t - a\cos\omega t = 0$

Let the signal picked up at R_2 from B be $y_B = a_1\cos\omega t$.

The path difference between signal at D and that at B is $\lambda/2$.

$\therefore \qquad y_D = -a_1\cos\omega t$

The path difference between signal at A and that at B is

$$\sqrt{(d)^2 + \left(\frac{\lambda}{2}\right)^2} - d = d\left(1 + \frac{\lambda^2}{4d^2}\right)^{1/2} - d \simeq \frac{1\lambda^2}{8d^2}$$

As $d \gg \lambda$, therefore this path difference $\to 0$

and phase difference $= \frac{2\pi}{\lambda}\left(\frac{1}{8}\frac{\lambda^2}{d^2}\right) \to 0$

Hence, $\quad y_A = a_1\cos(\omega t - \phi)$

Similarly, $y_C = a_1\cos(\omega t - \phi)$

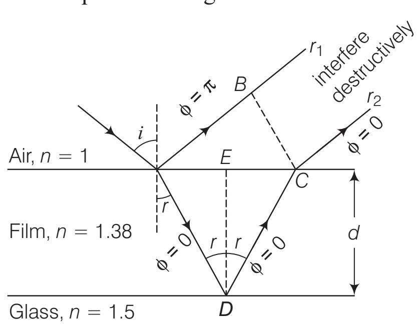
$\therefore$ Signal picked up by R_2 is

$$y_A + y_B + y_C + y_D = y = 2a_1\cos(\omega t - \phi)$$

$\therefore \qquad |y|^2 = 4a_1^2\cos^2(\omega t - \phi) \quad \therefore \quad \langle I \rangle = 2a_1^2$

Thus, R_1 picks up the larger signal.

207. (*c*) In this figure, we have shown a dielectric film of thickness d deposited on a glass lens.



Refractive index of film $= 1.38$

and refractive index of glass $= 1.5$.

Given, $\qquad \lambda = 5500\,\text{Å}$.

Consider a ray incident at an angle i. A part of this ray is reflected from the air-film interface and a part refracted inside. This is partly reflected at the film-glass interface and a part transmitted. A part of the reflected ray is reflected at the film-air interface and a part transmitted as r_2 parallel to r_1. Of course successive reflections and transmissions will keep on decreasing the amplitude of the wave.

The optical path difference between r_2 and r_1 is

$$n(AD + CD) - AB$$

If d is the thickness of the film, then

$$AD = CD = \frac{d}{\cos r} \quad \Rightarrow \quad AB = AC\sin i$$

$$\frac{AC}{2} = d\tan r$$

$\therefore \qquad AC = 2d\tan r$

Hence, $AB = 2d\tan r\sin i$.

Thus, the optical path difference $= \frac{2nd}{\cos r} - 2d\tan r\sin i$

$$= 2\cdot\frac{\sin i\, d}{\sin r\cos r} - 2d\frac{\sin r}{\cos r}\sin i = 2d\sin\left[\frac{1-\sin^2 r}{\sin r\cos r}\right]$$

$$= 2nd\cos r$$

For these waves to interfere destructively path difference $= \frac{\lambda}{2}$.

$\Rightarrow \qquad 2nd\cos r = \frac{\lambda}{2}$

$\Rightarrow \qquad nd\cos r = \frac{\lambda}{4} \qquad \text{... (i)}$

For photographic lenses, the sources are normally in vertical plane

$\therefore \qquad i = r = 0°$

From Eq. (i), $nd\cos 0° = \frac{\lambda}{4}$

$\Rightarrow \qquad d = \frac{\lambda}{4n} = \frac{5500\,\text{Å}}{4\times 1.38} \approx 1000\,\text{Å}$

208. (*a*) In case of transparent glass slab of refractive index μ, the path difference $= 2d\sin\theta + (\mu - 1)L$, slit width $= 2d$

For the principle maxima, (path difference is zero)

i.e., $2d\sin\theta_0 + (\mu - 1)L = 0$

or $\qquad \sin\theta_0 = -\frac{L(\mu-1)}{2d} = \frac{-L(0.5)}{2d} \qquad [\because L = d/4]$

or $\qquad \sin\theta_0 = \frac{-1}{16}$

$$OP = D\tan\theta_0 = D\sin\theta_0 = \frac{-D}{16}$$

For the first minima, the path difference is $\pm\frac{\lambda}{2}$.

$$2d\sin\theta_1 + 0.5L = \pm\frac{\lambda}{2}$$

or $\qquad \sin\theta_1 = \frac{\pm\lambda/2 - 0.5L}{2d}$

$$= \frac{\pm\lambda/2 - d/8}{2d} = \frac{\pm\lambda/2 - 2\lambda/8}{2\lambda} = \pm\frac{1}{4} - \frac{1}{16}$$

[$\because$ The diffraction occurs if the wavelength of waves in nearly equal to the slit width (d)].

On the positive side, $\quad \sin\theta'_1 = +\frac{1}{4} - \frac{1}{16} = \frac{3}{16}$

On the negative side, $\quad \sin\theta''_1 = -\frac{1}{4} - \frac{1}{16} = -\frac{5}{16}$

The first principal maxima on the positive side is at distance.

$$D\tan\theta'_1 = D\frac{\sin\theta'_1}{\sqrt{1-\sin^2\theta'_1}} = D\frac{3}{\sqrt{16^2 - 3^2}} = \frac{3D}{\sqrt{247}} \text{ above}$$

point O.

The first principal minima on the negative side is at distance.

$$D\tan\theta''_1 = \frac{5}{\sqrt{16^2 - 5^2}} = \frac{5}{\sqrt{231}} \text{ below point } O.$$