WAVE OPTICS

WAVE FRONT AND HUYGEN'S PRINCIPLE

1. Define the term 'wavefront'.
2. Sketch the refracted wavefront emerging from a convex lens if a plane wavefront is incident normally on it.
3. A plane wavefront is incident normally on a convex lens. Sketch the refracted wavefront.
4. Sketch the wavefront of converging rays of light.
5. Sketch the wavefront of diverging rays of light.
6. Sketch the wavefront of rays coming from a distant source of light.
7. State Huygen's principle.
8. What is the phase difference between any two particles on a wavefront?
9. Do the frequency and wavelength change when light passes from rarer to denser medium?
10. What happens to the frequency when light travels from one medium to another?
11. Light of wavelength 6000Å in air enters a medium of refractive index 1.5 what will be its frequency in the medium?
12. When light undergoes refraction, what happens to its frequency?
13. When light undergoes refraction at the surface of separation of two media, what happens to its wavelength?
14. What is the geometrical shape of the wavefront in each of the following cases :
    (a) Light diverging from a point source.
    (b) The portion of the wavefront of light from a distant star intercepted by the Earth.
    (c) A beam of parallel rays
    (d) Rays of light obtained by a linear source (such as a slit) illuminated by another source behind it.
    (e) When a plane wave passes through a convex lens?
    (f) When a plane wave passes through a concave lens?
    (g) When a plane wave passes through a glass prism?
15. 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 Why?
16. When light travels from a rarer to a denser medium, it loses some speed. Does the reduction in speed imply a reduction in the energy carried by the light wave?
17. What type of wavefront will emerge from a (i) point source, and (iii) distant light source?
18. Draw a diagram to show refraction of a plane wave front incident in a convex lens and hence draw the refracted wavefront.
19. Differentiate between a ray and a wavefront.

INTERFERENCE

20. State the conditions which must be satisfied for two light sources to be coherent.
21. Two identical coherent waves, each of intensity I, are producing an interference pattern. Write the value of the resultant intensity at a point (i) constructive interference and (ii) destructive interference.
22. State the path difference between two waves for destructive interference
23. Give one basic difference between interference and diffraction
24. Sketch the variation of intensity of the interference pattern in Young's double slit experiment.
25. State the path difference between two waves for constructive interference.
26. Two independent sources of light cannot be coherent. Why?
27. A region is illuminated by two sources of light. The intensity I at each point is found to be equal to $I_1 + I_2$, where I_1 is the intensity of light at the point when source 2 is absent and I_2 when source 1 is absent. Are sources coherent or incoherent? Explain.
28. How would the angular separation of interference fringes in Young's double slit experiment change when the distance between the slits and screen is doubled?
29. Define the term angular separation.
30. How does the fringe width, in Young's double-slit experiment, change when the distance of separation between the slits and screen is doubled?

DIFFRACTION

31. How does the fringe width of interference fringes change, when the whole apparatus of Young's experiment is kept in a liquid of refractive index 1.3?

32. How does the angular separation of interference fringes change, in Young's experiment
   (a) If the distance between the slits is increased

   (b) If the separation between the slits and the screen is doubled?
33. State the condition for diffraction of light to occur?
34. 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, how will the diffraction pattern be affected?
35. What is the condition for first minimum in case of diffraction due to a single slit?
36. What is the condition for first secondary maximum in case of diffraction due to a single slit?
37. Estimate the distance for which ray optics is good approximation for an aperture of 4 mm and wavelength 400 nm.
38. A parallel beam of monochromatic light falls normally on a single narrow slit. How does the angular width of the central maximum in the resulting diffraction pattern, depend on the wavelength of the incident light?
39. How does the angular separation between fringes in single-slit diffraction experiment change when the distance of separation between the slit and screen is doubled.
40. In a single-slit diffraction experiment, the width of the slit is made double the original width. How does this affect the size and intensity of the central diffraction band ?

POLARISATION

41. What is plane polarised light?
42. What evidence is there to show that sound is not electromagnetic in nature?
43. State Brewster's law.
44. What is polarising angle of medium of refractive index $\sqrt{3}$?
45. The polarising angle of a medium is 60°. What is the refractive index of the medium?
46. What is the value of refractive index of a medium of polarising angle 60°?
47. What is the polarising angle of a medium of refractive index 1.732?
48. Draw a graph showing the variation of intensity of polarised light transmitted by an analyser.
49. A partially plane polarised beam of light is passed through a polaroid. Show graphically the variation of the transmitted light intensity with angle of rotation of the polaroid.
50. At what angle of incidence should a light beam strike a glass slab of refractive index $\sqrt{3}$, such that the reflected and the refracted rays are perpendicular to each other?
51. The refractive index of a medium is $\sqrt{3}$. What is the angle of refraction, if the unpolarised light is incident on it, at the polarising angle of the medium?
52. If the angle between the planes of the polariser and analyser is 60°, by what factor does the intensity of transmitted light change when passing through the analyser?
53. Name the wave phenomenon which is exhibited by light but not by sound waves.
54. If the angle between the pass axis of polarizer and the analyser is 45°, write the ratio of the intensities of original light and the transmitted light after passing through the analyser.
55. Unpolarized light is incident on a plane surface of glass of refractive index μ at angle i. If the reflected light gets totally polarized, write the relation between the angle i and refractive index μ.
56. Which of the following waves can be polarized (i) Heat waves (ii) Sound waves? Give reason to support your answer.

WAVEFRONT AND HUYGEN'S PRINCIPLE

1. (a) State the postulates of Huygen's wave theory.
   (b) Draw the type of wavefront that corresponds to a beam of light
      (i) Coming from a very far off source and
      (ii) diverging from a point source.
2. State Huygen's postulates of wave theory. Sketch the wavefront emerging from a (i) point source of light (ii) linear source of light like a slit.
3. Deduce laws of reflection on the basis of Huygen's principle.
4. Deduce the laws of refraction on the basis of Huygen's Principle.
5. State Huygen's principle. Use it to describe reflection of a parallel beam of light from a plane mirror and prove that angle of incidence is equal to angle of reflection.
6. Verify Snell's law of refraction using Huygen's wave theory.
7. State the postulates of Huygen's wave theory. Draw the geometrical shape of the wave form in the following cases:
   (i) light emerging from a point source, and
   (ii) when the light source is emitting parallel rays.

8. What is a wavefront? Distinguish between a plane wavefront and a spherical wavefront. Explain with the help of a diagram the refraction of a plane wavefront at a plane surface using Huygen's construction.

9. What is a wavefront? What is the geometrical shape of a wavefront of light emerging out of a convex lens, when point source is placed at its focus? Using Huygen's principle show that, for a parallel beam incident on a reflecting surface, the angle of reflection is equal to the angle of incidence.

10. Monochromatic light of wavelength 589 nm is incident from air on a water surface. What are the wavelengths, frequency and speed of (a) reflected and (b) refracted light. (μ of water = 1.33)

11. (a) The refractive index of glass is 1.5. What is the speed of light in glass? (Speed of light in vacuum is 3.0×10^8 m/s)

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

■ INTERFERENCE

12. Derive the expression for the fringe width in Young's double slit interference experiment.

13. What is meant by coherent sources of light? Can two identical and independent sodium lamps act as coherent sources? Give reason for your answer.

14. What are co-herent sources of light? Why no interference pattern is observed when two coherent sources are
    (i) infinitely close to each other?
    (ii) far apart from each other?

15. State the conditions for obtaining sustained interference of light from different sources. The ratio of intensities of maxima and minima in an interference pattern is found to be 25:9. Calculate the ratio of light intensities of the sources producing this pattern.

16. Draw the curve depicting variation of intensity in the interference pattern in Young's double slit experiment. State conditions for obtaining sustained interference pattern of light.

17. What is the effect on the interference pattern observed in a Young's double slit experiment in the following cases:
    (i) Screen is moved away from the plane of slits.
    (ii) Separation between the slits is increased.
    (iii) Widths of the slits are doubled.
    Give reasons for your answer.

18. What are coherent sources of light? Deduce an expression for the intensity at any point on the screen in Young's double slit experiment.

19. In a double slit interference experiment, the two coherent beams have slightly different intensities I and $I + \delta I$ ($\delta I << I$). Show that the resultant intensity at the maxima is nearly 4I while that at the minima is nearly $\frac{(\delta I)^2}{4I}$.

20. Two sources of intensity I_1 and I_2 unddergo interference in Young's double slit experiment. Show that

$$\frac{I_{max}}{I_{min}} = \left[\frac{a_1 + a_2}{a_1 - a_2}\right]^2$$

where a_1 and a_2 are the amplitudes of disturbance for two sources S_1 and S_2.

21. State two conditions for sustained interference of light to occur. Two coherent sources of light have their intensities in the ratio 4:9. Calculate the ratio of the intensity of maxima and minima of the interference pattern.

22. Two coherent sources whose intensity ratio is 81:1, produce interference fringes. Calculate the ratio of intensity of maxima and minima in the fringes system.

23. What is the effect on the interference fringes in Young's double slit experiment due to each of the following operations. Give reason for your answer :
    (i) Separation between two slits is increased
    (ii) Monochromatic source is replaced by a source of white light.
    (iii) One of the slits is closed

24. What is the effect of slit width and wavelength of the light source on fringe width of the fringes formed in Young's double slit experiment?

25. What changes in interference pattern young's double slit experiment will be observed when
    (i) distance between the slits is reduced?
    (ii) if apparatus is immersed in water?

26. What will be the effect on the interference fringes in a Young's double slit experiment, if
    (i) Monochromatic sources is replaced by a source of white light
    (ii) The screen is moved away from the slit? Justify your answer.

27. What are coherent sources of light? Draw the variation of intensity with position, in the interference pattern of Young's double slit experiment.

28. Two slits in Young's double slit experiment are illuminated by two different lamps emitting light of the same wavelength. Will you observe the interference pattern? Justify your answer.
    Find the ratio of intensities at two points on a screen in Young's double slit experiment, when waves from the two slits have path difference of (i) 0 (ii) $\lambda/4$.

29. Consider interference between two sources of intensities I and $4I$. Obtain intensity at a point where the phase difference is $\pi/2$.

30. Find the ratio of intensities of two points P and Q on screen in Young's double slit experiment when waves from sources S_1 and S_2 have phase difference of (i) 0° and (ii) $\pi/2$ respectively.

31. Find the ratio of intensities of two points P and Q on a screen in Young's double slit experiment when waves from sources S_1 and S_2 have phase difference of (i) $\pi/3$ and (ii) $\pi/2$ respectively.

32. In a Young's experiment the slits are 1.5 m from the screen. The width of the fringes observed with light of the wavelength 6000 Å is 1.0 mm. What is the separation of the slits?

33. In Young's double slit experiment, the slits are separated by 0.24 mm. The screen is 1.2 m away from the slits. The fringe width is 0.3 cm. Calculate the wavelength of light used in the experiment.

34. The two slits in Young's double slit experiment are separated by a distance of 0.03 mm. An interference pattern is produced on a screen 1.5 m away. The 4^{th} bright fringe is at a distance of 1 cm from the central maximum. Calculate the wavelength of light used.

35. In Young's double slit experiment, while using a source of light of wavelength 5000 Å, the fringe width obtained is 0.6 cm. If the distance between the slits and the screen is reduced to half, calculate the new fringe width.

36. Laser light of wavelength 660 nm incident on a pair of slits produces an interference pattern in which the bright fringes are separated by 7.8 mm. A second light produce an interference pattern in which the fringes are separated by 6.5 mm. Calculate the wavelength of the second light.

37. What are coherent sources of light? In Young's double slit experiment, two slits are separated by 3 mm distance and illuminated by light of wavelength wavelength 480 nm. The screen is at 2 m from the plane of the slits. Calculate the separation between the 8^{th} bright fringe and the 3^{rd} dark fringe observed with respect to the central bright fringe.

38. What is meant by interference of light? In a double 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 distance between the slits is 10^{-3} m calculate the wavelength of light used.

39. Why is interference pattern not detected, when two coherent sources are far apart? In Young's experiment, the width of the fringes obtained with light of wavelength 6000 Å is 2.0 mm. Calculate the fringe width if the entire apparatus is immersed in a liquid medium of refractive index 1.33

40. State two conditions to obtain sustained interference of light.

In Young's double slit experiment, using light of wavelength 400 nm, interference fringes of width 'X' are obtained. The wavelength of light is increased to 600 nm and the separation between the slits is halved. If one wants the observed fringe width on the screen to be the same in the two cases, find the ratio of the distance between the screen and the plane of the interfering sources in the two arrangements.

41. In a Young's double slit experiment, the two slits are kept at 2 mm apart and the screen is positioned 140 cm away from the plane of the slits. The slits are illuminated with light of wavelength 600 nm. Find the distance of the third bright fringe, from the central maximum, in the interference pattern obtained on the screen. If the wavelength of the incident light were changed to 480 nm, find out the shift in the position of third bright fringe from the central maximum.

42. In a Young's double slit experiment, the slits are separated by 0.24 mm and the screen is kept 160 cm away from the slits. If the fringe width is measured to be 0.4 cm, calculate the wavelength of light used in experiment. What would be the new value of the 'fringe width', if for the same set up, and for the same wavelength of light, the screen is moved 'inward' *i.e.*, towards the slits, by 40 cm?

43. In Young's double slit experiment, monochromatic light of wavelength 630 nm illuminates the pair of slits and produces an interference pattern in which two consecutive bright fringes are separated by 8.1 mm. Another source of monochromatic light produces the interference pattern in which the two consecutive bright fringes are separated by 7.2 mm. Find the wavelength of light from the second source.

What is the effect on the interference fringes if the monochromatic source is replaced by a source of white light?

44. In Young's double slit experiment, the two slits 0.15 mm apart are illuminated by monochromatic light of wavelength 450 nm. The screen is 1.0 m away from the slits.

(a) Find the distance of the second (i) bright fringe, (ii) dark fringe from the central maximum.

(b) How will the fringe pattern change if the screen is moved away from the slits?

45. Describe Young's double slit experiment to produce interference pattern due to a monochromatic source of light. Deduce the expression for the fringe width.

46. For a single slit of width 'a', the first minimum of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of $\frac{\lambda}{a}$. At the same angle of $\frac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance 'a'. Explain.

■ DIFFRACTION

47. A slit of width 'a' is illuminated by monochromatic light at normal incidence. Draw the intensity distribution curve observed on screen due to diffraction.

48. Explain, using Huygen's principle, how diffraction is produced by a narrow slit which is illuminated by a monochromatic light.

Show that central maximum is twice as wide as the other maxima and the pattern becomes narrower as the width of the slit is increased.

49. Give two differences between fringes formed in single slit diffraction and Young double slit experiment.

50. Distinguish between interference and diffraction.

51. Derive an expression for the width of the central maxima for diffraction of light at a single slit. How does this width change with increase in width of the slit?

52. Derive an expression for the angular width of the central maximum of the diffraction produced by a single slit illuminated with monochromatic light.

