Date: 21/10/2021

Q1. State interference of light.

Q2. Is the speed of light in glass independent of the colour of light?

Q3. How does the frequency of a beam of ultraviolet light change when it goes from air into glass?

Q4. When light undergoes refraction, what happens of its frequency?

Q5. Why do two identical bulbs do not produce interference?

Q6. Does interference phenomenon violate the law of conservation of energy?

Q7. Give a relation between path difference and wavelength for constructive interference between two waves.

Q8. 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.

Q9. (a) The refractive index of glass is 1.5. What is the speed of light in glass? Speed of light in vacuum is $3.0 \times 10^8\ m\,s^{-1}$.

(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?

Q10. Light of wavelength 5000 Å falls on a plane reflecting surface. What are the wavelength and frequency of the reflected light? For what angle of incidence is the reflected ray normal to the incident ray?

Q11. What is the geometrical shape of wavefront of light emerging out of a convex lens; when a point source is placed at its focus?

Q12. When the 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 waves?

Q13. What is the shape of wavefront originating from (a) a point source and (b) a line source?

Q14. State Huygen's principle. Depict the wavefront emanating from a point of source?

Q15. 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?

Q16. Let us list some of the factors, which could possibly influence the speed of wave propagation:

Nature of the source.

Direction of propagation.

Motion of the source and/or observer.

Wave length.

Intensity of the wave.

On which of these factors, if any, does

The speed of light in vacuum,

The speed of light in a medium (say, glass or water), depend?

Q17. (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.

Q18. (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 $\lambda/3$.

Q19. How is wavefront defined? Using Huygen's construction draw a figure showing the propagation of a plane wave refracting at a plane surface separating two media. Hence, verify Snell's law of refraction.

Q20. (a) How does an unpolarized light incident on a polaroid get polarized?

Describe briefly, with the help of 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 $1/8^{th}$ of the intensity of unpolarized light incident on *A*?

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S1. The phenomenon of non-uniform distribution of energy in the medium due to superposition of two light waves is called interference of light.

S2. No. The speed of light in a medium depends on the wavelength.

S3. No change.

S4. No change.

S5. Two identical bulbs cannot produce interference. The emission of light in the bulbs in due to millions of atoms in which electrons jump from some higher orbit to the lower orbit. This process take place in a time of about 10^{-8} second. Thus, the phase difference can remain constant for about 10^{-8} second only. In other works, in one second, the phase will change 10^{8} times approximately. Such a fast variation in the interference pattern cannot be detected. Therefore, the interference pattern cannot be detected, Therefore, the interference will be produced, but it will go undetected.

S6. No. It simply redistributes the energy.

S7. Path difference = $n\lambda$ (where n is a whole number)

S8. Wavelength of incident monochromatic light,

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

Speed of light in air, $c = 3 \times 10^{8}$ m/s

Refractive index of water, $\mu = 1.33$

The ray will reflect back in the same medium as that of incident ray. Hence, the wavelength, speed, and frequency of the reflected ray will be the same as that of the incident ray.

Frequency of light is given by the relation,

$$\nu = \frac{c}{\lambda}$$

$$= \frac{3 \times 10^{8}}{589 \times 10^{-9}} = 5.09 \times 10^{14} \text{ Hz}$$

Hence, the speed, frequency, and wavelength of the reflected light are 3×10^{8} m/s, 5.09×10^{14} Hz, and 589 nm respectively.

Frequency of light does not depend on the property of the medium in which it is travelling. Hence, the frequency of the refracted ray in water will be equal to the frequency of the incident or reflected light in air.

$\therefore$ Refracted frequency, $\mu = 5.09 \times 10^{14}$ Hz

Speed of light in water is related to the refractive index of water as:

$$v = \frac{c}{\mu}$$

$$v = \frac{3 \times 10^8}{1.33}$$
$$= 2.26 \times 10^8 \text{ m/s}$$

Wavelength of light in water is given by the relation,

$$\lambda = \frac{c}{\nu}$$

$$= \frac{2.26 \times 10^8}{5.09 \times 10^{14}}$$
$$= 444.007 \times 10^{-9} \text{ m}$$

$$= 444.01 \text{ nm}$$

Hence, the speed, frequency, and wavelength of refracted light are 2.26×10^8 m/s, 444.01 nm, and 5.09×10^{14} Hz respectively.

S9. Refractive index of glass, $\mu = 1.5$

Speed of light, $c = 3 \times 10^8$ m/s

Speed of light in glass is given by the relation,

$$\nu = \frac{c}{\mu}$$

$$\nu = \frac{3 \times 10^8}{1.5}$$
$$= 2 \times 10^8 \text{ m/s}$$

Hence, the speed of light in glass is 2×10^8 m/s.

The speed of light in glass is not independent of the colour of light.

The refractive index of a violet component of white light is greater than the refractive index of a red component. Hence, the speed of violet light is less than the speed of red light in glass. Hence, violet light travels slower than red light in a glass prism.

