CLASS – 12

WORKSHEET- WAVE OPTICS

A. HUYGEN'S PRINCIPLE AND WAVE NATURE OF LIGHT

(1 Mark Question)

1. Draw the type of wave front that corresponds to a beam of light coming from a very far off source.

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2. Sketch wave from emerging from a point source of light.

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3. Sketch the wave front emerging from a linear source of light like a slit.

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4. Draw the laws of reflection of light on the basis of Huygens, principle of secondary wavelets.

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5. When light undergoes refraction, what happened to its frequency?

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6. How does the frequency of a beam of ultraviolet light change when it goes from air into glass?

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7. A light wave enters from air into glass. How will the following be affected: (i) energy of the wave (ii) Frequency of the wave?

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8. Assertion: Corpuscular theory falls in explaining velocities of light in air and water.
Reason: According to corpuscular theory, light should travel faster in denser media than in rarer media.
(a) Both Assertion and Reason are true and Reason is the correct explanation of Assertion
(b) Both Assertion and Reason are true but Reason is NOT the correct explanation of Assertion
(c) Assertion is true but Reason is false
(d) Assertion is false and Reason is also false

9. Is Huygen's principle valid for longitudinal sound waves?

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10. What is the shape of the wavefront on earth for sunlight?

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(2 Marks Questions)

11. Define wave-front of a travelling wave. Using Huygens principle, obtain the law of refraction at a plane interface when light passes from a rarer to a denser medium.

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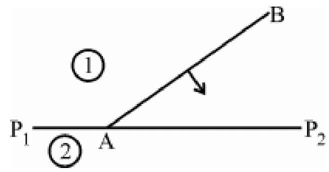
12. Define the term 'wave-front of light'. A plane wave front AB propagating from a denser medium (1) into a rarer medium (2) is incident on the source P_1P_2 separating the two media as shown in figure.

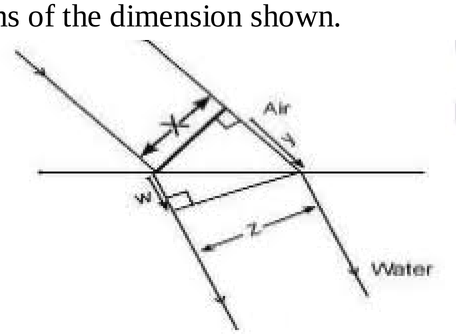


Using Huygens principle, draw the secondary wavelets and obtain the refracted wave-front in the diagram.

13. Using Huygens principle draw a diagram to show propagation of wavefront originating from a monochromatic point source.

14. For reflection of a plane wave front at a plane reflecting surface, construct the corresponding reflected wave front. Using this diagram, prove that angle of incidence is equal to angle of reflection.

15. A plane wavefront, of width x, is incident on an air-water interface and the corresponding refracted wavefront has a width z as shown. Express the refractive index of air with respect to water, in terms of the dimension shown.



(3 Marks Questions)

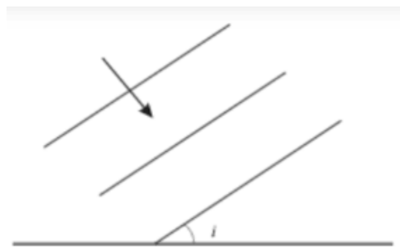
16. Use Huygens wave theory, derive Snell's law.

17. Define the term wave-front. Using Huygens wave theory, verify the law of reflection.

18. Define the term wave-front. State Huygens principle. Consider a plane wave-front incident on a thin convex lens. Draw a proper diagram to show how the incident wave-front traverses through the lens and after refraction focuses on the focal point of the lens, giving the shape of the emergent wave-front.

19. Explain the following, giving reasons:
(i) 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.
(ii) When light travels from a rarer medium, the speed decreases. Does this decrease in speed imply a reduction in the energy carried by the wave?
(iii) In the wave picture of light, intensity of light is determined by the square of the amplitude of the wave. What determines the intensity in the photon picture of light?

20. A plane wave-front propagating in a medium of refractive index ‘μ_1’ is incident on a plane surface making the angle of incidence i as shown in the figure. It enters into a medium of refraction of refractive index ‘μ_2’ ($\mu_2 > \mu_1$). Use Huygens construction of secondary wavelets to trace the propagation of the refracted wave-front. Hence verify Snell’s law of refraction.



21. Using Huygens principle and drawing sketches of wavefront, show how a parallel beam of light is reflected from a polished surface and hence verify $\angle i = \angle r$.

22. 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.

23. 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.

24. **(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^{-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? [Ans. (a) 2.0×10^8m/s]

25. You have learnt in the text how Huygen's principle leads to the laws of reflection and refraction. Use the same principle to deduce directly that a point object placed in front of a plane mirror produces a virtual image whose distance from the mirror is equal to the object distance from the mirror.