53. State the condition of diffraction of light to occur. In the diffraction at a single slit experiment, how would the width and the intensity of central maximum change, if

(i) Slit width is halved and

(ii) Visible light of longer wavelength is used?

54. State the condition for diffraction of light to occur. In diffraction at a single slit experiment, how will the width and intensity of central maximum change, if

(i) the slit width is doubled

(ii) wavelength of light incident on the slit is increased.

55. In a single slit diffraction experiment, if the width of the slit is doubled, how does the (i) intensity of light and (ii) width of the central maximum change. Give reason for your answer.

56. In a single slit diffraction experiment, the slit width is made double that of the original width. What would happen to the size and intensity of central diffraction band? Give reason for your answer.

57. In a single slit diffraction pattern, how is the angular width of central bright maximum changed, when

(i) the slit width is decreased?

(ii) the distance between the slit and the screen is increased?

(iii) light of smaller wavelength is used?

Justify your answer.

58. Why is diffraction of sound waves easier to observe than diffraction of light waves? What two main changes in diffraction pattern of a single slit will you observe when the monochromatic source of light is replaced by a source of white light?

59. How does diffraction limit the resolving power of an optical instrument?

60. Give Huygen's Principle of secondary wavelets. Show graphically the intensity distribution in a single slit diffraction pattern.

61. In a single slit diffraction pattern, how does the angular width of the central maximum vary, when (i) aperture of slit is increased, (ii) distance between the slit and screen is decreased and (iii) monochromatic visible light of larger wavelength is used? Justify your answer in each case.

62. How is Huygen's principle used to obtain the diffraction pattern due to a single slit? Show the plot of variation of intensity with angle and state the reason for the reduction in intensity of secondary maxima compared to central maximum.

63. Draw the diagram showing intensity distribution of light on the screen for diffraction of light at a single slit. How is the width of central maxima affected on increasing the (i) wavelength of light used (ii) width of the slit (iii) monochromatic yellow light is replaced with red light? What happens to the width of the central maxima if the whole apparatus is immersed in water and why?

64. Why is diffraction of sound waves easily observed than diffraction of light waves? Light of wavelength 600 nm is incident on a single slit of width 0.5 mm at normal incidence. Calculate the separation between the dark bands on either side of the central maximum, if the diffraction pattern is observed on a screen placed at 2 m from the slit.

65. State the essential condition for diffraction of light to occur. The light of wavelength 600 nm is incident normally on a slit of width 3 mm. Calculate the linear width of central maximum on a screen kept 3 m away from the slit.

66. Determine the angular separation between central maximum and first order maximum of the diffraction pattern due to a single slit of width 0.25 mm, when light of wavelength 5890Å is incident on it normally.

67. (a) A slit of width 'a' is illuminated by light of wavelength 6500Å. For what values of 'a' will the
(i) first minimum fall at an angle of diffraction of 30°?
(ii) first maximum fall at an angle of diffraction of 30°?
(b) Why does the intensity of the secondary maximum become less as compared to central maximum

68. Light of wavelengths 5×10^{-7} m is diffracted by an aperture of width 2×10^{-3} m. For what distance travelled by the diffracted beam does the spreading due to diffraction become greater than the width of the aperture?

69. Light of wavelength 600 nm is incident on an aperture of size 2 mm. Calculate the distance upto which the ray of light can travel such that its spread is less than the size of the aperture.

70. What is diffraction? Calculate the distance a beam of light of wavelength 500 nm can travel without significant broadening, if the diffracting aperture is 3 mm wide.

71. Two narrow slits are illuminated by a single monochromatic source. Name the patterns obtained on the screen. One of the slits is now completely covered. What is the name of the pattern now, obtained on the screen? Draw intensity pattern obtained in the two cases. Also write two differences between the patterns obtained in the above two cases

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

73. State one feature by which the phenomenon of interference can be distinguished from that of diffraction. A parallel beam of light of wavelength 600 nm is incident normally on a slit of width 'a'. If the distance between the slits and the screen is 0.8 m and the distance of 2nd order maximum from the centre of the screen is 15 mm, calculate the width of the slit

74. Light of wavelength 550 nm is incident as parallel beam on a slit of width 0.1 mm. Find the angular width and the linear width of the principal maxima in the resulting diffraction pattern on a screen kept at a distance of 1.1 m from the slit. Which of these widths would not change if the screen were moved to a distance of 2.2 m from the slit?

75. Monochromatic light, of wavelength λ, falling on a slit, produces a single slit diffraction pattern on a screen kept at a distance R from the slit. The distance between the first minima, on the left, and the first minima, on the right, of the principal maxima, is found to be y obtain a formula, for the width of the slit, in terms of y, R and λ.
What would be the separation between the first secondary maxima on the left and the first secondary maxima on the right of the principle maxima?

76. In a single slit diffraction experiment, when a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the shadow of the obstacle. Explain why? State two points of difference between the interference pattern in Young's double slit experiment and diffraction pattern due to a single slit.

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

78. (a) In what way is diffraction from each slit related to the interference pattern in a double slit experiment?
(b) Two wavelengths of sodium light 590 nm and 596 nm are used, in turn to study the diffraction taking place at a single slit of aperture 2×10^{-4} m. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of the first maxima of the diffraction pattern obtained in the two cases.

79. A parallel beam of light of 600 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1.2 m away. It is observed that the first minimum is at a distance of 3 mm from the centre of the screen. Calculate the width of the slit.

80. A parallel beam of light of 450 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1.5 m away. It is observed that the first minimum is at a distance of 3 mm from the centre of the screen. Calculate the width of the slit.

■ POLARISATION

81. Name one device for producing polarised light. Draw a graph showing the dependence of intensity of transmitted light on the angle between polariser and analyser

82. How can one distinguish between an unpolarised light beam and a linearly polarised light beam using a polariod?

83. What is meant by plane polarised light? What type of waves show the property of polarisation? Describe a method for producing a beam of plane polarised light.

84. Describe an experiment to demonstrate transverse wave nature of light.

85. Define the term 'linearly polarised light'.
When does the intensity of transmitted light become maximum, when a polaroid sheet is rotated between two crossed polaroids?

86. Distinguish between unpolarised and plane polarised light. An unpolarised light is incident on the boundary between two transparent media. State the condition when the reflected wave is totally plane polarised. Find out the expression for the angle of incidence in this case.

87. (a) Light, from a monochromatic source, is made to fall on a single slit of variable width. In experimentalist records the following data for the linear width of the principal maxima on a screen kept at a distance of 1 m from the plane of the slit.

S. No.	1	2	3	4	5
Width of the slit	0.1 mm	0.2 mm	0.3 mm	0.4 mm	0.5 mm
Linear width of the principal maxima	6 mm	3 mm	1.98 mm	1.52 mm	1.2 mm

Use any two observations from this data to estimate the value of the wavelength of light used.

(b) Show that the Brewster angle, (i_B), for a given pair of transparent media, is related to their critical angle, i_C, through the relation $i_C = \sin^{-1}(\cot i_B)$

88. What does the statement, "natural light emitted from the sun is unpolarised" mean in terms of the direction of electric vector? Explain briefly how plane polarized light can be produced by reflection at the interface separating the two media.

89. What is a polaroid? How is plane polarised light obtained with its help? How will you use it to distinguish between unpolarised light and plane polarised light?

90. Define polarising angle. Derive the relation connecting polarising angle and the refractive index of a medium.

91. Sketch the graph showing the variation of intensity of transmitted light on the angle of rotation between a polariser and analyser. A ray of light is incident at an angle of incidence i_P on the surface of separation between air and a medium of refractive index μ, such that the angle between the reflected and refracted rays is 90°. Obtain the relation between i_P and μ.

92. What is the phenomenon of polarisation? Derive the relation connecting the polarising angle of a medium and its refractive index

93. The refractive index of the denser medium is 1.732. Calculate
(i) the polarising angle of medium
(ii) the angle of refraction.

94. Which of the following waves can be polarised:
(i) X-rays (ii) Sound waves? Give reasons.
Two polaroids are used to study polarisation. One of them (the polariser) is kept fixed and the other (the analyser) is initially kept with its axis parallel to the poalriser. The analyser is then rotated through angles of 45°, 90° and 180° in turn. How would the intensity of light coming out of analyser be affected for these angles of rotation, as compared to the initial intensity and why?

95. The polarisation of a beam of light by reflection, is best achieved when the reflected and refracted rays are at right angles to each other. Show that the polarising angle of incidence is then given by $i_p = \tan^{-1} \mu$.

96. Which out of the following can be polarized.
X-rays, sound waves and radio-waves? Name one device for producing polarized light. Draw a graph showing the dependence of intensity of transmitted light on the angle between polarizer and analyser.

97. What is a polaroid? How are these artificially made? Mention two uses of polaroids. Draw a graph showing the dependence of intensity of transmitted light on the angle between polarizer and analyser.

98. An incident beam of light of intensity I_0 is made to fall on a polaroid *A*. Another polaroid *B* is so oriented with respect to *A* that there is no light emerging out of *B*. A third polaroid *C* is now introduced mid way between *A* and *B* and is so oriented that its axis bisects the angle between the axes of *A* and *B*. What is the intensity of light now between (i) *A* and *C* (ii) *C* and *B*. Give reasons for your answers.

99. Two polaroids P_1 and P_2 are placed at 90° to each other. Find the transmitted intensity if a third polaroid P_3 is placed between P_1 and P_2 bisecting the angle between them.

100. Define the term 'linearly polarised light'.
When does the intensity of transmitted light become maximum, when a polaroid sheet is rotated between two crossed polaroids?

101. How does an unpolarised light get polarised when passed through a polaroid?
Two polaroids are set in crossed positions. A third polaroid is placed between the two making an angle θ with the pass axis of the first polaroid. Write the expression for the intensity of light transmitted from the second polaroid. In what orientations will the transmitted intensity be (i) minimum and (ii) maximum?

102. (a) Describe briefly, with the help of suitable diagram, how the transverse nature of light can be demonstrated by the phenomenon of polarization.
(b) When unpolarized light passes from air to transparent medium, under what condition does the reflected light get polarized?

103. (a) What is linearly polarized light? Describe briefly using a diagram how sunlight is polarised.

(b) Unpolarised light is incident on a polaroid. How would the intensity of transmitted light change when the polaroid is rotated?

104. (a) Using the phenomenon of polarisation, show how transverse nature of light can be demonstrated.

(b) Two polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. Unpolarised light of intensity I_0 is incident on P_1. A third polaroid P_3 is kept in between P_1 and P_2 such that its pass axis makes an angle of 30° with that of P_1. Determine the intensity of light transmitted through P_1, P_2 and P_3.

105. (a) Show, with the help of a diagram, how unpolarised sunlight gets polarised due to scattering.

(b) Two polaroids P_1 and P_2 are placed with their pass axes perpendicular to each other. Unpolarised light of intensity I_0 is incident on P_1. A third polaroid P_3 is kept in between P_1 and P_2 such that its pass axis makes an angle of 45° with that of P_1. Determine the intensity of light transmitted through P_1, P_2 and P_3.

■ WAVEFRONT AND HUYGEN'S PRINCIPLE

1. (a) How is a wavefront different from a ray? Draw the geometrical shape of the wavefronts when
   (i) light diverges from a point source
   (ii) light emerges out of a convex lens when a point source is placed at its focus.

   (b) State Huygen's principle, with the help of a suitable diagram, prove Snell's law of refraction using Huygen's principle.

2. State Huygen's principle. Using the geometrical construction of secondary wavelets, explain the refraction of a plane wavefront incident at a plane surface. Hence verify Snell's law of refraction.
   Illustrate with the help of diagram the action of (i) convex lens and (ii) concave mirror on a plane wavefront incident on it.

3. State the principle which helps us to determine the shape of the wavefront at a later time from its given shape at any time. Apply this principle to
   (i) show that a spherical/plane wavefront continues to propagate forward as a spherical/plane wavefront.
   (ii) derive Snell's law of refraction by drawing the refracted wavefront corresponding to a plane wavefront incident on the bounding separating a rarer medium from a denser medium.

4. (a) State Huygen's principle. Using this principle draw a diagram to show how a plane wavefront incident at the interface of the two media gets refracted when it propagates from a rarer to a denser medium. Hence verify Snell's law of refraction.

   (b) When monochromatic light travels from a rarer to a denser medium, explain the following, giving reasons:
   (i) Is the frequency of reflected and refracted light same as the frequency of incident light?
   (ii) Does the decrease in speed imply a reduction in the energy carried by light wave?

■ INTERFERENCE

5. Deduce the conditions of maxima and minima is Young's double slit experiment and find an expression for the fringe width.

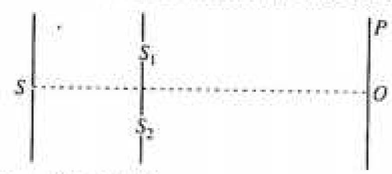
6. What are coherent sources of light? State two conditions for two light sources to be coherent. Derive a mathematical expression for the width of interference fringes obtained in Young's double slit experiment with the help of a suitable diagram.

7. Derive an expression for the intensity at any point on the screen in Young's double slit experiment. Using it obtain the condition of maxima and minima and hence obtain the ratio of maximum and minimum intensity of fringes on screen.

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

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

9. Figure shows an experiment setup similar to Young's double slit experiment to observe interference of light.



Here $SS_2 - SS_1 = \lambda/4$

Write the condition of (i) constructive, (ii) destructive interference at any point P in terms of path difference.

$\Delta = S_2P - S_1P$

Does the central fringe observed in the above setup lie above or below O? Give reason in support of your answer.

Yellow light of wavelength 6000Å produces fringes of width 0.8 mm in Young's double slit experiment. What will be the fringe width if the light source is replaced by another monochromatic source of wavelength 7500Å and separation between the slits is doubled?

10. In Young's experiment, deduce the conditions for the constructive and destructive interference pattern observed on the screen by drawing the necessary diagram. Hence establish the relation between the fringe width, the wavelength λ of the monochromatic source, separation between the two slits and the distance between the screen and the plane of the slits. If the set-up were to be put up in a medium optically denser than air, what effect would there be on the observed fringe width? Give reason for your answer.

11. What are coherent sources of light? Why are coherent sources required to obtain sustained interference pattern?

State three characteristic features which distinguish the interference pattern due to two coherently illuminated sources as compared to that observed in a diffraction pattern due to a single slit.

12. What is interference of light? Write two essential conditions for sustained interference pattern to be produced on the screen. Draw a graph showing the variation of intensity versus the position on the screen in Young's experiment when

(a) both the slits are opened and

(b) one of the slits is closed.

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

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

(ii) Separation between two slits is increased.

Explain your answer in each case.

13. (a) What are coherent sources of light? Two slits in Young's double slit experiment are illuminated by two different sodium lamps emitting light of the same wavelength. Why is no interference pattern observed?

(b) Obtain the condition for getting dark and bright fringes in Young's experiment. Hence write the experiment for the fringe width.