S10. Wavelength of incident light, $\lambda = 5000 \text{ Å} = 5000 \times 10^{-10}$ m

Speed of light, $c = 3 \times 10^8$ m

Frequency of incident light is given by the relation,

$$\nu = \frac{c}{\lambda}$$

$$= \frac{3 \times 10^8}{5000 \times 10^{-10}} = 6 \times 10^{14}\ \text{Hz}$$

The wavelength and frequency of incident light is the same as that of reflected ray. Hence, the wavelength of reflected light is 5000 Å and its frequency is 6×10^{14} Hz.

When reflected ray is normal to incident ray, the sum of the angle of incidence, $\angle i$ and angle of reflection $\angle r$, is 90°.

According to the law of reflection, the angle of incidence is always equal to the angle of reflection. Hence, we can write the sum as:

$$\angle i + \angle r = 90°$$

$$\angle i + \angle i = 90°$$

$$\angle i = \frac{90}{2} = 45°$$

Therefore, the angle of incidence for the given condition is 45°.

S11. When a point source is placed at the focus of a convex lens, it renders the light into the form of a parallel beam. The rays of light are always perpendicular to the wave front. Therefore, the light emerging out of the convex lens will be in the form of a plane wavefront.

S12. No, the decrease in the speed of light does not imply reduction in the energy carried by the light wave. It is because, energy carried by a wave does not depend upon its speed of propagation. Instead, it depends upon its amplitude.

S13. (a) The wave front originating from a point source is *spherical* in shape. It is because, the locus of all such points, which are equidistant from the point source, is a sphere.

(b) The wave front originating from a line source is *cylindrical* in shape. It is because, all the points, which are equidistant from the linear source, lie on the surface of a cylinder.

S14. Huygens' principle is based on the following assumptions:

(a) Each point on the given or primary wavefront acts as a source of secondary wavelets, sending out disturbance in all directions in a similar manner as the original source of light does.

(b) The new position of the wavefront at any instant (called secondary wavefront) is the envelope of the secondary wavelets at that instant.

The above two assumptions are known as *Huygens' principle* or *Huygens' construction*.

The wavefront emanating from a point source is as shown in figure.

S15. Since $\nu\lambda = c$, $-\dfrac{\Delta\nu}{\nu} = \dfrac{\Delta\lambda}{\lambda}$ (for small changes in ν and λ). For

$$\Delta\lambda = 589.6 - 589.0 = +0.6 \text{ nm}$$

we get [using Eq. (10.9)]

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

or, $$v_{\text{radial}} \cong +C\left(\frac{0.6}{589.0}\right) = +3.06 \times 10^{5} \text{ m s}^{-1}$$

$$= 306 \text{ km/s}^{-1}$$

Therefore, the galaxy is moving away from us.

S16. Thespeed of light in a vacuum *i.e.*, 3×10^{8} m/s (approximately) is a universal constant. It is not affected by the motion of the source, the observer, or both. Hence, the given factor does not affect the speed of light in a vacuum.

Out of the listed factors, the speed of light in a medium depends on the wavelength of light in that medium.

S17. (a) Reflection and refraction arise through interaction of incident light with the atomic constituents of matter. Atoms may be viewed as oscillators, which take up the frequency of the external agency (light) causing forced oscillations. The frequency of light emitted by a charged oscillator equals its frequency of oscillation. Thus, the frequency of scattered light equals the frequency of incident light.

(b) No. Energy carried by a wave depends on the amplitude of the wave, not on the speed of wave propagation.

(c) For a given frequency, intensity of light in the photon picture is determined by the number of photons crossing an unit area per unit time.

S18. (a) In order to obtain sustained interference pattern, the phase difference between the light waves arriving at a point on the screen from the two sources must remain constant with time. This can be made possible only if the two sources are derived from a single source. Such sources are called coherent sources. A change in phase, if any, will affect the two sources equally. Moreover, light waves from the two coherent sources are of same wavelength and amplitude.

(b) Resultant intensity at a point on the screen is

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

For a path difference λ, phase difference is 2π.

Assuming $I_1 = I_2 = I$

So $I_R = I + I + 2I\cos 2\pi$

$$I_R = 4I$$

$$I_R = K \quad \text{(Given)}$$

$$4I = K \qquad \dots \text{(i)}$$

Now for a path difference of $\lambda/3$ phase difference is $2\pi/3$.