26. A ray of light of frequency 5×10^{14} Hz is passed through a liquid. The wavelength of light measured inside the liquid to be 450nm. Calculate (i) wave length of light in vacuum. (ii) refractive index of liquid (iii) velocity of light in the liquid. Take velocity fo light in vacuum as 3×10^{8} ms^{-1}.

(5 Marks Questions)

27. What is a wave-front? How does it propagate? Using Huygens principle, explain reflection of a plane wave-front from a surface and verify the laws of reflection.

28. (a) Define wave-front. How is it different from a ray?
(b) Depict the shape of a wave-front in each of the following cases:
(i) Light diverging from point source.
(ii) Light emerging out of a convex lens when a point source is placed at its focus.
(iii) Using Huygens construction of secondary wavelets, draw a diagram showing the passage of a plane wave-front from a denser into a rarer medium.

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29. (i) A plane wave-front approaches a plane surface separating two media. If medium 'one' is optically denser and medium 'two ' is optically rarer, using Huygens principle, explain and show how a refracted wave-front is constructed.
(ii) Hence verify Snell's law.
(iii) When a light wave travels from rarer to denser medium, the speed decreases. Does it imply reduction in its energy? Explain.

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30. (a) How is wave different from a ray? Draw the geometrical shape of the wave-fronts when (i) light diverges from a point source and (ii) light emerges out of a convex lens when a point source is placed at its focus.
(b) State Huygens principle. With the help of suitable diagram, prove Snell's law of refraction using Huygens principle.

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31. State Huygens principle. Using the geometrical construction of secondary wavelets, explain the refraction of a plane wave-front incident at a plane surface. Hence verify Snell's law of refraction. Illustrate with the help of diagrams the action of (i) convex lens and (ii) concave mirror on a plane wave-front incident on it.

32. 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 source and/or observer.
(iv) Wave length.
(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?

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B. INTERFERENCE OF LIGHT

(1 Mark Question)

1. Define the term 'coherent sources' which are required to produce interference pattern in Young's double slit experiment.

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2. In Young's double slit experiment, the path difference between two interfering waves at a point on the screen is $5\lambda/2$, λ being wavelength of light used. The ______ dark fringe will lie at this point.

3. If one of the slits in Young's double slit experiment is fully closed, the new pattern has ______ central maximum in angular size.

4. Write the conditions on path difference under which (i) constructive (ii) destructive interference occur in Young's double slit experiment.

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5. What is meant by interference of light?

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6. State the reason, why two independent sources of light cannot be considered as coherent sources.

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7. State two conditions for sustained interference of light.

8. How does the angular separation of interference fringes change in Young's experiment, if the distance between the slits is increased?

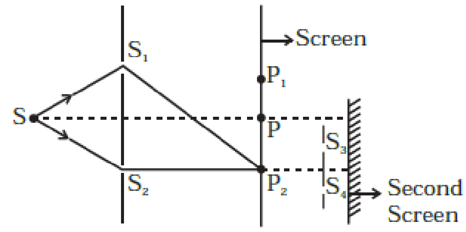
9. How does the fringe width of interference change, when the whole apparatus of Young's experiment is kept in a liquid of refractive index 1.3?

10. In Young's double slit experiment three lights of blue, yellow and red colour are used successively. The fringe width will be maximum for which colour of light and why?

11. Two identical coherent waves, each of intensity I_0, are producing an interference pattern. Write the value of the resultant intensity at a point of (i) constructive interference and (ii) destructive interference.

12. In a Young's double slit experiment, the source is white light. One of the holes is covered by a red filter and another by a blue filter. In this case
(a) there shall be alternate interference patterns of red and blue.
(b) there shall be an interference pattern for red distinct from that for blue.
(c) there shall be no interference fringes.
(d) there shall be an interference pattern for red mixing with one for blue.

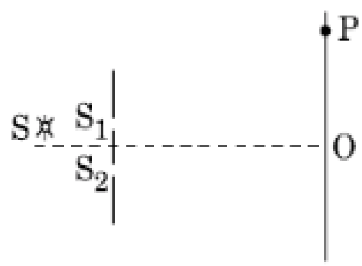
13. Figure shows a standard two slit arrangement with slits S_1, S_2. P_1, P_2 are the two minima points on either side of P (Figure).



At P_2 on the screen, there is a hole and behind P_2 is a second 2- slit arrangement with slits S_3, S_4 and a second screen behind them.
(a) There would be no interference pattern on the second screen but it would be lighted.
(b) The second screen would be totally dark.
(c) There would be a single bright point on the second screen.
(d) There would be a regular two slit pattern on the second screen

(2 Marks Questions)

14. The figure shows a modified Young's double slit experimental set up. Here $SS_2 - SS_1 = \lambda/4$.



(a) Write the condition for constructive interference.
(b) Obtain an expression for the fringe width.