(c) If S is the size of the source and d is the distance from the plane of the two slits, what should be the criterion for the interference fringes to be seen?

14. (a) In Young's double slit experiment, derive the condition for constructive interference and (ii) destructive interference at a point on the screen.

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

15. (a) In Young's double slit experiment, describe briefly how bright and dark fringes are obtained on the screen kept in front of a double slit. Hence obtain the expression for the fringe width.

(b) The ratio of the intensities at minima to the maxima in the Yong's double slit experiment is 9 : 25. Find the ratio of the widths of the two slits.

16. (a) (i) Two independent monochromatic sources of light cannot produce a sustained interference pattern'. Give reason.

(ii) Light waves each of amplitude "a" and frequency "ω", emanating from two coherent light sources superpose at a point. If the displacements due to these waves is given by $y_1 = a \cos \omega t$ and $y_2 = a \cos(\omega t + \phi)$ where ϕ is the phase difference between the two, obtain the expression for the resultant intensity at the point.

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

17. (a) How does one demonstrate, using a suitable diagram, that unpolarised light when passed through a polaroid gets polarised?

(b) A beam of unpolarised light is incident on a glass-air interface. Show, using a suitable ray diagram, that light reflected from the interface is totally polarised, when $\mu = \tan i_B$ where μ is the refractive index of glass with respect to air and i_B is the Brewster's angle.

■ DIFFRACTION

18. Explain diffraction at a single slit and derive relation for linear width of maxima.

19. Discuss Fraunhoffer diffraction at a single slit. Also derive the relation for linear width of central maximum

20. What is meant by diffraction? Draw a graph to show the relative intensity distribution for a single slit diffraction pattern. Obtain an expression for the diffraction of the first minimum and first maximum in the diffraction pattern.

21. Derive an expression for the diffraction of n^{th} secondary maximum and minimum in diffraction at single slit.

22. Obtain an expression for the position of n^{th} secondary maximum and minimum in diffraction at single slit. Hence obtain relation for linear width of central maximum.

23. Using Huygen's principle, draw a diagram to show propagation of wave-front originating from a mono-chromatic point source.

Describe diffraction of light due to a single slit. Explain formation of a pattern of fringes obtained on the screen and plot showing variation of intensity with angle θ in single slit diffraction.

24. State the essential condition for diffraction of light to take place.
Use Huygen's principle to explain diffraction of light due to a narrow single slit and the formation of a pattern of fringes obtained on the screen. Sketch the pattern of fringes formed due to diffraction at a single slit showing variation of intensity with angle θ.

25. (a) Describe briefly how a diffraction pattern is obtained on a screen due to a single narrow slit illuminated by a monochromatic source of light. Hence obtain the conditions for the angular width of secondary maxima and secondary minima.

(b) Two wavelengths of sodium light of 590 nm and 596 nm are used in turn to study the diffraction taking place at a single slit of aperture 2×10^{-6} m. The distance between the slit and the screen is 1.5 m. Calculate the separation between the positions of first maxima of the diffraction pattern obtained in the two cases.

■ POLARISATION

26. What is meant by a linearly polarised light? Which type of waves can be polarised? Briefly explain a method for producing polarised light. Two polaroids are placed at 90° to each other and the intensity of transmitted light is zero. What will be the intensity of transmitted light when one more polaroid is placed between these two bisecting the angle between them? Take intensity of unpolarised light as I_0.

27. Which special characteristic of light is demonstrated only by the phenomenon of polarization? Distinguished clearly between linearly polarized light and unpolarized light. Light is incident at the Brewster angle, from air, on to a transparent medium. How are the resulting reflected and refracted rays oriented with respect to each other? Obtain a relation between the refractive index of the medium and the Brewster angle. What is the nature of polarization of the reflected light, in this case?

28. (a) What is plane polorised light? The poloroids are placed at 90° to each other and the transmitted intensity is zero. What happens when one more polaroid is placed between these two, bisecting the angle between them? How will the intensity of transmitted light very on further rotating the third polaroid?

(b) If a light beam shows no intensity variation when transmitted through a polaroid which is rotated, does it mean that the light is unpolarised? Explain briefly.

29. What do we understand by 'polarization' of a wave? How does this phenomenon help us to decide whether a given wave is transverse or longitudinal in nature? Light from an ordinary source (say, a sodium lamp) is passed through a polaroid sheet P_1. The transmitted light is then made to pass through a second polaroid sheet P_2 which can be rotated, so that the angle (θ) between the two polaroid sheets varies from 0° to 90°. Show graphically the variation of the intensity of light, transmitted by P_1 and P_2, as a function of the angle θ. Take the incident beam intensity as I_0. Why does the light from a clear blue portion of the sky show a rise and fall of intensity when viewed through a polaroid which is rotated?

30. (a) How does an unpolarized light incident on a polaroid get polarized?
Describe briefly, with the help of a necessary diagram, the polarization of light by reflection from a transparent medium.

(b) Two polaroids '*A*' and '*B*' are kept in crossed position. How should a third polaroid '*C*' be placed between them so that the intensity of polarized light transmitted by polaroid *B* reduces to 1/8th of the intensity of unpolarized light incident on *A*?

Hints and Solutions

VERY SHORT ANSWER TYPE QUESTIONS

8. Zero

9. Frequency remains same but wavelength decreases.

10. Frequency remains same but wavelength decreases.

11. $\upsilon = \frac{v}{\lambda} = \frac{3\times10^8}{6\times10^{-7}} = 5\times10^{14}$ Hz

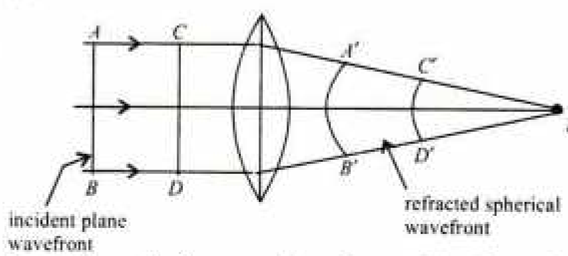
14. (a) spherical (b) plane
(c) plane (d) cylindrical
(e) and (f) spherical (g) plane

15. As the frequency of light does not change, on passing from one medium to the other.

16. No, because energy carried by light wave depends only on its frequency, which does not change on passing from one medium to the other.

17. (i) Spherical wavefront
(ii) Plane wavefront

18.



19. Ray is the path of propagation of wave. Wavefront of a wave is the locus of all the particles of the medium in same phase of vibration, when the wave passes through the medium.

20. Light emitted by two coherent sources should be of same frequency and in same phase or with stable phase difference.

21. (i) $I_{max} = (a + a)^2 = 4a^2 = 4I$ [As $I = a^2$]
(ii) $I_{min} = (a - a)^2 = 0$

22. $\Delta x = (2n-1)\frac{\lambda}{2}$, where $n = 1, 2, 3, \ldots$

23. Interference is the result of superposition of light waves from two sources, whereas diffraction takes place due to interference of light waves from the different parts of the same source of light.

25. $\Delta x = n\lambda$, where $n = 1, 2, 3, \ldots.$

26. Because light produced by them may be of same frequency but never in same phase nor with constant phase difference.

27. Incoherent, because intensity I is same at each point and hence the two sources have not produced interference of light.

28. Angular separation will not change.

30. Fringe width will become double.

31. Fringe width of interference fringes decreases to $\beta' = \frac{\beta}{\mu} = \frac{\beta}{1\cdot3}$.

32. In Young's experiment, angular width of fringes is $\theta = \frac{\lambda}{d}$

(a) If the 'd' between the slits is increased, angular width 'θ' decreases, as $\theta \propto \frac{1}{d}$.

(b) If the distance 'D' between the plane of slits and screen is increased, then 'θ' remains same, as 'θ' is independent of 'D'.

33. Size of the aperture should be the order of wavelength of light.

34. X-rays will not get diffracted.

35. Angle of diffraction θ_1 be such that $\sin\theta_1 = \frac{\lambda}{a}$

36. Angle of diffraction θ_1' be such that $\sin\theta_1' = \frac{3}{2}\frac{\lambda}{a}$

37. $Z_f = \frac{a^2}{\lambda} = \frac{(4\times10^{-3})^2}{400\times10^{-9}} = \frac{4\times10^{-6}}{4\times10^{-7}} = 10$ m

38. Angular width of central maximum $\theta_0 \propto \lambda$.

39. Angular width of central fringe $= \frac{2\lambda}{d}$

So, there is no effects on angular separation by changing of the distance of separation 'D' between slit and the screen.

40. Size of central maxima will become half.
Intensity becomes 4 times.

42. Sound does not exhibit polarisation.

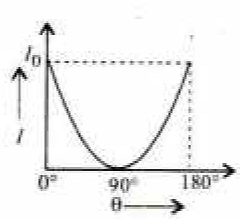
44. $\mu = \tan p$ or $\tan p = \sqrt{3}$ or $p = 60°$

45. $\mu = \tan 60° = \sqrt{3}$

46. $\mu = \tan 60° = \sqrt{3}$

47. $\mu = \tan p$ or $\tan p = \sqrt{3}$
or $p = 60°$

48.



50. At polarising angle p, where $\tan p = \mu = \sqrt{3}$
or $p = 60°$
Angle of polarising = Angle of incidence = 60°

51. $\tan p = \mu = \sqrt{3}$ or $p = 60°$

By Snell's law, $\mu = \frac{\sin i}{\sin r}$

or $\sin r = \frac{\sin p}{\mu}$ $[\ i = p]$

or $\sin r = \frac{\sin 60°}{\sqrt{3}} = \frac{\sqrt{3}/2}{\sqrt{3}} = \frac{1}{2}$

or $r = 30°$

52. $I = I_0 \cos^2 60° = I_0 \times \frac{3}{4}$

or $\frac{I}{I_0} = \frac{3}{4}$ or $\frac{I - I_0}{I_0} = \frac{-1}{4}$

So, intensity decreases by one-fourth.

53. Polarisation.

54. Let intensity of original unpolarised light be I_0.
Then intensity of light on passing through polariser becomes $I_0/2$. Intensity of light after emerging from analyser becomes

$$I = \frac{I_0}{2}\cos^2 45° = \frac{I_0}{2} \times \frac{1}{2}$$

or $I = \frac{I_0}{4}$

55. $\mu = \tan i_p$
where i_p is called polarising angle of that medium.

56. As only the transverse wave can be polarized, that is why the heat waves which are transverse wave and have vibrations perpendicular to the direction of propagation can be polarized whereas the sound waves cannot be polarized being longitudinal in nature and having vibrations in the direction of propagation.

SHORT ANSWER TYPE QUESTIONS

10. $\lambda = 589$ nm, $\upsilon = \frac{c}{\lambda} = \frac{3 \times 10^8}{589 \times 10^{-9}}$

or $\nu = 5.1 \times 10^{14}$ Hz

(i) Of reflected wave
Frequency $\nu = 5.1 \times 10^{14}$ Hz
Wavelength $\lambda = 589$ nm
Speed $c = 3 \times 10^8$ m/s

(ii) Of refracted wave
Frequency $\nu' = 5.1 \times 10^{14}$ Hz

Wavelength $\lambda' = \frac{\lambda}{\mu} = \frac{589}{1.33} = 443$ nm

Speed $v = \frac{c}{\mu} = \frac{3 \times 10^8}{1.33} = 2.25 \times 10^8$ m/s

11. (a) $\mu = c/v$

or $v = \frac{c}{\mu} = \frac{3 \times 10^8}{1.5} = 2 \times 10^8$ m/s

(b) No, As $\mu \propto \frac{1}{\lambda}$ and $\lambda_V < \lambda_R$
So $\mu_V > \mu_R$ and hence $v_V < v_R$
i.e., violet travels slower in glass prism.

13. No, because two independent sources of light can produce light waves of same wavelength and frequency but never in same phase or with stable phase difference.

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

(i) When d is infinitely small, β is infinitely large. Hence no interference pattern is observed on screen and the screen generally appears illuminated.

(ii) When d is infinitely large, β is infinitely small and so distinct interference pattern is observed.

15. $\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \frac{25}{9}$

or $\frac{a_1 + a_2}{a_1 - a_2} = \frac{5}{3}$ or $4a_2 = a_1$

$\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{16a_2^2}{a_2^2}$ or $\frac{I_1}{I_2} = \frac{16}{1}$

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

(i) When D is increased, fringe width β also increases.
(ii) When d is decreased, fringe width β increases.
(iii) When widths of the slits are increased, then intensity of bright fringes increases.

19. Given $I_1 = a_1^2 = I$ or $a_1 = \sqrt{I}$

and $I_2 = a_2^2 = I + \delta I$ or $a_2 = \sqrt{I + \delta I}$

$$I_{max} = (a_1 + a_2)^2 = \left[\sqrt{I} + \sqrt{I + \delta I}\right]^2$$

$$= \left[\sqrt{I} + \sqrt{I}\left(1 + \frac{\delta I}{I}\right)^{\frac{1}{2}}\right]^2 = I\left[1 + \left(1 + \frac{\delta I}{I}\right)^{\frac{1}{2}}\right]^2$$

As $\delta I << I$, expanding if binomially

$$I_{max} = I\left(1 + 1 + \frac{\delta I}{2I}\right)^2 = I\left(2 + \frac{\delta I}{2I}\right)^2$$

$$= I\left[4 + 2\frac{\delta I}{I} + \frac{\delta I^2}{4I^2}\right]$$

$\therefore$ $\delta I << I$, so

$I_{max} \approx 4I$

$$I_{min} = (a_1 - a_2)^2 = \left[\sqrt{I} - \sqrt{I + \delta I}\right]^2$$

$$= \left[\sqrt{I} - \sqrt{I}\left(1 + \frac{\delta I}{I}\right)^{\frac{1}{2}}\right]^2 = I\left[1 - \left(1 + \frac{\delta I}{I}\right)^{\frac{1}{2}}\right]^2$$

As $\delta I << I$, expanding it binomially

$$I_{\min} = I\left[1 - \left(1 - \frac{\delta I}{2I}\right)\right]^2 = I\left[1 - 1 + \frac{\delta I}{2I}\right]^2 = \frac{(\delta I)^2}{4I}$$

21. $\frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2 = \frac{4}{9}$ or $\frac{a_1}{a_2} = \frac{2}{3}$ or $a_1 = \frac{2}{3}a_2$

$$\frac{I_{\max}}{I_{\min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)} = \frac{(2/3a_2 + a_2)^2}{(2/3a_2 - a_2)^2}$$

or $\frac{I_{\max}}{I_{\min}} = \frac{25}{1}$

22. $\frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2 = \frac{81}{1}$ or $\frac{a_1}{a_2} = \frac{9}{1}$ or $a_1 = 9a_2$

$$\frac{I_{\max}}{I_{\min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \frac{(9a_2 + a_2)^2}{(9a_2 - a_2)^2} = \frac{25}{16}$$

23. (i) $\beta = \frac{\lambda D}{d}$, so separation d between the slits is increased then fringe width β decreases.