So $I'_R = I + I + 2I\cos(2\pi/3)$

$$= I + I - 2I \times \frac{1}{2}$$

$$I'_R = I \qquad \dots \text{(ii)}$$

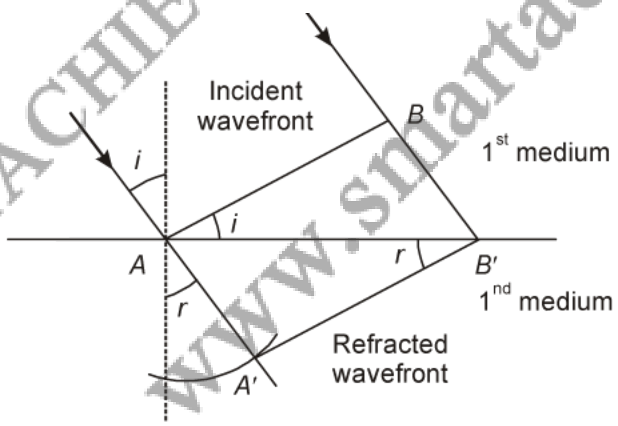
From equations (i) and (ii), we get

$$I'_R = \frac{K}{4}.$$

Hence, resultant intensity at the point would be $\frac{K}{4}$.

S19. Wavefront: It is a locus of points oscillating in same phase.

Figure showing refraction of a plane wavefront using Huygen's construction.



Here $v_2 = v_1$

$$BB' = v_1 t$$

$$AA' = v_2 t$$

Verification of Snell's law of refraction

$$\sin i = \frac{BB'}{AB'} \qquad \text{(From } \Delta ABB'\text{)}$$

$$\sin r = \frac{AA'}{AB'} \qquad \text{(From } \Delta AA'B'\text{)}$$

Now $$\frac{\sin i}{\sin r} = \frac{BB'}{AA'} = \frac{v_1 t}{v_2 t}$$

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \mu$$

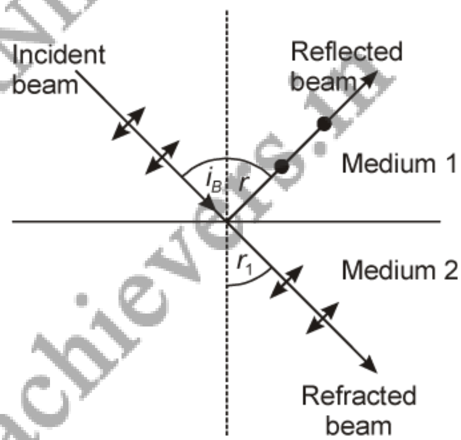
Where μ is a constant.

S20. (a) A polaroid consists of long chain of molecules aligned in a particular direction. The electric vectors of light waves along the direction of the aligned molecules get absorbed.

When unpolarised light wave is incident as such a polaroid, the wave will get linearly polarised with the electric vector oscillating along a direction perpendicular to the direction of alignment of molecules. (pass-axis).

Polarization of light by reflection.

Suppose 1st medium is water. When a beam of unpolarised light is incident on the interface separating the two media, electric field vector makes the electron oscillate on the water surface. These oscillating electrons produce reflected wave and refracted wave. In the reflected wave motion of optical vector (electric field vector) get confined only in a direction parallel to the plane of the interface.



The reflected wave is polarized.

Refracted wave moves into the 2nd medium in a direction perpendicular to the direction of reflected wave.

Angle of incidence in this situation is called Brewster's angle (i_B).

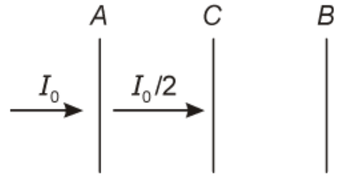
Here $$i_B + r' = \pi/2$$

According to Snell's law

$$\mu = \frac{\sin i}{\sin r'} = \frac{\sin i_B}{\sin(\pi/2 - i_B)} = \tan i_B.$$

We get Brewster's law.

(b) If I_0 is intensity of unpolarized light, the intensity of polarized light would be $I_0/2$,



i.e., $$I_A = I_0/2$$

Suppose pass axis of polaroid '*C*' makes angle 'θ' with pass axis of '*A*' . We have

$$I_C = I_A \cos^2\theta = I_0/2 \cos^2\theta \qquad \text{[Law of Malus]}$$

As the polaroids *A* and *B* are crossed angle between the pass axis of *C* and *B* would be $90° - \theta$.

$$I_B = I_C \cos^2(90° - \theta) = I_C \sin^2\theta$$

$$I_B = I_u/\alpha \cos^2\theta \sin^2\theta = I_u/8 (\sin 2\theta)^2$$

Intensity transmitted by a polaroid *B* would $I_0/8$ if

$$\sin 2\theta = I \quad \Rightarrow \quad 2\theta = \pi/2 \quad \Rightarrow \quad \theta = \pi/4$$

Thus, polaroid '*C*' should be placed making angle $\pi/4$ with the pass axis of poleroid *A*.

Date: 21/10/2021

Q1. State the reason, why two independent sources of light cannot be considered as coherent sources.

Q2. Why are coherent sources necessary to produce sustained interference pattern?

Q3. State the conditions which must be satisfied for two light source to be coherent.

Q4. What is unpolarised light?

Q5. Why do we need coherent sources for producing interference of light?