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15. (a) State two conditions required for obtaining coherent sources.
(b) In Young's arrangement to produce interference pattern, show that dark and bright fringes appearing on the screen are equally spaced.
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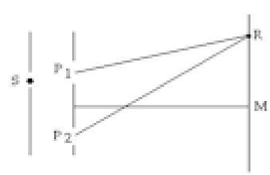
16. Laser light of wavelength 640nm incident on a pair of slits produces an inference pattern in which the bright fringes are separated by 7.2 mm. Calculate the wavelength of another source of light which produces interference fringes separated by 8.1 mm using same arrangement. Also find the minimum value of the order (n) of bright fringe of shorter wavelength which coincides with that of the longer wavelength.

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

18. Laser light of wavelength 630 nm incident on a pair of slits produces an interference pattern in which the bright fringes are separated by 7.2 mm. Calculate the wavelength of another source of laser light which produces interference fringes separated by 8.1 mm using same pair of slits.

19. A slit, S is illuminated by a monochromatic source of light to give two coherent sources P_1 and P_2. These give bright and dark bands on a screen. At a point R on the screen, there is a dark fringe. What relationship must exist between the lengths P_1R and P_2R?



20. In Young's experiment, two coherent sources are 1.5mm apart and fringes are obtained at a distance of 2.5m from them. If the wavelength of light is 600nm, find the number of fringes in the interference pattern, which is 5×10^{-3}m wide.

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21. In a double slit experiment with monochromatic light, fringes are obtained on a screen placed at same distance from the slits. If the screen is moved by 5×10^{-2}m towards thee slits, the change in fringe width is 3×10^{-5}m. If the distance between the slits is 10^{-3}m, calculate the wavelength of light used.

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22. Find the ratio of intensities of two points P and Q on a screen in a Young's double slit experiment when waves from S_1 and S_2 have path difference of (i) 0 and (ii) $\lambda/4$.

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23. What is effect on the interference fringes in a Young's double slit experiment due to the following operation? Give reason for your answer. Monochromatic source is replaced by a source of white light.

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24. What will be the effect on the interference fringes in Young's double slit experiment if the screen is moved away from the slit? Justify your answer.

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25. In Young's experiment, the width of fringes obtained with the light of wavelength 6000Å is 2.0mm. Calculate the fringe width if the entire apparatus is immersed in a liquid medium of refractive index 1.33.

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26. Light of wavelength 600nm is incident on a single slit of width 0.5mm at normal incidence. Calculate the separation between two dark bands on either side of the central maximum, if the diffraction pattern is observed on a screen placed at 2m from slit.

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27. In double-slit experiment using light of wavelength 600 nm, the angular width of a fringe formed on a distant screen is 0.1^o. What is the spacing between the two slits?

[Ans. 3.44×10^{-4}m]

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(3 Marks Questions)

28. Deduce an expression for the intensity at any point on the screen in Young's double slit experiment.

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29. Define the term "refractive index" of a medium. Verify Snell's law of refraction when a plane wave-front is propagating from a denser to a rarer medium.

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30. (a) If one of two identical slits producing interference in Young's experiment is covered with glass, so that the light intensity passing through it is reduced to 50%, find the ratio of the maximum and minimum intensity of the fringe in the interference pattern.
(b) What kind of fringes do you expect to observe if white light is used instead of monochromatic light?

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31. Answer the following questions:
(a) In a double slit experiment using light of wavelength 600 nm, the angular width of the fringe formed on a distant screen is 0.1°. Find the spacing between the two slits.
(b) Light of wavelength 500Å propagating in air gets partly reflect from the surface of water. How will the wavelengths and frequencies of the reflected and refracted light be affected?

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32. Why cannot two independent monochromatic sources produce sustained interference pattern? Deduce, with the help of Young's arrangement to produce interference pattern, an expression for the fringe width.

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33. (a) The ratio of the widths of two slits in Young's double slit experiment is 4:1. Evaluate the ratio of intensities at maxima and minima in the interference pattern.
(b) Does the appearance of bright and dark fringes in the interference pattern violate, in any way, conservation of energy? Explain.

34. (a) Two monochromatic waves emanating from two coherent sources have the displacements represented by: $y_1 = a \cos \omega t$ and $y_2 = a \cos (\omega t + \phi)$ where ϕ is the phase difference between the two displacements, Show that the resultant intensity at a point due to their superposition is given by $I = 4 I_0 \cos^2 \phi/2$, where $I_0 = a^2$.
(b) Hence obtain the conditions for constructive and destructive interference.

35. (a) Why are coherent sources necessary to produce a sustained interference pattern?
(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 $\lambda/3$.