(ii) When source of white light is used, then central bright fringe formed is white, with coloured fringes on its either side such that violet is closest and red is farthest.

24. (i) $\frac{I_{\max}}{I_{\min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2}$ and $\frac{w_1}{w_2} = \frac{a_1^2}{a_2^2}$

So on increasing the slit widths, amplitudes a_1 and a_2 of lights emerging from them increase and hence the intensity of fringes also increases.

(ii) $\beta = \frac{\lambda D}{d}$ on increasing the wavelength λ of light, fringe width β of the fringes also increases.

25. As $\lambda' = \frac{\lambda}{\mu}$, so on immersing the appartus in water, wavelength λ of light decreases and hence fringe width β also decreases.

28. Two different lamps emit light waves which are not coherent, as they are not in same phase or not have stable phase difference. Due to this no sustained interference pattern can be obtained on screen.

(i) When path difference $\Delta x = 0$, then phase difference

$$\Delta\phi = \frac{2\pi\Delta x}{\lambda} = 0$$

Hence $I = a_1^2 + a_2^2 + 2a_1a_2\cos 0$

or $I = (a_1 + a_2)^2$

(ii) When path difference $\Delta x = \lambda/4$

Phase difference $\Delta\phi = \frac{2\pi}{\lambda}\frac{\lambda}{4} = \frac{\pi}{2}$

Hence $I' = a_1^2 + a_2^2 + 2a_1a_2\cos\pi/2$

$I' = a_1^2 + a_2^2$

the ratio is $\frac{I}{I'} = \frac{(a_1 + a_2)^2}{a_1^2 + a_2^2}$

If $a_1 = a_2$, $\frac{I}{I'} = \frac{2}{1}$

29. $\frac{a_1^2}{a_2^2} = \frac{I}{4I}$ or $\frac{a_1}{a_2} = \frac{1}{2}$ or $a_2 = 2a_1$

$I' = a_1^2 + a_2^2 + 2a_1a_2\cos\pi/2$

or $I' = a_1^2 + (2a_1)^2 + 0 = a_1^2 + 4a_1^2 = 5a_1^2$

or $I' = 5I$

30. $I = a_1^2 + a_2^2 + 2a_1a_2\cos 0 = (a_1 + a_2)^2$

$I' = a_1^2 + a_2^2 + 2a_1a_2\cos\frac{\pi}{2} = a_1^2 + a_2^2$

So $\frac{I}{I'} = \frac{(a_1 + a_2)^2}{a_1^2 + a_2^2}$

If $a_1 = a_2$, then

$\frac{I}{I'} = \frac{2}{1}$

31. $I = a_1^2 + a_2^2 + 2a_1a_2\cos\pi/3$

$I = a_1^2 + a_2^2 + + a_1a_2$

$I' = a_1^2 + a_2^2 + 2a_1a_2\cos\pi/2 = a_1^2 + a_2^2$

So, $\frac{I}{I'} = \frac{a_1^2 + a_2^2 + a_1a_2}{a_1^2 + a_2^2}$

If $a_1 = a_2$, then

$\frac{I}{I'} = \frac{3}{2}$

32. $D = 1.5$ m, $\lambda = 6000\text{Å} = 6 \times 10^{-7}$ m

$\beta = 1$ mm $= 1 \times 10^{-3}$ m

$\beta = \frac{\lambda D}{d}$ or $d = \frac{\lambda D}{\beta} = \frac{6 \times 10^{-7} \times 1.5}{1 \times 10^{-3}}$

or $\beta = 9 \times 10^{-4}$ m

33. $d = 0.24$ mm $= 0.24 \times 10^{-3}$ m, $D = 1.5$ m

$\beta = 0.3$ cm $= 0.3 \times 10^{-2}$ m

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

or $\lambda = \frac{0.3 \times 10^{-2} \times 0.24 \times 10^{-3}}{1.2}$

or $\lambda = 6 \times 10^{-7}$ m $= 6000\text{Å}$

34. $d = 0.03$ mm $= 3 \times 10^{-5}$ m, $D = 1.5$ m

$y_4 = 1$ cm $= 1 \times 10^{-2}$ m

$y_4 = \frac{4\lambda D}{d}$

or $\lambda = \frac{y_4 d}{4D} = \frac{3 \times 10^{-5} \times 1 \times 10^{-2}}{4 \times 1.5}$

$\lambda = 5 \times 10^{-8}$ m

35. $\beta = 0.6$ cm, $D' = \frac{D}{2}$

$$\frac{\beta'}{\beta} = \frac{\lambda D'/d}{\lambda D/d} = \frac{D'}{D} = \frac{1}{2}$$

$$\beta' = \frac{\beta}{2} \quad \text{or} \quad \beta' = \frac{0.6}{2} = 0.3 \text{ cm}$$

36. $\lambda_1 = 660$ nm, $\beta_1 = 7.8$ mm, $\beta_2 = 6.5$ mm

$$\frac{\beta_2}{\beta_1} = \frac{\lambda_2}{\lambda_1} \quad \text{or} \quad \lambda_2 = 660 \times \frac{6.5}{7.8}$$

or $\lambda_2 = 550$ nm

37. $d = 3 \times 10^{-3}$ m, $\lambda = 480$ nm $= 4.8 \times 10^{-7}$ m

$D = 2$ m

$$Y_8 - Y_3' = \frac{8\lambda D}{d} - \frac{5}{2}\frac{\lambda D}{d} = \frac{11}{2}\frac{\lambda D}{d}$$

$$= \frac{11}{2} \times \frac{4.8 \times 10^{-7} \times 2}{3 \times 10^{-3}}$$

$= 1.76 \times 10^{-3}$ m

38. $\Delta D = 5 \times 10^{-2}$ m

$\Delta\beta = 3 \times 10^{-5}$ m

$d = 10^{-3}$ m

$$\Delta\beta = \frac{\lambda \Delta D}{d} \quad \text{or} \quad \lambda = d \cdot \frac{\Delta\beta}{\Delta D}$$

$$\text{or} \quad \lambda = 10^{-3} \times \frac{3 \times 10^{-5}}{5 \times 10^{-2}} = 6 \times 10^{-7} \text{ m} = 6000\text{Å}$$

39. $\lambda = 6000$Å, $\beta = 2$ mm, $\mu = 1.33$

$$\frac{\beta'}{\beta} = \frac{\lambda'}{\lambda} = \frac{\lambda/\mu}{\lambda} = \frac{1}{\mu}$$

$$\text{or} \quad \beta' = \frac{\beta}{\mu} = \frac{2}{1.33} = 1.5 \text{ mm}$$

40. $\lambda = 400$ nm, fringe width $\beta = \frac{\lambda D}{d}$

$\lambda' = 600$ nm, $d' = d/2$, $\beta' = \frac{\lambda' D'}{d'}$

As, $\beta' = \beta$

$$\frac{\lambda' D'}{d'} = \frac{\lambda D}{d} \quad \text{or} \quad \frac{D'}{D} = \frac{\lambda}{\lambda'} \times \frac{d'}{d}$$

$$\text{or} \quad \frac{D'}{D} = \frac{400}{600} \times \frac{1}{2} = \frac{1}{3}$$

41. $d = 2$ mm $= 2 \times 10^{-3}$ m, $D = 140$ cm $= 1.4$ m

$\lambda = 600$ nm $= 600 \times 10^{-9}$ m $= 6 \times 10^{-7}$ m

Distance of 3rd bright fringe from central maximum is

$$y_3 = \frac{3\lambda D}{d} = \frac{3 \times 6 \times 10^{-7} \times 1.4}{2 \times 10^{-3}} = 1.26 \times 10^{-3} \text{ m}$$

$y_3 = 1.26$ mm

when $\lambda' = 480$ nm $= 4.8 \times 10^{-7}$ m

$$\text{then } y_3' = \frac{3\lambda' D}{d} = \frac{3 \times 4.8 \times 10^{-7} \times 1.4}{2 \times 10^{-3}} = 1.008 \times 10^{-3} \text{ m}$$

or $y'_3 = 1.008 \times 10^{-3}$ m

$y'_3 = 1.008$ mm.

So, shift in the position of third bright fringe from central maximum is

$\Delta y = y_3 - y'_3 = (1.26 - 1.008)$ mm

or $\Delta y = 0.252$ mm

42. $d = 0.24$ mm $= 0.24 \times 10^{-3}$ m, $D = 160$ cm $= 1.6$ m

$\beta = 0.4$ cm $= 0.4 \times 10^{-2}$ m

$$\beta = \frac{\lambda D}{d} \quad \text{or} \quad \lambda = \frac{\beta \cdot d}{D} = \frac{0.4 \times 10^{-2} \times 0.24 \times 10^{-3}}{1.6}$$

or $\lambda = 6 \times 10^{-7}$ m $= 6000$Å

when $D' = D - 40$ cm $= 160 - 40 = 120$ cm $= 1.2$ m

then

$$\beta' = \frac{\lambda D'}{d} = \frac{6 \times 10^{-7} \times 1.2}{0.24 \times 10^{-3}} = 3 \times 10^{-3} \text{ m}$$

or $\beta' = 0.3$ cm

43. $$\frac{\beta_2}{\beta_1} = \frac{\lambda_2 D/d}{\lambda_1 D/d}$$

$$\text{or} \quad \lambda_2 = \frac{\beta_2}{\beta_1} \times \lambda_1 = \frac{7.2 \text{ mm}}{8.1 \text{ mm}} \times 630 \text{ nm}$$

or $\lambda_2 = 560$ nm.

If monochromatic source of light in Young's double slit exp. is replaced by a source of white light, then the central bright fringe formed is white with coloured fringes on its either side.

44. Given that distance between the two slits,

$d = 0.15$ mm

Wavelength of monochromatic light, $\lambda = 450$ nm

Distance between the screen and slits, $D = 1$ m

(a) (i) Distance of n^{th} bright fringe from central maximum

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

$$= 2 \times \frac{450 \times 10^{-9} \times 1}{0.15 \times 10^{-3}} \qquad [\quad n = 2 \text{ here}]$$

$= 6 \times 10^{-3}$ m

$= 6$ mm

(ii) Distance of n^{th} dark fringe from central maximum

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

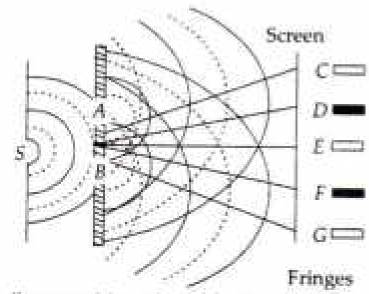
$$= (2 \times 2 - 1) \times \frac{450 \times 10^{-9} \times 1}{2 \times 0.15 \times 10^{-3}} \quad [\quad n = 2 \text{ here}]$$

$$= \frac{3}{2} \times 3 \times 10^{-3} = 4.5 \text{ mm}$$

(b) Since width of bright or dark fringes is given by $\beta = \frac{\lambda D}{d}$.

Thus when screen is moved away, D increases and hence fringe width increases.

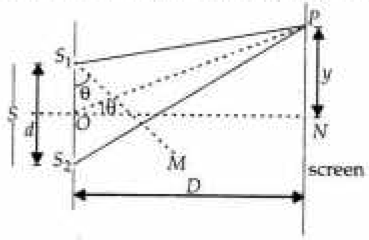
45. Young's double slit experiment :



Superposition of wavefronts

S is a narrow slit (of width about 1 mm) illuminated by a monochromatic source of light, S. At a suitable distance (about 10 cm) from S, there are two fine slits A and B about 0.5 mm apart placed symmetrically parallel to S. When a screen is placed at a large distance (about 2 m) from the slits A and B, alternate bright and dark fringes running parallel to the lengths of slits appear on the screen. These are the interference fringes. The fringes disappear when one of the slits A or B is covered.

Expression for fringe width : In Young's double slit experiment we obtain two sources from a single source.



Here S_1P and S_2P are nearly parallel since the distance $S_1S_2 = d$ is much less than D. The angle that these two lines make with the normal to the screen is taken as θ.

Path difference between the waves reaching the point P on screen is

$$\Delta x = S_2P - S_1P = S_2P - MP = S_2M = d\sin\theta$$

As angle is very small

$$d\sin\theta \approx d\tan\theta$$

i.e. $\Delta x = \frac{yd}{D} \quad \left(\text{In } \Delta\, NOP, \tan\theta = \frac{y}{D}\right)$ ...(i)

We know, that for maxima

$\Delta x = n\lambda$ ...(ii)

where, $n = 1, 2, 3, ...$

From equation (i) and (ii), we get

$$y_n = \frac{n\lambda D}{d}$$

Similarly for minima

$$y'_n = \frac{(2n-1)\lambda D}{2d}$$

The fringe width is the separation between two consecutive maxima or minima,

$$\Delta y = \frac{D\lambda}{d}(n+1-n) = \frac{D\lambda}{d}$$

It is denoted by β

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

46. For a single slit of width "a" the first minima of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of (λ/a) because the light from centre of the slit differs by a half of a wavelength.

Whereas a double slit experiment at the same angle of (λ/a) and slits separation "a" produces maxima because one wavelength difference in path length from these two slits is produced.

53. $\beta_0 = \frac{2\lambda D}{a}$

(i) If slit width a is halved, then width β_0 of central bright fringe doubles, but its intensity remains same.

(ii) When light of longer wavelength λ is used, width β_0 of central bright fringe increases, but its intensity remains same.

55. If width a of the slit is doubled, then of central bright fringe the intensity remains same and fringe width β_0 becomes half.

57. Angular width $\theta_0 = \frac{2\lambda}{a}$

(i) When slit width 'a' is decreased, angular width θ_0 increases.

(ii) No effect on angular width θ_0, when distance between the slit and screen is increased.

(iii) Angular width θ_0, decreases when λ is decreased.

58. Size of obstacles or openings like windows and doors in buildings are comparable to wavelength of sound waves but much larger than that of light waves. So diffraction of sound waves is easier to observe than that of light waves.

Two main changes in diffraction pattern on using white light are :

(i) In each order of diffraction, the diffracted image of the slit gets dispersed into the colours constituting white light.

(ii) In higher order spectra, the dispersion is more and it results in overlapping of different colours

59. If two bright point objects lying close to each other are seen with an optical instrument, then they may or may not be seen as two separate distinct objects due to the overlapping of their diffraction pattern. The two objects are seen just separated when the distance between the central maxima of their diffraction pattern is just equal to the distance between the central maximum of one object and first secondary minimum of the other object. This is how diffraction limits the resolving power of an optical instrument.

61. $\theta_0 = \frac{2\lambda}{a}$ So, θ_0

(i) decreases, (ii) No effect, (iii) increases.

63. $\beta_0 = \frac{2\lambda D}{a}$

(i) When λ is increased, β_0 increases

(ii) When a is increased, β_0 decreases

When whole apparatus is immersed in water then wavelength of light decreases to $\lambda' = \frac{\lambda}{\mu}$ and β_0 decreases.