Q6. What are coherent source of light?

Q7. What will be the effect on the interference pattern if the phase difference between the two interfering waves changes continuously?

Q8. What are the conditions for two sources to be coherent?

Q9. Assume that light of wavelength 6000 Å is coming from a star. What is the limit of resolution of a telescope whose objective has a diameter of 100 inch?

Q10. State the necessary conditions for the sustained interference.

Date: 21/10/2021

S1. No it is because, the phase difference between the light waves from the two independent sources keeps on changing continuously.

S2. In order to obtain sustained interference pattern, the phase difference between the light waves arriving at a point on the screen from the two sources must remain constant with time. This can be made possible only if the two sources are derived from a single source. Such sources are called coherent sources. A change in phase, if any, will affect the two sources equally. Moreover, light waves from the two coherent sources are of same wavelength and amplitude.

S3. Two sources are said to be coherent, if they emit light waves of same frequency or wavelength and of a stable phase difference.

S4. The light, which has vibrations in all the planes perpendicular to the direction of its propagation, is called unpolarised light.

S5. It the two waves reaching at a particular point on the screen are not coherent, then their phase difference will vary with time hence that point may correspond to a dark fringe at one time, a grey or a bright at another time. Hence, interference cannot be observed.

S6. The sources of light which emit continuous light waves of the same wavelength, same frequency and in same phase or having a constant phase difference are called coherent sources.

S7. There will be no sustained interference.

S8. (a) Two sources should emit light waves continuously.

(b) The light waves emitted by the two sources should be of the same wavelength.

(c) The phase difference between light waves emitted by the two sources should not change with the passage of time.

S9. A 100 inch telescope implies that $2a$ = 100 inch = 254 cm. Thus if,

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

then
$$\Delta\theta \approx \frac{0.61 \times 6 \times 10^{-5}}{127} \approx 2.9 \times 10^{-7} \text{ radians.}$$

S10. The interference pattern, in which the positions of maximum and minimum of intensity of light remain fixed all along on the screen, is called *sustained or permanent interference pattern*.

Conditions for sustained interference:

(a) *The two sources should emit the light waves continuously*.

(b) *The light waves should be of same wavelength*.

(c) *The light waves emitted should preferably be of the same amplitude*. If the amplitudes of the waves are equal the dark fringes are completely dark (zero intensity of light).

(d) *The waves emitted by the two sources of light should either be in phase or should have a constant phase difference*.

(e) *The two sources of light must lie very close to each other*. If it is not so, then the path difference between the light waves reaching a particular point will be very large. As we shall see, in such a case, maxima and minima will lie very close to each other and may result in overlapping.

(f) *The two light sources should be very narrow*. A broad source of light is equivalent to a large number of narrow sources lying together. Each set of two sources will, therefore, give its own interference pattern and their overlapping will result in general illumination.

Date: 21/10/2021

Q1. How does the angular separation of interference fringes change in Young's experiment, if the distance between the slits is increased?

Q2. What is the effect on the interference fringes in a Young's double slit experiment if the screen is moved away from the plane of the slits?

Q3. Why is interference pattern not detected when two coherent sources are far apart?

Q4. State two conditions for sustained interference of light.

Q5. What is meant by interference of light?

Q6. Can two independent identical narrow sources produce permanent (steady) interference? If not why?

Q7. For what distance is ray optics a good approximation when the aperture is 3 mm wide and the wavelength is 500 nm?

Q8. Two slits are made one millimetre apart and the screen is placed one metre away. What is the fringe separation when bluegreen light of wavelength 500 nm is used?

Q9. 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?

Q10. 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?

Q11. What is the effect of slit width and wavelength of light source on fringe width of the fringes formed by young's double slit experiment?

Q12. If the separation between two slits is decreased in Young's double slit experiment, keeping the screen position fixed, what will happen to the fringe width?

Q13. Widths of two slits in a Young's experiment are in the ratio 4 : 1. What is the ratio of the amplitudes of light waves from them?

Q14. State the condition for destructive interference.

Q15. What is the main condition to produce interference of light?

Q16. Describe a method for producing beam of plane polarized light.

Q17. 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.

Q18. 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?

Q19. 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?

Q20. When a thin transparent file is placed just in front of one of the slits in the Young's double slit experiment using white light, what change results in the fringe system?

Q21. 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.

Q22. Estimate the distance for which ray optics is good approximation for an aperture of 4 mm and wavelength 400 nm.

Q23. 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?

Q24. Draw the graph showing the variation of intensity in the interference pattern in Young's double slit experiment.

Q25. Find the ratio of intensities at the two points X and Y on a screen in Young's double slit experiment, where waves from the two sources S_1 and S_2 have path difference of (a) 0 and (b) $\lambda/4$.

Q26. Consider interference between two sources of intensities I and $4I$. Obtain intensity at a point, where the phase difference is $\pi/2$.