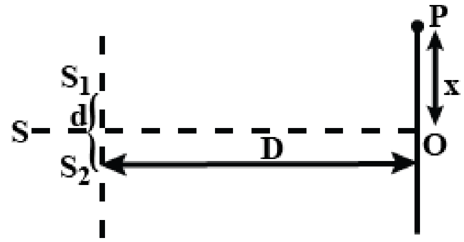
36. Describe Young's experiment of interference of light. Obtain the conditions for maxima and minima of light.

37. Two narrow slits are illuminated by a single monochromatic source. Name the pattern 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 tow differences between the patterns obtained in the above two cases.

38. 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. [Ans. 6000Å]

39. 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? [Ans. 1.17m (b) 1.56mm]

40. The intensity at the central maximum (O) in a Young's double slit setup shown in figure is I_0. If the distance OP equals one third of the fringe width of the patter, show that the intensity at point P, would equal to $I_0/4$.



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41. In Young's double slit experiment, the distance between the slits S_1 and S_2 is 1mm. What should be the width of each slit be so as to obtain 10 maxima of the double slit pattern within the central maximum of the single slit patter?

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(5 Marks Questions)

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

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C. DIFFRACTION OF LIGHT

(1 Mark Question)

1. What is diffraction of sound waves more easily observed than diffraction of light waves?
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2. The light of wavelength 600nm is incident normally on a slit of width 3mm. Calculate the linear width of central maximum on a screen kept 3m away from the slit.
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3. Diffraction is common in sound but not common in light waves? Why?
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4. Why is the diffraction of sound waves more evident in daily experience than that of light wave?
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(2 Marks Questions)

5. State Huygens principle of diffraction of light.
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6. 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 λ /a. At the same angle of λ /a, we get a maximum for two narrow slits separated by a distance 'a'. Explain.

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

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

9. 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.

[Ans. λ/a’]

(3 Marks Questions)

10. In what way is diffraction from each slit related to the interference pattern in a double pattern in a double slit experiment?

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11. State the condition for diffraction of light to occur. If the diffraction in 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?

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12. Describe diffraction of light due to 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.

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

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14. Give two points of difference between the phenomenon of interference and diffraction of a single slit diffraction experiment, the width of the slit is made double the original width. How does this affect the (i) size and (ii) intensity of the central maximum?

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15. 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? [Ans. 12.5cm]

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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. [Ans. 0.2 mm]

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17. 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 displacement is basic to understanding intensity distributions in diffraction and interference patterns. What is the justification of this principle?

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(5 Marks Questions)

18. What is diffraction of light? Draw a graph showing the variation of intensity with angle in a single slit diffraction experiment. Write one feature which distinguishes the observed pattern from the double slit interference pattern. How would the diffraction pattern of a single slit be affected when (i) the width of the slit is decreased, (ii) the monochromatic source of light is replaced by a source of white light.

19. State the condition under which the phenomenon of diffraction of light takes place. Derive an expression for the width of the central maximum due to diffraction of light at a single slit.
A slit of width 'a' is illuminated by a monochromatic light of wavelength 700nm at normal incidence. Calculate the value of 'a' for position of (i) first minimum if diffraction of 30° (ii) first maximum at angle of diffraction of 30°.

20. 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?

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D. POLARISATION

(1 Mark Question)

1. What is plane polarized light?

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2. Describe a method for producing a beam of plane polarized light?

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3. What is Polaroid?

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4. What type of waves show the property of polarization?

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5. Which of the following can be polarized: X-rays, sound waves and radio waves?

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6. What is polarization angle of medium in which the angle of refraction is 33°?

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7. What is value of refractive index of medium of polarizing angle 60°?

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(2 Marks Questions)

8. How can one distinguish an un-polarized light beam and al linearly polarized light beam using a Polaroid?

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9. What is the Brewster angle for air to glass transition? (Refractive index of glass = 1.5.) [Ans. 56.3°]

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

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(3 Marks Questions)

11. How are polaroids artificially made? Mention two use\s of polaroids. Draw a graph showing the dependence of intensity of transmitted light on the angle between polarizer and analyzer?

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(**5 Marks Questions)**

12. (a) What is plane polarized light? Two polaroids 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 vary 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 un-polarized? Explain briefly.

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13. 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 widths of two sluts are increased

(g) The monochromatic source is replaced by source of white light?

(In each operation, take all parameters, other than the one specified, to remain unchanged).

E. DOPPLET EFFECT

(2 Marks Questions)

1. The 6563 Å H_α line emitted by hydrogen in a star is found to be red shifted by 15 Å. Estimate the speed with which the star is receding from the Earth. [Ans. 6.86×10^5 m/s]

F. CHALLENGING PROBLEMS

1. Explain how Corpuscular theory predicts the speed of light in a medium, say, water, to be 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?

SPACE FOR ROUGH WORK

SPACE FOR NOTES