64. $\lambda = 600$ nm $= 6 \times 10^{-7}$ m, $a = 5 \times 10^{-4}$ m

$D = 2$ m

$$2y_1 = \frac{2\lambda D}{a} = \frac{2 \times 6 \times 10^{-7} \times 2}{5 \times 10^{-4}} = 4.8 \times 10^{-3} \text{ m}$$

65. $\lambda = 600$ nm $= 6 \times 10^{-7}$ m, $a = 3 \times 10^{-3}$ m

$D = 3$ m

$$\beta_0 = \frac{2\lambda D}{a} = \frac{2 \times 6 \times 10^{-7} \times 3}{3 \times 10^{-3}} = 1.2 \times 10^{-3} \text{ m}$$

66. $a = 0.25$ mm $= 2.5 \times 10^{-4}$ m, $\lambda = 5.89 \times 10^{-7}$ m

$$\theta_1' = \frac{3}{2}\frac{\lambda}{a} = \frac{3}{2} \times \frac{5.89 \times 10^{-7}}{2.5 \times 10^{-4}} = 3.53 \times 10^{-3} \text{ rad}$$

67. **(a)** (i) $\sin\theta_1 = \frac{\lambda}{a}$ or $a = \frac{6.5 \times 10^{-7}}{\sin 30°}$

or $a = 1.3 \times 10^{-6}$ m

(ii) $\sin\theta_1' = \frac{3}{2}\frac{\lambda}{a}$ or $a = \frac{3}{2} \times \frac{6.5 \times 10^{-7}}{\sin 30°}$

$a = 1.95 \times 10^{-6}$ m

(b) Because wavelengths from the lesser and lesser part of slit will produce constructive interference.

68. $\lambda = 5 \times 10^{-7}$ m, $a = 2 \times 10^{-3}$ m

required distance is Fresnel's distance

$$Z_f = \frac{a^2}{\lambda} = \frac{\left(2 \times 10^{-3}\right)^2}{5 \times 10^{-7}} = 8 \text{ m}$$

69. $\lambda = 600$ nm $= 6 \times 10^{-7}$ m, $a = 2$ mm $= 2 \times 10^{-3}$ m

$$Z_f = \frac{a^2}{\lambda} = \frac{\left(2 \times 10^{-3}\right)^2}{6 \times 10^{-7}} = 6.67 \text{ m}$$

70. $\lambda = 500$ nm $= 5 \times 10^{-7}$ m, $a = 3$ mm $= 3 \times 10^{-3}$ m

$$Z_f = \frac{a^2}{\lambda} = \frac{\left(3 \times 10^{-3}\right)^2}{5 \times 10^{-7}} = 18 \text{ m}$$

72. Here $a = 50$ m and $Z_f = 40/2 = 20$ km $= 2000$ m

As $Z_f = a^2/\lambda$

or $\lambda = \frac{a^2}{Z_f} = \frac{50^2}{20000} = 0.125 \text{ m} = 12.5 \text{ cm}$

73. $\lambda = 600$ nm $= 600 \times 10^{-9}$ m $= 6 \times 10^{-7}$ m

$D = 0.8$ m, $y'_2 = 15$ mm $= 15 \times 10^{-3}$ m

$$y_2' = \frac{5}{2}\frac{\lambda D}{a} \quad \text{or} \quad a = \frac{5}{2}\frac{\lambda D}{y_2'} = \frac{5}{2} \times \frac{6 \times 10^{-7} \times 0.8}{15 \times 10^{-3}}$$

$a = 8 \times 10^{-5}$ m

74. $\lambda = 550$ nm $= 5.5 \times 10^{-7}$ m, $a = 0.1$ mm $= 1 \times 10^{-4}$ m

$D = 1.1$ m

Linear width of central maximum is

$$\beta_0 = \frac{2\lambda D}{a} = \frac{2 \times 5.5 \times 10^{-7} \times 1.1}{1 \times 10^{-4}} = 12.1 \times 10^{-3} \text{ m}$$

or $\beta_0 = 12.1$ mm

Angular width of central maximum is

$$\theta_0 = \frac{2\lambda}{a} = \frac{2 \times 5.5 \times 10^{-7}}{1 \times 10^{-4}} = 1.1 \times 10^{-2}$$

or $\theta_0 = 0.011$ rad.

As angular width θ_0 is independent of distance D of screen from plane of slit, so it will not change when screen is moved to a distance of 2.2 m from the slit.

75. Here $D = R$ and distance between first dark fringes on either side of central maximum is

$$y = \beta_0 = \frac{2\lambda D}{a} \quad \text{or} \quad y = \frac{2\lambda R}{a} \quad \text{or,} \quad a = \frac{2\pi R}{\gamma}$$

Separation between first secondary maxima on either side of central bright fringe is

$$= 2\,y_1' = 2 \times \frac{3}{2}\frac{\lambda D}{a}$$

$$= 3\frac{\lambda D}{a}$$

76. When a tiny circular obstacle is placed in the path of light from a distant source a bright spot is seen at the centre of the shadow of the obstacle because of the constructive interference of diffracted rays of light by the circular obstacle.

Interference pattern		Diffraction pattern	
In interference pattern obtained by Young's double slit experiment.		In diffraction pattern obtained due to a single slit.	
(i)	All the bright and dark fringes are of same width.	(i)	Central bright fringe is twice the width of any other secondary bright or dark fringe.
(ii)	All the bright fringes are of same intensity.	(ii)	Intensity of central bright fringe is maximum and it decreases with increase in the order of secondary bright fringes.

77. Position of first minimum in diffraction pattern $y = \frac{D\lambda}{d}$

So, slit width $d = \frac{D\lambda}{y} = \frac{1 \times 500 \times 10^{-9}}{2.5 \times 10^{-3}} = 2 \times 10^{-4}$m

78. (a) If the width of each slit is comparable to the wavelength of light used, the interference pattern thus obtained

in the double-slit experiment is modified by diffraction from each of the two slits.

(b) Given that: Wavelength of the light beam,
$\lambda_1 = 590$ nm $= 5.9 \times 10^{-7}$ m
Wavelength of another light beam,
$\lambda_2 = 596$ nm $= 5.96 \times 10^{-7}$ m
Distance of the slits from the screen $= D = 1.5$ m
Distance between the two slits $= a = 2 \times 10^{-4}$ m
For the first secondary maxima,

$$\sin\theta = \frac{3\lambda_1}{2a} = \frac{x_1}{D}$$

$$x_1 = \frac{3\lambda_1 D}{2a} \text{ and } x_2 \quad \frac{3\lambda_2 D}{2a}$$

$\therefore$ Separation between the positions of first secondary maxima of two sodium lines

$$x_2 - x_1 = \frac{3D}{2a}(\lambda_2 - \lambda_1)$$

$$= \frac{3 \times 1.5}{2 \times 2 \times 10^{-4}}(5.96 \times 10^{-7} - 5.9 \times 10^{-7})$$

$$= 6.75 \times 10^{-5} \text{ m}$$

79. $d = \frac{D\lambda}{y} = \frac{1.2 \times 600 \times 10^{-9}}{3 \times 10^{-3}} = 2.4 \times 10^{-4}$ m

80. $d = \frac{D\lambda}{y} = \frac{1.5 \times 450 \times 10^{-9}}{3 \times 10^{-3}} = 2.25 \times 10^{-4}$ m

82. Light beam is passed through a polaroid and the polaroid is rotated. If the intensity of emergent light changes with rotation of polaroid, then the light beam is plane-polarised. But if the intensity of emergent light remains same, then light beam is unpolarised.

83. Transverse wave. By passing the light beam through a polariser.

84. Light is passed through a pair of polaroids called polariser and analyser respectively. On rotating analyser with respect to polariser, intensity of emergent light from the analyser changes. This experiment shows that light exhibits plane polarisation and hence is transverse in nature.

85. When two polaroids are kept crossed to each other *i.e.*, $\theta = 90°$ between them, then intensity of transmitted light is zero.
But when a polaroid sheet is kept a angle of $\theta = 45°$ with their planes of transmission, then intensity of transmitted light becomes maximum.

87. (a) When $a_1 = 0.1$ mm $= 1 \times 10^{-4}$ m,
$\beta_0' = 6$ mm $= 6 \times 10^{-3}$ m

then $\beta_0' = \frac{2\lambda D}{a}$

or $\lambda = \frac{\beta_0' a_1}{2D} = \frac{6 \times 10^{-3} \times 1 \times 10^{-4}}{2 \times 1}$

or $\lambda = 3 \times 10^{-7}$ m ...(i)

When $a_2 = 0.2$ mm $= 2 \times 10^{-4}$ m,

$\beta_0'' = 3$ mm $= 3 \times 10^{-3}$ m

$$\lambda = \frac{\beta_0'' a_2}{2D} = \frac{3 \times 10^{-3} \times 2 \times 10^{-4}}{2 \times 1}$$

$\lambda = 3 \times 10^{-7}$ m ...(ii)

By (i) and (ii), we found that wavelength of light used is 3×10^{-7} m.

(b) At Brewester's angular i_B,
$\tan i_B = \mu$ ...(i)
whereas, at critical angle i_C,

$$\mu = \frac{1}{\sin i_C} \text{ or } \sin i_C = \frac{1}{\mu}$$

$$\mu = \frac{1}{\sin i_C} = \tan i_B \Rightarrow \sin i_c = \cot i_B$$

or $i_C = \sin^{-1}(\cot i_B)$

94. (i) *X*-rays as these are transverse in nature.
$I = I_0 \cos^2\theta$

(a) When $\theta = 45°$, then $I = I_0 \cos^2 45° = \frac{I_0}{2}$

(b) When $\theta = 90°$, then $I = I_0 \cos^2 90° = 0$

(c) When $\theta = 180°$, then $I = I_0 \cos^2 180° = I_0$

98. Polaroids *A* and *B* are oriented at an angle of 90°, so no light is emerging out of *B*. On placing polaroid *C* between *A* and *B* such that its axis bisects the angle between axes of *A* and *B*, then angle between axes of polaroids *A* and *C* is 45° and that of *C* and *B* also 45°.

(a) Intensity of light on passing through polaroid *A* or between *A* and *C* is

$$I_1 = \frac{I_0}{2}$$

(b) On passing through polaroid *C*, intensity of light between *C* and *B* becomes

$$I_2 = I_1 \cos^2 45°$$

or $I_2 = \frac{I_0}{2} \times \frac{1}{2} = \frac{I_0}{4}$

99. Let intensity of light incident on P_1 be I_0, then intensity of light after emerging from P_1 is $I_0/2$. As angle between P_1 and P_3 is 45°, so intensity of light on emerging from P_3 is

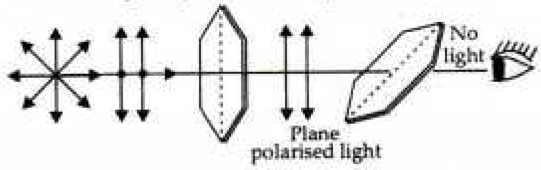
$$I_1 = \frac{I_0}{2}\cos^2 45° = \frac{I_0}{2} \times \frac{1}{2} = \frac{I_0}{4}$$

As angle between P_3 and P_2 is also 45°, so intensity of finally emerging light from P_2 is

$$I = \frac{I_0}{4}\cos^2 45° = \frac{I_0}{4} \times \frac{1}{2} = \frac{I_0}{8}$$

100. When the vibrations of the electric field vector E are confined to only one direction in plane perpendicular to the direction of propagation of light, then light is called linearly polarised light.
Intensity of transmitted light is maximum when the polaroid sheet makes an angle of 45° with the pass axis.

101. When unpolarised light is made to pass through a polaroid, only those electric field vectors, parallel to its crystallographic axis emerge out of it. Thus the emerging light is plane polarised. Such a crystal is called polariser. If the emergent plane polarised light is passed through another crystal called analyser with its plane of transmission normal to that of polariser then no light emerges from it, as it is completely absorbed by the analyser.



Demonstration of polarisation of light.

Let two polaroids P_1 and P_3 are placed in crossed positions. Let P_2 be the polaroid sheet placed between P_1 and P_3 making an angle θ with pass axis of P_1.

If I_1 = intensity of polarised light after passing through P_1, then intensity of light after passing through P_2 will be

$$I_2 = I_1\cos^2\theta \qquad ...(i)$$

Now angle between P_2 and $P_3 = \left(\frac{\pi}{2} - \theta\right)$

[∵ P_1 and P_3 are in crossed position]

∴ Outcoming intensity after P_3 is

$$I_3 = I_2 \cos^2\left(\frac{\pi}{2} - \theta\right)$$

$$I_3 = I_1 \cos^2\theta \cdot \cos^2\left(\frac{\pi}{2} - \theta\right) \qquad \text{[Using (i)]}$$

$$= I_1\cos^2\theta\sin^2\theta$$

$$= I_1\left(\frac{1}{2}\sin 2\theta\right)^2$$

If I_0 = intensity of unpolarised light, then

$$I_1 = \frac{I_0}{2} \Rightarrow I_3 = \frac{I_0}{2}\left(\frac{1}{2}\sin 2\theta\right)^2$$

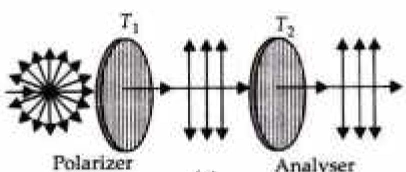
(i) Maximum outcoming intensity is received when $\theta = \frac{\pi}{4}$

$$\Rightarrow I_3 = \frac{I_0}{2}\left(\frac{1}{2}\right)^2 = \frac{I_0}{8}$$

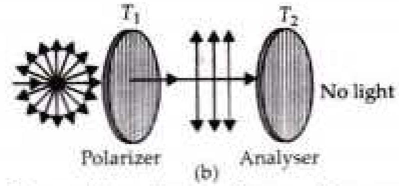
(ii) Minimum intensity, when $\theta = \frac{\pi}{2}$

$$I_3 = 0$$

102.



(a)



(b)

If two thin plates of tourmaline crystals T_1 and T_2 are rotated with the same angular velocity in the same direction as shown in the figure above, no change in intensity of transmitted light is observed.

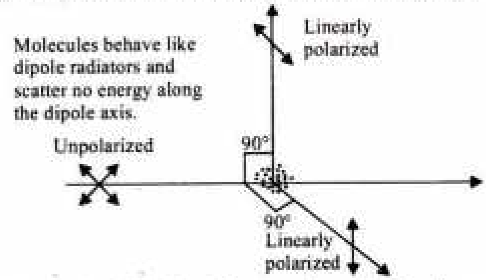
The phenomenon can be explained only when we assume that light waves are transverse. Now the unpolarized light falling on T_1 has transverse vibrations of electric vector lying in all possible directions. The crystal T_1 allows only those vibrations to pass through it, which are parallel to its axis. When the crystal T_2 is, introduced with its axis kept parallel to the axis of T_1, the vibrations of electric vector transmitted by T_1 are also transmitted through T_2. However, when axis of T_2 is perpendicular to axis of T_1, vibrations of electric vector transmitted from T_1 are normal to the axis of T_2. Therefore, T_2 does not allow them to pass and hence eye receives no light.