Q27. Discuss the intensity of transmitted light when a polaroid sheet is rotated between two crossed polaroids?

Q28. 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.

Q29. Why is no interference pattern observed, when two coherent sources are:

(a) infinitely close to each other?

(b) far apart from each other?

Q30. What is the effect on the interference pattern in Young's double slit experiment due to each of the following operations?

(a) The widths of the slits are increased equally.

(b) The whole apparatus is kept in a denser medium.

Q31. How does the angular width of interference fringes change in Young's experiment, if the distance between the two slits is increased ?

Q32. What will be the effect on the fringes formed in Young's double slit experiment,

(a) the apparatus is immersed in water,

(b) white light is used instead of monochromatic light?

Q33. Draw a labelled diagram to show how interference can take place in thin transparent films by reflected light.

Q34. 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.

Q35. 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.

Q36. 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 $\lambda/3$?

Q37. You have learnt in the text how Huygens' 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.

Q38. 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?

Q39. Describe Young's double slit experiment to produce interference pattern due to a monochromatic source of light. Deduce the expression for the fringe width.

Q40. The intensity at the central maxima (O) in a Young's double slit experiment is I_0. If the distance OP equals one-third of the fringe width of the pattern, show that the intensity at point P would be $\frac{I_0}{4}$.

Q41. 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 ?

Q42. 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?

Q43. 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 the distance between slits is 10^{-3} m, calculate the wavelength of light used.

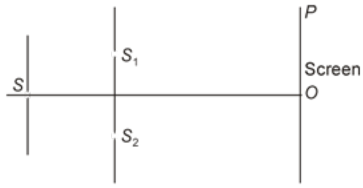
Q44. In diffraction by a single slit experiment, how would the width and intensity of central maxima change, if

(a) width of the slit is doubled,

(b) the wavelength of the incident monochromatic light on the slit is increased, and

(c) the distance between the screen and the slit is reduced?

Q45. The figure given below shows an experimental set up for Young's double slit experiment to observe interference of light on the screen *OP*.



Here path difference $SS_2 - SS_1 = \lambda/4$. Obtain the condition for (a) constructive, and
(b) destructive interference at any point *P* in terms of path difference, $\Delta = S_2P - S_1P$

Q46. 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.

Q47. 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 480 nm. The screen is at 2 m from the plane of the slits. Calculate the separation between the 8^{th} fringe and the 3^{rd} dark fringe observed with respect to the central bright fringe.

Q48. What are coherent sources of light? Deduce an expression for the intensity at any point on the screen in Young's double slit experiment.

Q49. What should be the order of size of obstacle / aperture for diffraction of light?
Monochromatic light of wavelength 600 nm is incident normally on a slit of width 0.5 mm. Calculate (a) angular width, (b) linear width of the 1^{st} order maximum. Assume the distance between the slits and screen to be 2 m.

Q50. By what percent the apparent depth of water filled in a tank will change of its refractive index increases by 2% ? Draw a graph showing variation of apparent depth with refractive index (μ).

Q51. 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?

The distance between the slits is 2 mm and the distance between the plane of the slits and screen is 120 cm.

Q52. The ratio of the width of the two slits in Young's double slit experiment is 9 : 1. Prove that in the interference pattern,

$$\frac{I_{max} + I_{min}}{I_{max} - I_{min}} = \frac{5}{3}$$

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S1. Decreases

S2. The fringe-width increases.

S3. As fringe width, $\omega \propto \frac{1}{d}$

When sources are far apart i.e., d is larger, the fringe width is reduced beyond the visible range. Hence the pattern is not seen.

S4. (a) The two sources of light must be coherent, *i.e.*, they should emit continuous light waves of same wavelength or frequency, which have either the same phase or a constant phase difference.

(b) The amplitude of waves from two sources should preferably be equal.

S5. Interference of light is the phenomenon of redistribution of light energy of a medium on account of superposition of light waves from two coherent sources.

S6. No, because the two sources will not be coherent.

S7.

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

Here, z_F = Fresnel's distance

a = aerture

λ = Wavelength of light

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.

S8.

$$\text{Fringe spacing} = \frac{D\lambda}{d} = \frac{1\times 5\times 10^{-7}}{1\times 10^{-3}} \text{ m}$$

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

S9. The principle of linear superposition of wave displacement is essential to our understanding of intensity distributions and interference patterns. This is because superposition follows from the linear character of a differential equation that governs wave motion. If y_1 and y_2 are the solutions of the second order wave equation, then any linear combination of y_1 and y_2 will also be the solution of the wave equation.

S10. In a single slit diffraction experiment, if the width of the slit is made double the original width, then the size of the central diffraction band reduces to half and the intensity of the central diffraction band increases up to four times.

S11. Again, $\beta = \frac{D\lambda}{d}$

It follows that when the slit (distance between slits is increased, the fringe width will decrease).

On the other hand, when the wavelength is increased, the fringe width will increase.