Light coming out of the crystal T_1 is said to be polarized *i.e.* it has vibrations of electric vector which are restricted only in one direction (*i.e.* parallel to the optic axis of crystal T_1).

Since the intensity of polarized light on passing through a tourmaline crystal changes, with the relative orientation of its crystallographic axes with that of polariser, therefore, light must consist of transverse waves.

(b) The reflected ray is totally plane polarised, when reflected rays and refracted rays are perpendicular to each other.

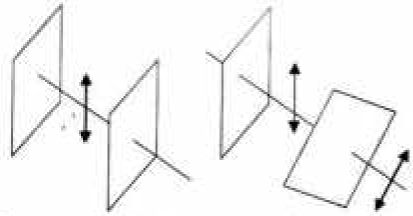
103. (a) If the electric field vector of a light wave vibrates just in one direction perpendicular to the direction of the propagation then it is said to be linearly polarised.



Unpolarised light incident on air molecules is scattered and gets polarized.

(b) Same/Unchanged/constant

104. (a) Light from the sodium lamp passing through the single polaroid sheet (P_1) does not show any variation in intensity when this sheet is rotated.



However, if the light, transmitted by P_1 is made to pass through another polaroid sheet (P_2) the light intensity, coming out of P_2 varies from a maximum to zero, and again to maximum, when P_2 is rotated. These observations are consistent only with the transverse nature of light waves.

(b) Intensity of light transmitted through $P_1 = I_0/2$

Intensity of light transmitted through

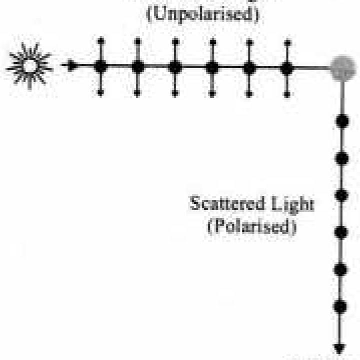
$P_3 = (I_0/2) \times \cos^2 30°$

$= 3I_0/8$

Intensity of light transmitted through

$$P_2 = \frac{3}{8} I_0 \cos^2 60° = \frac{3}{32} I_0$$

105. (a)



The acceleration of the charges, in the scattering molecules, due to the electric field of the incident radiation, can be in two mutually perpendicular directions.

The observer, however, receives the scattered light, corresponding to only one of these two sets of the accelerated charges.

This causes scattered light to get polarised.

Alternatively : The observer receives scattered light corresponding to only one of the two sets of accelerated charges *i.e.* electrons oscillating perpendicular to the direction of propagation.

LONG ANSWER TYPE QUESTIONS

4. (b) (i) The frequency of reflected and refracted light remains same as the frequency of incident light because frequency only depends on the source of light.

(ii) Since the frequency remains same, hence there is no reduction in energy.

9. Given $SS_2 - SS_1 = \frac{\lambda}{4}$

Now path difference between the two waves from slits S_1 and S_2 on reaching point P on screen is

$\Delta x = (SS_2 + S_2P) - (SS_1 + S_1P)$

or $\Delta x = (SS_2 - SS_1) + (S_2P - S_1P)$

or $\Delta x = \frac{\lambda}{4} + \frac{yd}{D}$

(i) For constructive interference at point P, path difference $\Delta x = n\lambda$

or $\frac{\lambda}{4} + \frac{yd}{D} = n\lambda$

or $\frac{yd}{D} = \left(n - \frac{1}{4}\right)\lambda$ ...(i)

where $n = 0, 1, 2, 3, \ldots\ldots$

(ii) For destructive interference at point P, path difference

$\Delta x = (2n-1)\frac{\lambda}{2}$ or $\frac{\lambda}{4} + \frac{yd}{D} = (2n-1)\frac{\lambda}{2}$

or $\frac{yd}{D} = \left(2n - 1 - \frac{1}{2}\right)\frac{\lambda}{2} = (4n-3)\frac{\lambda}{4}$ ...(ii)

where $n = 1, 2, 3, 4, \ldots\ldots$

For central bright fringe, putting $n = 0$ in equation (i), we get

$$\frac{yd}{D} = -\frac{\lambda}{4} \quad \text{or} \quad y = \frac{-\lambda D}{4d}$$

The –ve sign indicates that central bright fringe will be observed below centre O of screen, at distance $\frac{\lambda d}{4d}$ below it.

Given for λ_1 = 6000Å, fringe width β_1 = 0.8 mm, then for λ_2 = 7500Å, fring width β_2 = ?

Also, $d_2 = 2d_1$

So, $\frac{\beta_2}{\beta_1} = \frac{\lambda_2 D/d_2}{\lambda_1 D/d_1} = \frac{\lambda_2}{\lambda_1} \times \frac{d_1}{d_2}$

or $\beta_2 = \frac{7500}{6000} \times \frac{d_1}{2d_1} \times 0.8$

or $\beta_2 = 0.5$ mm

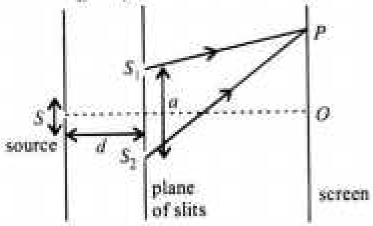
12. As fringe width $\beta = \frac{\lambda D}{d}$ of interference pattern in YDSE, so

(i) On moving screen closer to plane of slits, D decreases and hence fringe width β also decreases.

(ii) On increasing separation d between two slits, fringe width β decreases.

13. (a) As two different sources of light can never produce light waves of same frequency and wavelength in same phase or with constant phase difference.

(b) If 'a' is the distance between the two slits S_1 and S_2, 'λ' is wavelength of light, 'd' is distance of source from plane of slits, and 'S' is the size of the source, then interference fringes can be seen only, if the condition $\frac{S}{d} < \frac{\lambda}{a}$ should be satisfied.



14. Condition for constructive and destructive Interference:
Let the two waves emerging form two coherent sources S_1 and S_2 be in same phase, given by
$y_1 = a_1 \sin \omega t$ and $y_2 = a_2 \sin \omega t$
where a_1 and a_2 are the amplitudes of two waves and ω is their same angular frequency. Let the wave form S_1 travels a distance $S_1P = x_1$ and wave from S_2 travels distance $S_2P = x_2$ on reaching same point P on the screen. Then at point P on screen the two superimposing wave are:

$y_1 = a_1 \sin(\omega t - kx_1)$

and $y_2 = a_2 \sin(\omega t - kx_2)$

So, on reaching point P, the phase difference between the two wave becomes

$\Delta\phi = k(x_2 - x_1)$ or $\Delta\phi = \frac{2\pi}{\lambda}\Delta x$

where $\Delta x = x_2 - x_1 = S_2P - S_1P$

gives the "path difference" of the two waves on reaching point P on screen from the two slits S_1 and S_2.

So by superposition principle of waves, the resultant wave at point P is

$y = y_1 + y_2 = a_1 \sin(\omega t - kx_1) + a_2 \sin(\omega t - kx_2)$

$= a_1 \sin\omega t \cos kx_1 - a_1 \cos \omega t \sin kx_1 + a_2 \sin\omega t \cos kx_2 - a_2 \cos \omega t \sin kx_2$

$= \sin \omega t(a_1 \cos kx_1 + a_2 \cos kx_2) - \cos\omega t(a_1 \sin kx_1 + a_2 \sin kx_2)$ ...(i)

Let $a_1 \cos kx_1 + a_2 \cos kx_2 = A\cos\theta$ ...(ii)

$a_1 \sin kx_1 + a_2 \sin kx_2 = A\sin\theta$ ...(iii)

Using (ii) and (iii) in (i), we get $y = A\sin[\omega t - \theta]$

$y = A(\sin\omega t \cos t\theta - \cos\omega t \sin\theta)$

where A is the resultant amplitude which can be obtained by squaring and adding equations (ii) and (iii) as

or $A^2 = a_1^2 + a_2^2 + 2a_1a_2(\cos kx_1 \cos kx_2 + \sin kx_1 \sin kx_2)$

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

or $A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\Delta\phi}$

The intensity I of the resultant wave at point P on screen is then given by $I = A^2$

or $I = a_1^2 + a_2^2 + 2a_1a_2\cos\Delta\phi$

OR

Let the two wave emerging from two coherent sources S_1 and S_2 has some initial phase difference ϕ.

$y_1 = a_1 \sin \omega t$ and $y_2 = a_2 \sin(\omega t + \phi)$

By superposition of waves, the resultant wave is

$y = y_1 + y_2 = a_1 \sin \omega t + a_2 \sin(\omega t + \phi)$

$y = a_1 \sin\omega t + a_2 (\sin \omega t \cos\phi + \cos\omega t \sin\phi)$

$y = \sin\omega t\,(a_1 + a_2 \cos\phi) + a_2 \cos\omega t \sin\phi$

Let us assume $a_1 + a_2 \cos\phi = A\cos\theta$ ...(i)

$a_2 \sin\phi = A\sin\theta$ ...(ii)

$y = A\cos\theta \sin\omega t + A\sin\theta \cos\omega t$

Resultant wave $y = A\sin(\omega t + \theta)$

where 'A' is resultant amplitude, squaring and adding equation (i) and (ii)

net amplitude, $A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}$

Relation between phase difference and path difference

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

(i) Condition for constructive interference or MAXIMA

At point P intensity I will be maximum only when

$\cos\Delta\phi = +1$

or $\Delta\phi = 0, 2\pi, 4\pi, 6\pi,$ ....

or $2\pi\frac{\Delta x}{\lambda} = 0, 2\pi, 4\pi$ ....

or $\Delta x = 0, \lambda, 2\lambda,$ ....

or $\Delta x = n\lambda$

when $n = 0, 1, 2, 3$

This is called condition of "constructive interference" or "MAXIMA". So bright fringe will be formed at point P on the screen, only if the path difference between the two superimposing waves is integral multiple of λ, and the maximum intensity of the fringe obtained is the given by $I_{max} = (a_1 + a_2)^2$

(ii) Condition for destructive interference or MINIMA At point P intensity I will be minimum only when

$\cos\Delta\phi = -1$

or $\Delta\phi = \pi, 3\pi, 5\pi,$ ....

or $2\pi\frac{\Delta x}{\lambda} = 0, 3\pi, 5\pi,$ ....

or $\Delta x = \frac{\lambda}{2}, \frac{3}{2}\lambda, \frac{5}{2}\lambda,$ ....

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

when $n = 1, 2, 3,$ ....

This is called condition of "destructive interference" or "MINIMA". So dark fringe will be formed at points P on the screen, only if the path difference between the two superimposing waves is $(2n - 1)\lambda/2$.

(b) The two bright fringes will coincide when

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

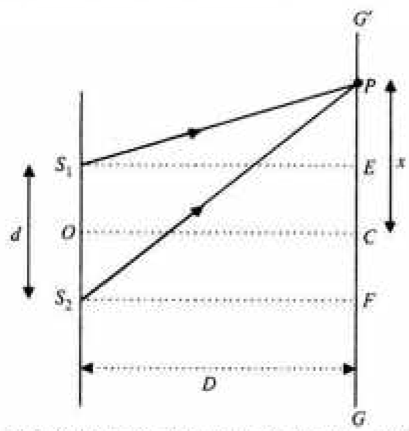
$n\ 800 \times 10^{-9} = (n + 1)\ 600 \times 10^{-9}$

$\therefore\ n = 3$

$\Rightarrow \quad Y_m = \frac{(nD\lambda_1)}{d}$

$= \frac{(3 \times 1.4 \times 800 \times 10^{-9})}{(0.28 \times 10^{-3})} \text{m} = 12 \times 10^{-3} \text{mm}$

15. (a) In Young's double-slit experiemnt, the wavefronts from two illuminated slits superpose on the screen. This leads to formation of alternate dark and bright fringes due to constructive and destructive interference, respectively. At the centre C of the screen, the intensity of light is maximum and it is called central maxima.



Let S_1 and S_2 be two slits separated by a distance d. GG' is the screen at a distance D from the slits S_1 and S_2. Point C is equidistant from both the slits. The intensity of light will be maximum at this point because the path difference of the waves reaching this point will be zero.

At point P, the path difference between the rays coming from the slits S_1 and S_2 is $S_2P - S_1P$.

Now, $S_1S_2 = d$, $EF = d$, and $S_2F = D$

$\therefore$ In ΔS_2PF,

$$S_2P = \left[S_2F^2 + PF^2\right]^{1/2}$$

$$S_2P = \left[D^2 + \left(x + \frac{d}{2}\right)^2\right]^{1/2} = D\left[1 + \frac{\left(x + \frac{d}{2}\right)^2}{D^2}\right]^{1/2}$$

Similarly, in ΔS_1PE,

$$S_1P = D\left[1 + \frac{\left(x - \frac{d}{2}\right)^2}{D^2}\right]^{1/2}$$

$$\therefore \quad S_2P - S_1P = D\left[1 + \frac{1}{2}\frac{\left(x + \frac{d}{2}\right)^2}{D^2}\right] - D\left[1 + \frac{1}{2}\frac{\left(x - \frac{d}{2}\right)^2}{D^2}\right]$$

On expanding it binomially,

$$S_2P - S_1P = \frac{1}{2D}\left[4x\frac{d}{2}\right] = \frac{xd}{D}$$

For bright fringes (constructive interference), the path difference is an integral multiple of wavelengths, *i.e.* path difference is $n\lambda$.

$$\therefore \quad n\lambda = \frac{xd}{D}$$

$x = \frac{n\lambda D}{d}$ where $n = 0, 1, 2, 3, 4, \ldots$

For $n = 0$, $x_0 = 0$

$n = 1, x_1 = \frac{\lambda D}{d}$

$n = 2, x_2 = \frac{2\lambda D}{d}$

$n = 3, x_3 = \frac{3\lambda D}{d}$

.

.

.

$n = n, x_n = \frac{n\lambda D}{d}$

Fringe width (β) : Separation between the centres of two consecutive bright fringes is the width of a dark fringe, and called fringe width.

$$\therefore \quad \beta_1 = x_n - x_{n-1} = \frac{\lambda D}{d}$$

Similarly, for dark fringes,

$$x_n = (2n-1)\frac{\lambda}{2}\frac{D}{d}$$

For $n = 1$, $x_1 = \frac{\lambda D}{2d}$

For $n = 2$, $x_2 = \frac{3\lambda D}{2d}$

The separation between the centres of two consecutive dark interference fringes is the width of a bright fringe.

$$\therefore \quad \beta_2 = x_n - x_{n-1} = \frac{\lambda D}{d}$$

$\therefore \quad \beta_1 = \beta_2$

All the bright and dark fringes are of equal width as $\beta_1 = \beta_2$

(b) We have

$$\frac{I_{max}}{I_{min}} = \frac{(a_1 + a_2)^2}{(a_1 - a_2)^2} = \frac{25}{9}$$

$$\therefore \quad \frac{a_1}{a_2} = \frac{4}{1}$$

$$\therefore \quad \frac{W_1}{W_2} = \frac{I_1}{I_2} = \frac{(a_1)^2}{(a_2)^2} = \frac{16}{1}$$

16. (a) (i) There is no exact relation between phases of light waves from two different sources. So, they are incoherent. Due to this reason, two independent monochromatic sources of light cannot produce a sustained interference pattern.

(ii) Displacement of two waves are

$y_1 = a\cos\omega t$

$y_2 = a\cos(\omega t + \phi)$

where ϕ is the phase difference between them. Resultant displacement at point P is given by superposition principle,

$y = y_1 + y_2 = a\cos\omega t + a\cos(\omega t + \phi)$

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

$$= a\left[2\cos\frac{(\omega t + \omega t + \phi)}{2}\cos\frac{(\omega t - \omega t - \phi)}{2}\right]$$

$$\therefore \quad y = 2a\cos\left(\omega t + \frac{\phi}{2}\right)\cos\left(\frac{\phi}{2}\right) \qquad \text{...(i)}$$

Let $2a\cos\left(\frac{\phi}{2}\right) = A$, then equation (i) becomes

$y = A\cos\left(\omega t + \frac{\phi}{2}\right)$ where A is the amplitude of resultant wave.

Now, $A = 2a\cos\left(\frac{\phi}{2}\right)$

Squaring both sides, we get $A^2 = 4a^2\cos^2\left(\frac{\phi}{2}\right)$

Since, intensity $\propto$ (amplitude)^2

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

where, I_0 = intensity of the source.

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

Given, for path difference λ intensity of resultant light wave is K units

We know,

Phase difference $= \frac{2\pi}{\lambda} \times$ path difference

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

Plug in the given values in equation (i), we get

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

$\Rightarrow I_0 = \frac{K}{4}$ ... (ii)

If path difference is $\lambda/3$, then phase difference is given by

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

Required intensity, $I' = 4\left(\frac{K}{4}\right)\cos^2\left(\frac{2\pi}{2\times 3}\right)$

$\Rightarrow I' = K\cos^2\left(\frac{\pi}{3}\right) \Rightarrow I' = K\left(\frac{1}{2}\right)^2 = \frac{K}{4}$

$\Rightarrow I' = \frac{K}{4}$ units

25. (b) Angular width of the secondary maxima

$\approx 2(2n+1)\frac{\lambda}{a}$

$\therefore$ Linear width $= \left[(2n+1)\frac{\lambda}{a}\right]D$

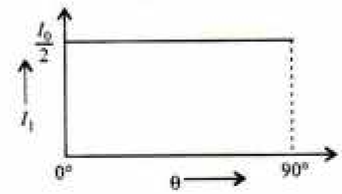
$\therefore$ Linear separation, between the first maxima ($n = 1$) of the two wavelengths, on the screen, is $\frac{3(\lambda_2 - \lambda_1)}{a} \times D$

$\therefore$ Separation $= \frac{3(596 - 590)\times 10^{-9}}{2\times 10^{-6}} \times 1.5$ m

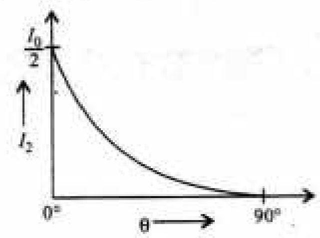
$= 13.5 \times 10^{-3}$ m $= 13.5$ mm

28. (b) Yes, the light incident on the rotating polaroid is unpolarised. On passing through polaroid it becomes plane polarised in the plane of transmission of polaroid, whatever the angle it makes with vertical. So, intensity of transmitted plane polarised light does not change on rotating the polaroid.

29. Unpolarised light intensity I_0 when passes through the polaroid P_1, it becomes plane polarised and intensity reduces to $I_1 = I_0/2$, which remains constant, even on rotation of polaroid P_1.

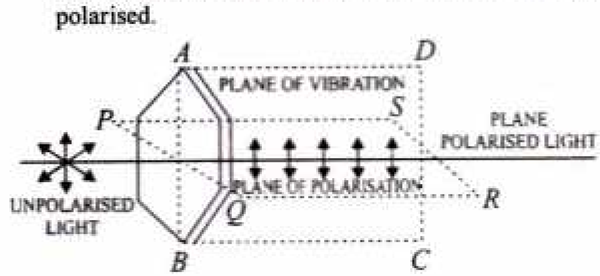


When polaroised light o intensity $\frac{I_0}{2}$ passes through the polaroid P_2, then intensity of light emerging from P_2 decreasing on rotating it from $\theta = 0°$ to $\theta = 90°$ as shown below :

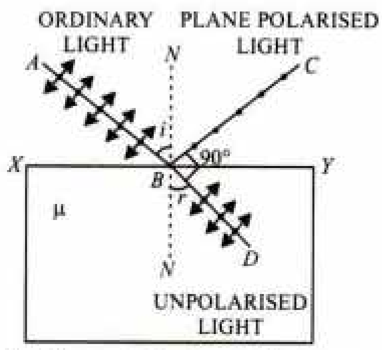


Polarisation of light takes place due to scattering. Thus the blue light of the sky is plane polarised light. So, when this polarised light is seen through a polaroid, then there is rise and fall in intensity of emergent light on rotation of polaroid.

30. (a) When unpolarised light falls on a polaroid, it lets only those of its electric vectors that are oscillating along a direction perpendicular to its aligned molecules to pass through it. The incident light thus gets linearly polarised.



Whenever unpolarised light is incident on a transparent surface, the reflected light gets partially or completely polarized/the reflected light gets completely polarized when the reflected and refracted light are perpendicular to each other.



(b) Let θ be the angle between the pass axis of A and C

Intensity of light passing through $A = \frac{I_0}{2}$

Intensity of light passing through $C = \left(\frac{I_0}{2}\right)\cos^2\theta$

Intensity of light passing through

$$B = \left(\frac{I_0}{2}\right)\cos^2\theta[\cos^2(90-\theta)]$$

$$= \left(\frac{I_0}{2}\right)\cdot(\cos\theta\cdot\sin\theta)^2 = \frac{I_0}{8} \text{ (Given)}$$

$\therefore$ $\sin 2\theta = 1,\ 2\theta = 90°$

The third polaroid is placed at $\theta = 45°$.

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

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

(c) In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity of light in the photon picture of light

Sol. (a) In the phenomena of reflection or refraction of light the frequency of light remains unchanged although wavelength and velocity changes in refraction.

As the incident light on surface forces atoms to vibrate with the frequency of light. These charged oscillator further produce light with same frequency. So both the reflected and refracted light have same frequency.

(b) According to relation $E = h\upsilon$, the energy of light wave depend upon frequency 'υ'. As the frequency remain same, so energy also remains same.

(c) In the wave picture intensity of light is determined by the square of amplitude of wave.

$$I = 2\pi^2 f^2 A^2 \rho v$$

But in photon picture the intensity of light is determined by number of photons incident per unit area around that point.

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

Sol. (a) In the process of reflection wavelength, frequency and speed of incident light remain unchanged.

So, speed of reflected light = speed of incident light

$$c = 3 \times 10^8 \text{ ms}^{-1}$$

Wavelength of reflected light = Wavelength of incident light

$$\lambda = 589 \times 10^{-9} \text{ m}$$

frequency of reflected light = frequency of incident light

$$\upsilon = \frac{c}{\lambda} = \frac{3\times10^8}{589\times10^{-9}} = 5.09\times10^{14} \text{ Hz}$$

(b) In the process of refraction wavelength and speed change but the frequency remains the same.

Speed of light in water

$$v = \frac{c}{{}^a\mu_w} = \frac{3\times10^8}{1.33} = 2.26\times10^8 \text{ ms}^{-1}$$

Wavelength of light in water

$$\lambda = \frac{v}{\upsilon} = \frac{2.26\times10^8}{5.09\times10^{14}} = 444\times10^{-9} \text{ m}$$

So, $\lambda = 444$ nm.

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

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

Sol. (a) Speed of light in glass

$$v = \frac{c}{{}^a\mu_g} = \frac{3\times10^8}{1.5} = 2\times10^8 \text{ ms}^{-1}$$

(b) Speed of light depends upon refraction index.

Thus speed of light is different for red and violet colours.

As $\mu_v > \mu_R$

So, $v_v < v_R$

Speed of red colour is more than violet colour light in glass.

4. What is the shape of the wavefront in each of the following cases :

(a) Light diverging from a point source.

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

(c) The portion of the wavefront of light from a distant star intercepted by the Earth.

Sol. (a) **Spherical wavefront :** All particles vibrating in same phase will lie on a sphere.

(b) **Plane wavefront :** Light will be a parallel beam after passing through the convex lens.

(c) **Plane wavefront :** Light rays from a distant star are nearly parallel as a small portion of a huge spherical wavefront is nearly plane.

5. Let us list some of the factors which could possibly influence the speed of wave propagation:

(i) nature of the source

(ii) direction of propagation

(iii) motion of the sources and/or observer

(iv) wavelength

(v) intensity of the wave

On which of these factors, if any, does

(a) the speed of light in vacuum

(b) the speed of light in a medium (say glass or water) depend?

Sol. (a) Speed of light in vaccum is independent of all the factors listed above. It is also independent of relative motion between source and observer.

(b) Dependence of speed of light in a medium:

(i) The speed of light in a medium does not depend on the nature of the source. Although speed is determined by the properties of the medium of propagation.

(ii) The speed of light in a medium is independent of the direction of propagation for isotropic media.

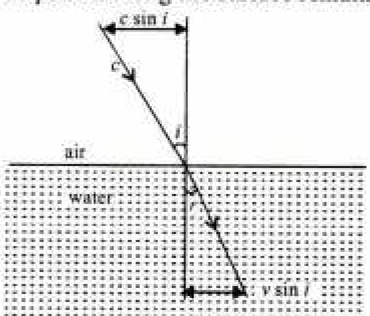
(iii) The speed of light is independent of the motion of the source relative to the medium but it depends on the motion of the observer relative to the medium.

(iv) The speed of light in a medium depends on wavelength of light.

(v) The speed of light in a medium is independent of intensity.

6. Explain how Newton's corpuscular theory predicts that the speed of light in a medium, say water, is greater than the speed of light in vacuum. Is the prediction confirmed by experimental determination of the speed of light in water? If not, which alternative picture of light is consistent with experiment?

Sol. In Newton's corpuscular (particle) picture of refraction, particles of light incident from a rarer to a denser medium experience a force of attraction normal to the surface. This results in an increase in the normal component of velocity but the component along the surface remains unchanged.



Considering a ray of light going from a rarer medium (air) to a denser medium (water).

Let c = speed of light in vacuum (or air),

v = speed of light in water,

i = angle of incidence, and

r = angle of refraction

Then according to Newton's corpuscular theory,

Component of velocity c along surface of separation = Component of velocity v along the surface of separation

$\therefore\ c \sin i = v \sin r$

or $\dfrac{v}{c} = \dfrac{\sin i}{\sin r} = {}^{a}\mu_{w}$

As ${}^{a}\mu_{w} > 1$, therefore, $v > c$.

So, according to Newton's corpuscular theory the speed of light in medium is larger than speed of light in air. $v > c$ but in fact the experimental observation shows that speed of light is smaller in denser medium as compared to rare medium. $v < c$.

7. Light of wavelength 5000 Å falls on a plane reflecting surfaced. What are the wavelength and frequency of the reflected light? For what angle of incidence is the reflected ray normal to the incident ray?

Sol. In the reflected light the wavelength and frequency remain the same as that of incident light. Wavelength of reflected light = 5000 Å, frequency of reflected light = ?

$$c = \upsilon\lambda$$

$$\upsilon = \frac{c}{\lambda} = \frac{3\times 10^{8}}{5\times 10^{-7}}$$

$$\upsilon = 6 \times 10^{14}\ \text{Hz}$$

for an angle of incidence 45° the reflected ray is normal to incident ray.

8. What is the effect on the interference fringes in a Young's double-slit experiment due to each of the following operations :

(a) the screen is moved away from the plane of the slits ;

(b) the (monochromatic) source is replaced by another (monochromatic) source of shorter wavelength;

(c) the separation between the two slits is increased;

(d) the source slit is moved closer to the double-slit plane;

(e) the width of the source slit is increased;

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

Sol. In Young's double slit experiment the fringe width is given by

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

(a) When the screen is moved away from the plane of slit 'D' increases and thus fringe width also increases, fringes become wider.

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

$$D\uparrow \text{ so } \beta\uparrow$$

(b) When the wavelength of incident monochromatic light is reduced the fringe width also reduces, fringes became shorter.

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

$$\lambda\downarrow \text{ so } \beta\downarrow$$

(c) When the separation between two slits is increased, fringe width reduces.

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

$$d\uparrow \text{ so } \beta\downarrow$$

(d) When the source slit is brought closer to the double slit plane the interference pattern become less and less sharp, however, the fringe width remain constant. Once the source is very lose the fringes disappear.

(e) A single broad source will contain a number of point sources. Due to a number of light waves from all these point sources an overlapped interference pattern is observed.

(f) White light consist of seven colours with different wavelengths each wavelength produce its own interference pattern with different fringe width.

The central bright fringes for different colours are at the same position. Therefore, the central fringe is white. For a point P for which $S_2P - S_1P = \lambda_b/2$, where λ_b (= 4000 Å) represents the wavelength for the blue colour, the blue component will be absent and the fringe will appear red in colour. Slightly farther away where $S_2Q - S_1Q = \lambda_b = \lambda_r/2$ where λ_r (= 8000 Å) is the wavelength for the red colour, the fringe will be predominantly blue.

Thus, the fringes closest on either side of the central white fringe is red and the farthest will appear blue. After a few fringes, no clear fringe pattern is seen.

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

Sol. Here d = 0.28 mm

D = 1.4 m

Distance of fourth bright from center = 1.2 cm

Linear position of n^{th} bright fringe $y_n = \dfrac{nD\lambda}{d}$

Linear position of 4^{th} bright fringe $y_4 = \dfrac{4D\lambda}{d}$

$1.2 \times 10^{-2} = \dfrac{4\,(1.4)\,\lambda}{0.28 \times 10^{-3}}$ $\qquad \lambda$ = 6000 Å

10. In Young's double-slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen where path difference is λ, is K units. What is the intensity of light at a point where path difference is λ/3?

Sol. In Young's double – slit experiment net intensity of light at a point on screen is

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

for $I_1 = I_2 = I$

$I_{net} = 2I + 2I\cos\phi$

relation between path difference and phase difference

$\Delta\phi = \dfrac{2\pi}{\lambda}\Delta x$

for path difference λ, phase difference

$\Delta\phi = \dfrac{2\pi}{\lambda}\lambda = 2\pi$

$I_{net} = K = 2I + 2I\cos 2\pi$

$K = 4I$ ...(i)

for a path difference λ/3

phase difference $\Delta\phi = \dfrac{2\pi}{\lambda}\Delta x$

$\Delta\phi = \dfrac{2\pi}{\lambda}\left(\dfrac{\lambda}{3}\right) = \dfrac{2\pi}{3}$

now the intensity

$I_{net} = 2I + 2I\cos\dfrac{2\pi}{3}$

$I_{net} = 2I - 2I\sin 30°$

$I_{net} = I = \dfrac{K}{4}$

11. 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.