S12. We know that $\beta = \frac{D\lambda}{d}$

When the two slits are moved closer (d is decreased), the fringe width will increase.

S13. Here, $\frac{w_1}{w_2} = \frac{4}{1}$

Now, $\frac{a_1^2}{a_2^2} = \frac{w_1}{w_2} = \frac{4}{1}$

Therefore $\frac{a_1}{a_2} = \mathbf{\frac{2}{1}}$.

S14. Path difference, x = $(2n+1)\frac{\lambda}{2}$, where n = 0, 1, 2,.... .

S15. For observing interference of light, the two sources of light must be coherent sources.

S16. By passing unpolarized light through nicol prism or calcite prism.

S17. Linear width of central maximum = $\frac{2D\lambda}{d} = \frac{2 \times 3 \times 600 \times 10^{-9}}{3 \times 10^{-3}} = 1.2 \times 10^{-3}$m.

S18. As $\lambda_r > \lambda_y > \lambda_b >$ and $\beta \propto \lambda$

Therefore width would be maximum for red light fringe.

S19. Decreases (becomes 1/1.3 times of its initial value)

S20. The entire fringe pattern will get displaced.

S21. Distance of the screen from the slits, D = 1 m

Wavelength of light used, λ_1 = 600 nm

Angular width of the fringe in air, $\theta_1 = 0.2°$

Angular width of the fringe in water $= \theta_2$

Refractive index of water, $\mu = \frac{4}{3}$

Refractive index is related to angular width as:

$$\mu = \frac{\theta_1}{\theta_2}$$

$$\mu = \frac{3}{4}\theta_1$$

$$= \frac{3}{4} \times 0.2 = 0.15$$

Therefore, the angular width of the fringe in water will reduce to 0.15°.

S22. Fresnel's distance (Z_F) is the distance for which the ray optics is a good approximation. It is given by the relation,

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

Where,

Aperture width, $a = 4 \text{ mm} = 4 \times 10^{-3}\,\text{m}$

Wavelength of light, $\lambda = 400\,\text{nm} = 400 \times 10^{-9}\,\text{m}$

$$Z_r = \frac{(4 \times 10^{-3})^2}{400 \times 10^{-9}} = 40\,\text{m}$$

Therefore, the distance for which the ray optics is a good approximation is 40 m.

S23. Wavelength of light used, $\lambda = 6000\,\text{nm} = 600 \times 10^{-9}\,\text{m}$

Angular width of fringe, $\theta = 0.1^\circ = 0.1 \times \frac{\pi}{180} = \frac{3.14}{1800}\,\text{rad}$

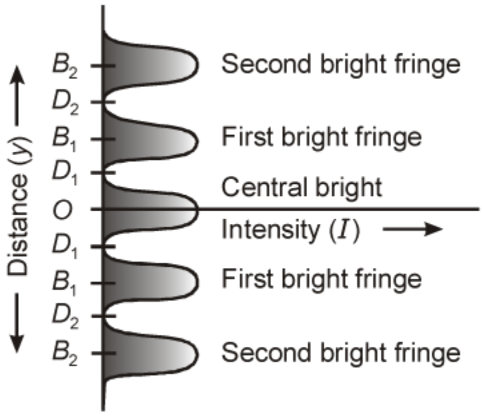
Angular width of a fringe is related to slit spacing (d) as:

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

$$d = \frac{\lambda}{\theta} = \frac{600 \times 10^{-9}}{\frac{3.14}{1800}} = 3.44 \times 10^{-4}\,\text{m}$$

Therefore, the spacing between the slits is 3.44×10^{-4} m.

S24.



S25. Resultant light intensity,

$$I = a_1^2 + a_2^2 + 2a_1 a_2 \cos\phi.$$

(a) The path difference equal to zero at the point X corresponds to phase difference $\phi = 0°$ at the point.

$$\therefore \qquad I_X = a_1^2 + a_2^2 + 2a_1 a_2 \cos 0° = a_1^2 + a_2^2 + 2a_1 a_2$$

(b) The path difference equal to $\lambda/4$ at point Y corresponds to phase difference $\phi = \pi/2$ at that point

$$\therefore \qquad I_Y = a_1^2 + a_2^2 + 2a_1 a_2 \cos\frac{\pi}{2} = a_1^2 + a_2^2$$

$$\therefore \qquad \frac{I_X}{I_Y} = \frac{a_1^2 + a_2^2 + 2a_1 a_2}{a_1^2 + a_2^2}$$

In case, $a_1 = a_2 = a$ (say), then

$$\frac{I_X}{I_Y} = \frac{a^2 + a^2 + 2a \times a}{a^2 + a^2} = \frac{\mathbf{2}}{\mathbf{1}}$$

S26. Let a_1 and a_2 be amplitude of the waves from the two sources.