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

(b) What is the least distance from the central maximum where the bright fringes due to both the wavelengths coincide?

Sol. Here d = 2 mm

D = 1.2 m

λ_1 = 650 nm

λ_2 = 520 nm

(a) Distance of third bright fringe from the central maximum for the wavelength 650 nm.

$y_3 = \dfrac{3\lambda D}{d} = \dfrac{3\,(650 \times 10^{-9})\,1{\cdot}2}{2 \times 10^{-3}}$

$y_3 = 1{\cdot}17$ mm.

(b) Let at linear distance 'y' from center of screen the bright fringes due to both wavelength coincides. Let n_1 number of bright fringe with wavelength λ_1 coincides with n_2 number of bright fringe with wavelength λ_2.

We can write

$y = n_1\beta_1 = n_2\beta_2$

$n_1\dfrac{\lambda_1 D}{d} = n_2\dfrac{D\lambda_2}{d}$

$n_1\lambda_1 = n_2\lambda_2$ ...(i)

Also at first position of coincide the n^{th} bright of one will coincide with (n + 1)th bright fringe of other.

If $\lambda_2 < \lambda_1$

So then $n_2 > n_1$

then $n_2 = n_1 + 1$ ...(ii)

Using equation (ii) in equation (i)

$n_1\lambda_1 = (n_1 + 1)\,\lambda_2$

$n_1\,(650) \times 10^{-9} = (n_1 + 1)\,520 \times 10^{-9}$

$65\,n_1 = 52\,n_1 + 52$

$12\,n_1 = 52$

$n_1 = 4$

So, the fourth bright fringe of wavelength 520 nm coincides with 5^{th} bright fringe of wavelength 650 nm.

$\therefore\ y = n_1\beta_1 = n_1\dfrac{D\lambda_1}{d}$

$$= 4 \times \frac{1.2 \times 650 \times 10^{-9}}{2 \times 10^{-3}}$$
$$= 1.56 \text{ mm}$$

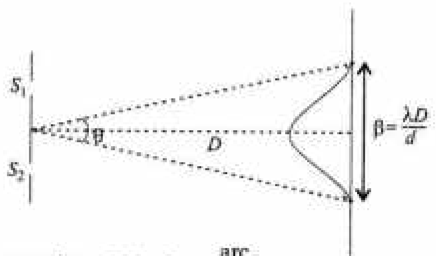
12. Two slits are made one millimetre apart and the screen is placed one metre away. What is the fringe separation when blue-green light of wavelength 500 nm is used?

Sol. Fringe width $\beta = \frac{D\lambda}{d} = \frac{1 \times 5 \times 10^{-7}}{1 \times 10^{-3}}$ m

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

13. In a 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. What will be the angular width of the fringe if the entire experimental apparatus is immersed in water? Take refractive index of water to be 4/3.

Sol.



angular width $\theta = \frac{\text{arc}}{\text{radius}}$

$$\theta = \frac{\lambda D / d}{D} = \lambda / d \qquad \text{...(i)}$$

With air between slit and screen.

$$\theta = 0.2 = \frac{600 \times 10^{-9}}{d}$$

With water as the medium between slit and screen.

$\lambda' = \lambda/\mu$

angular width $\theta' = \lambda'/d$ ...(ii)

dividing $\frac{\theta'}{\theta} = \frac{\lambda'}{\lambda}$

$$\theta' = \frac{\lambda'}{\lambda}\theta = \frac{\lambda}{\mu\lambda}\theta = \frac{\theta}{\mu}$$

$$\theta' = \frac{0.2°}{(4/3)} = 0.15°$$

14. In 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?

Sol. Angular width $\theta = \frac{\lambda}{d}$

$$0 \cdot 1° = \frac{0 \cdot 1}{180}\pi = \frac{6 \times 10^{-7}}{d}$$

$$d = \frac{6 \times 180 \times 10^{-7}}{0.1 \times \pi}$$

$d = 3.44 \times 10^{-4}$ m

15. Answer the following questions :

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

(b) In what way is diffraction from each slit related to the interference pattern in a double-slit experiment?

(c) When a tiny circular obstacle is placed in the path of light from a distant source, a bright spot is seen at the centre of the shadow of the obstacle. Explain why?

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

(e) Ray optics is based on the assumption that light travels in a straight line. Diffraction effects (observed when light propagates through small apertures/slits or around small obstacles) disprove this assumption. Yet the ray optics assumption is so commonly used in understanding location and several other properties of images in optical instruments. What is the justification?

Sol. (a) Linear width of central maximum

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

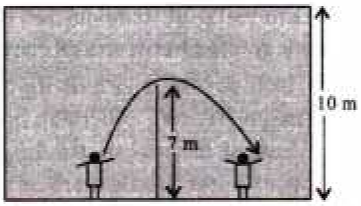
On doubling the slit width 'd', the size of central diffraction band is halved.

Because the width of central maximum is halved. Its area become 1/4 times and hence the intensity become 4 times the initial intensity.

(b) In double slit experiment an interference pattern is observed by waves from two slits but as each slit provide a diffraction pattern of its own, thus the intensity of interference pattern in Young's double slit experiment is modified by diffraction pattern of each slit.

(c) Waves from the distant source are diffracted by the edge of the circular obstacle and these waves superimpose constructively at the centre of obstacle's shadow producing a bright spot.

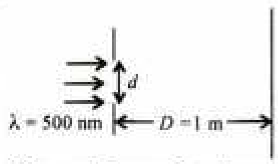
(d) We know for diffraction to take place, size of the obstacle/aperture should be of the order of wavelength. Wavelength of sound waves is of the order of few meters that is why sound waves can bend through the aperture in partition wall but wavelength of light waves is of the order of micrometer, hence light waves can not bend through same big aperture. That is why the two students can hear each other but can not see each other.



(e) In optical instruments, the sizes of apertures are much larger as compared to wavelength of light. So the diffraction effects are negligibly small. Hence the assumption that light travels in straight line is used in the optical instruments.

16. A parallel beam of light of wavelength 500 nm falls on a narrow slit and the resulting diffraction pattern is observed on a screen 1 m 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.

Sol.



First minimum is observed at a distance 2.5 mm from centre of the screen.

Width of central bright

$$\beta = \frac{2\lambda D}{d} = 2 \times 2.5 \text{ mm}$$

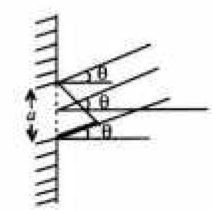
Slit width $d = \dfrac{\lambda D}{2.5 \times 10^{-3}}$

Slit width $d = \dfrac{500 \times 10^{-9} \times 1}{2.5 \times 10^{-3}}$

$d = 0.2$ mm

17. In deriving the single slit diffraction pattern, it was stated that the intensity is zero at angles of $n\lambda/a$. Justify this by suitably dividing the slit to bring out the cancellation.

Sol. It is observed that intensity is zero at $\theta = \dfrac{n\lambda}{a}$ where a is slit width. Path difference between extreme beams from the slit $a \sin\theta = n\lambda$



where n = 1, 2, 3, 4 ....

for $n = 1$ let us divide the whole slit in two parts, a path difference of $\lambda/2$, exist between the corresponding waves from each part. These waves superimpose destructively on the screen and cancells each other, thus producing zero intensity.

Similarly zero intensity for n = 2, 3, ... can also be explained.

18. For what distance is ray optics a good approximation when the aperture is 3 mm wide and the wavelength is 500 mm

Sol. Fresnal distance required for appreciable diffraction

$$D_f = \frac{a^2}{\lambda} = \frac{\left(3 \times 10^{-3}\right)^2}{5 \times 10^{-7}} = 18 \text{ m}$$

This example shows that even with a small aperture, diffraction spreading can be neglected for rays many metres in length. Thus, ray optics is valid in many common situations.

19. Estimate the distance for which ray optics is good approximation for an aperture of 4 mm and wavelength 400 nm.

Sol. Fresnal distance required for a sufficient spreading of central bright, so that diffraction is appreciable

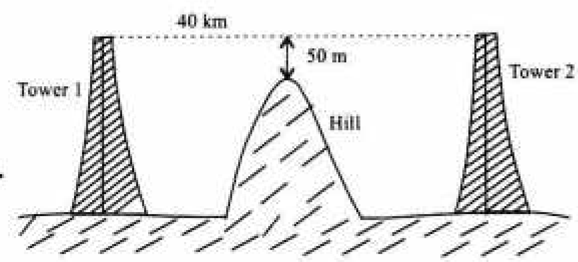
$$D_F = \frac{a^2}{\lambda} = \frac{\left(4 \times 10^{-3}\right)^2}{400 \times 10^{-9}}$$

$D_f = 40$ m

So, for distance less than 40 m between slit and screen, ray optics is a good approximation as within this distance, the spreading is negligible.

20. 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?

Sol.



For diffraction of radiowaves not to occur the distance of middle hill should be less than fresnal distance for a slit width 'a' of 50 m.

$$D_F = \frac{a^2}{\lambda}$$

longest wavelength of radio wave which can be sent without appreciable diffraction effect

$$\lambda = \frac{a^2}{D_f} = \frac{50 \times 50}{20 \times 10^3}$$

$\lambda = 12.5$ cm

Thus wavelength of radio waves longer than 12.5 cm will bend due to the hill in the middle of towers.

21. Answer the following questions :

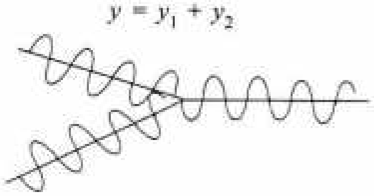
(a) When a low-flying aircraft passes overhead, we sometimes notice a slight shaking of the picture on our TV screen. Suggest a possible explanation.

(b) As you have learnt in the text, the principle of linear superposition of wave displacements is basic to understanding intensity distributions in diffraction and interference patterns. What is the justification of this principle?

Sol. (a) The low flying aircraft reflects the TV signals. Due to interference between the direct signal received by the antenna and the reflected signals from aircraft. We sometimes notice slight shaking of the picture on the TV screen.

(b) Superposition principle states how to explain the formation of resultant wave by combination of two or more waves. Let y_1 and y_2 represent instantaneous displacement of two superimposing waves, then resultant wave instantaneous displacement is given by

$$y = y_1 + y_2$$



22. Assume that light of wavelength 6000Å is coming from a star. What is the limit of resolution of a telescope whose objective has a diameter of 100 inch?

Sol. A 100 inch telescope implies that $2a = 100$ inch = 254 cm.

Thus if, $\lambda = 6000\text{Å} = 6 \times 10^{-5}$ cm

then, $\Delta\theta \approx \dfrac{0.61 \times 6 \times 10^{-5}}{127} \approx 2.9 \times 10^{-7}$ radians

23. What is Brewster angle for air to glass transition? (μ for glass is 1.5)

Sol. By Brewster law, $\tan i_p = {}_a\mu_g = 1.5$

$\therefore$ Brewster angle, $i_p = \tan^{-1}(1.5) = 56.3°$.

24. Unpolarised light is incident on a plane glass surface. What should be the angle of incidence so that the reflected and refracted rays are perpendicular to each other?

Sol. Reflected and refracted light are perpendicular at polarising angle.

$$i_p + r = \pi/2$$

According to Brewster's law, condition is

$$\tan i_p = {}_a\mu_g = 1.5$$

Angle of incidence $i_p = \tan^{-1}(1.5)$

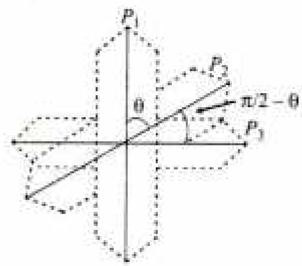
(Polarising angle) $i_p = 57°$

This is Brewster's angle (Polarising angle) for air to glass interface.

25. Discuss the intensity of transmitted light when a polaroid sheet is rotated between two crossed polaroids?

Sol. Let 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 polarised P_2 will be

$$I = I_0 \cos^2\theta,$$



Let P_2 be the polaride sheet rotated between P_1 and P_3. Let so be intensity of unpolarised light incident on polaride P_1 the outcoming intensity will after P_1 will be $I_1 = I_0/2$

Let at a moment angle between polariser P_1 and P_2 is θ. The outcoming intensity will be

$$I_2 = I_1 \cos^2\theta = \frac{I_0}{2}\cos^2\theta$$

As the angle between polariser P_1 and P_3 is π/2 and angle between P_1 and P_2 is θ. So the angle between P_2 and P_3 is $(\pi/2 - \theta)$.

Outcoming intensity after P_3 is

$$I_3 = I_2\cos^2(\pi/2 - \theta)$$

$$I_3 = \frac{I_0}{2}\cos^2\theta\sin^2\theta$$

or $\quad I_3 = \dfrac{I_0}{2}\left[\dfrac{1}{2}\sin 2\theta\right]^2$

Maximum outcoming intensity is received, when $\theta = \pi/4$

$$I_3 = \frac{I_0}{2}\left[\frac{1}{2}\right]^2 = \frac{I_0}{8}$$

Minimum outcoming intensity is received, when $\theta = \pi/2$

$$I_3 = \frac{I_0}{2}[0] = 0$$

26. What speed should a galaxy move with respect to us so that the sodium line at 589.0 nm is observed at 589.6 nm?

Sol. $\Delta\lambda = 589.6 - 589.0 = +0.6$ nm

We know $\Delta\lambda = \dfrac{v}{c}\lambda$

or $\quad v \cong +c\left(\dfrac{0.6}{589.0}\right) = +3.06 \times 10^5\ \text{ms}^{-1} = 306$ km/s

Therefore, the galaxy is moving away from us.

27. For sound waves, the Doppler formula for frequency shift differs slightly between the two situations : (1) source at rest; observer moving, and (ii) source moving; observer at rest. The exact Doppler formulas for the case of light waves in vacuum are, however, strictly identical for these situations. Explain why this should be so. Would you expect the formulas to be strictly identical for the two situations in case of light travelling in a medium?

Sol. Sound waves require a medium for propagation.

The Doppler formula for frequency shift differs slightly in two situations

(i) source at rest, observer moving

$$\upsilon' = \upsilon\left[\frac{v \pm v_0}{v}\right]$$

(ii) observer at rest, source moving

$$\upsilon' = \upsilon\left[\frac{v}{v \pm v_0}\right]$$

The two formulas are different because motion of the observer relative to the medium is different in the two situations for light waves in vacuum, no such relative relation of observer and medium exist.

Hence only the relative motion between the source and the observer counts and the frequency shift formula is same.

$$\upsilon' = \upsilon\left[1 \pm \frac{v}{c}\right]$$