Here, $I_1 = a_1^2 = I$ and $I_2 = a_2^2 = 4I$

Resultant light intensity,

$$I' = a_1^2 + a_2^2 + 2a_1 a_2 \cos\phi$$

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

$$= I + 4I + 2\sqrt{I}\sqrt{4I}\cos\phi = 5I + 4I\cos\phi$$

When $\phi = \pi/2$

$$I' = 5I + 4I\cos\frac{\pi}{2} = 5I + 4I \times 0 = \mathbf{5I}.$$

S27. 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 polariser P_2 will be

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

where θ is the angle between pass axes of P_1 and P_2. Since P_1 and P_3 are crossed the angle between the pass axes of P_2 and P_3 will be $(\pi/2 - \theta)$. Hence the intensity of light emerging from P_3 will be

$$I = I_0 \cos^2 \theta \cos^2 \frac{\pi}{2} - \theta$$

$$= I_0 \cos^2 \theta \sin^2 \theta = (I_0/4) \sin^2 2\theta$$

Therefore, the transmitted intensity will be maximum when $\theta = \pi/4$.

S28. Wavelength of light beam, $\lambda = 500 \text{ nm} = 500 \times 10^{-9} \text{ m}$

Distance of the screen from the slit, $D = 1$ m

For first minima, $n = 1$

Distance between the slits = d

Distance of the first minimum from the centre of the screen can be obtained as:

$$x = 2.5 \text{ mm} = 2.5 \times 10^{-3} \text{ m}$$

It is related to the order of minima as:

$$x = \frac{nd\lambda}{d}$$

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

$$d = \frac{n\lambda D}{x} = \frac{1 \times 500 \times 10^{-9} \times 1}{2.5 \times 10^{-3}}$$

$$= 2 \times 10^{-4} \text{ m} = 0.2 \text{ mm}$$

Therefore, the width of the slits is 0.2 mm.

S29. We know that,

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

(a) When the two sources are close to each other (d quite small) sufficiently wide fringes are formed. In case the two sources are infinitely close to each other, general illumination will take place.

(b) When the sources are moved far apart (d very large), the fringe width will be very small and they will not be separately visible.

S30. (a) As the widths of the slits are increased equally, the fringe width decreases. It is because,

$$\beta \propto \frac{1}{d}$$

(b) When the apparatus is immersed in denser medium of refractive index μ, the wavelength of the light used decreases. Since $\beta \propto \lambda$, the fringe width decreases.

S31. The angular width of a fringe is given by

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

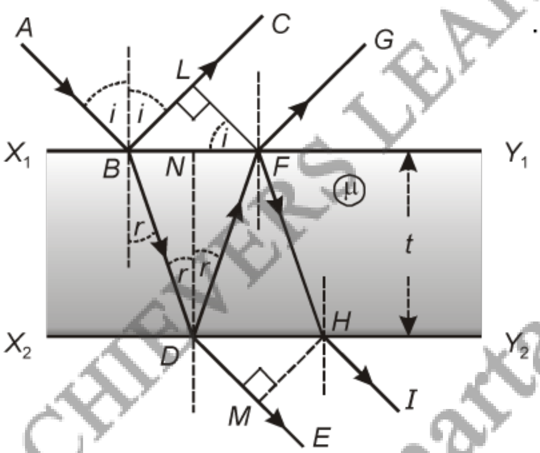
It follows that the angular width of interference fringes will *decrease*, when the distance between the two slits is increased.

S32. (a) When the apparatus is immersed in water, the wavelength of light decreases to λ/μ.

$$\beta_{water} = \frac{D\lambda}{\mu d}$$

(b) The different colours of white light will produce different interference patterns but the central bright fringes due to all colours are at the same position. Therefore, the central bright fringe is white in colour. Since the wave length of the blue light is smallest, the fringe closest on the either side of the central white fringe is blue and the farthest is red. Beyond a few fringes, no clear fringe pattern is visible.

S33.



S34. Let D_1 be the distance between the screen and the sources, when light of wavelength 400 nm is used.

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

$$\therefore \quad \frac{D_1 \times 400 \times 10^{-9}}{d} = X \qquad \text{... (i)}$$

Let D_2 be the distance between the screen and sources to obtain the same fringe width, when light of wavelength 600 nm is used. Then,

$$\frac{D_2 \times 600 \times 10^{-9}}{d} = X \qquad \text{... (ii)}$$

From the Eqns (i) and (ii), we gate

$$\frac{D_1}{D_2} = \frac{600 \times 10^{-9}}{400 \times 10^{-9}} = \mathbf{1.5}.$$

S35. Distance between the slits, $d = 0.28\text{ mm} = 0.28 \times 10^{-3}\text{ m}$

Distance between the slits and the screen, $D = 1.4$ m

Distance between the central fringe and the fourth ($n = 4$) fringe,

$$u = 1.2\text{ cm} = 1.2 \times 10^{-2}\text{ m}$$

In case of a constructive interference, we have the relation for the distance between the two fringes as:

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

Where, n = Order of fringes = 4

λ = Wavelength of light used

$$\therefore \qquad \lambda = \frac{uD}{nD}$$

$$= \frac{1.2 \times 10^{-2} \times 0.28 \times 10^{-3}}{4 \times 1.4}$$

$$= 6 \times 10^{-7} = 600\text{ nm}$$

Hence, the wavelength of the light is 600 nm.

S36. Let I_1 and I_2 be the intensity of the two light waves. Their resultant intensities can be obtained as:

$$I' = I_1 + I_2 + 2\sqrt{I_1 I_2}\, \cos\phi$$

Where, ϕ = Phase difference between the two waves

For monochromatic light waves,

$$I_1 = I_2$$

$$\therefore \qquad I' = I_1 + I_1 + 2\sqrt{I_1 I_1}\, \cos\phi$$

$$= 2I_1 + 2I_1 \cos\phi$$

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

Since path difference = λ,

Phase difference, $\phi = 2\pi$

$\therefore$ $I' = 2I_1 + 2I_1 = 4I_1$

Given, $I' = K$

$\therefore$ $I_1 = \frac{K}{4}$ … (i)

When path difference, $= \frac{\lambda}{3}$

Phase difference, $\phi = \frac{2\pi}{3}$

Hence, resultant intensity, $I'_R = I_1 + I_1 + 2\sqrt{I_1 I_1}\cos\frac{2\pi}{3}$

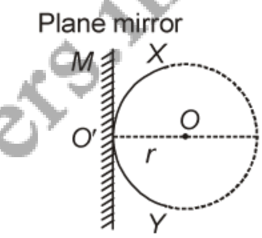
$$= 2I_1 + 2I_1\left(-\frac{1}{2}\right) = I_1$$

Using Eq. (i), we can write:

$$I_R = I_1 = \frac{K}{4}$$

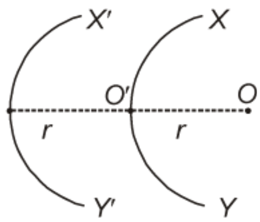
Hence, the intensity of light at a point where the path difference is $\frac{\lambda}{3}$ is $\frac{K}{4}$ units.

S37. Let an object at O be placed in front of a plane mirror MO' at a distance r (as shown in the given figure).



A circle is drawn from the centre (O) such that it just touches the plane mirror at point O'. According to Huygens' Principle, XY is the wavefront of incident light.

If the mirror is absent, then a similar wavefront $X'Y'$ (as XY) would form behind O' at distance r (as shown in the given figure).



$X'Y'$ can be considered as a virtual reflected ray for the plane mirror. Hence, a point object placed in front of the plane mirror produces a virtual image whose distance from the mirror is equal to the object distance (r).

S38. No, Wave theory. Newton's corpuscular theory of light states that when light corpuscles strike the interface of two media from a rarer (air) to a denser (water) medium, the particles experience forces of attraction normal to the surface. Hence, the normal component of velocity increases while the component along the surface remains unchanged.

Hence, we can write the expression:

$$c \sin i = v \sin r$$ … (i)

Where, i = Angle of incidence

r = Angle of reflection

c = Velocity of light in air

v = Velocity of light in water

We have the relation for relative refractive index of water with respect to air as:

$$\mu = \frac{v}{c}$$

Hence, Eq. (i) reduces to

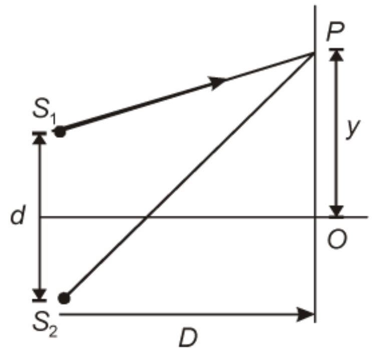
$$\frac{v}{c} = \frac{\sin i}{\sin r} = \mu \qquad \text{... (ii)}$$

But, $\mu > 1$.

Hence, it can be inferred from equation (ii) that $v > c$. This is not possible since this prediction is opposite to the experimental results of $c > v$.

The wave picture of light is consistent with the experimental results.

S39.



A monochromatic source of light is used to obtain coherent sources of light.

Waves from monochromatic sources S_1 and S_2 superpose at different points on the screen and produce maxima and minima (interference pattern) depending on phase with which they meet at the particular point. These equally spaced dark and bright bands appearing on the screen are called fringes.

Distance between two consecutive bright of dark bands is called fringe width.

Position of a bright band on the screen is

$$y_n^{\max} = \frac{n\lambda D}{d}; \qquad n = 0, \pm 1, \pm 2, \ldots$$

and dark band is

$$y_n^{\min} = \left(n + \frac{1}{2}\right)\frac{\lambda D}{d}; \quad n = 0, \pm 1, \pm 2, \ldots$$

according to definition fringe width (β)

$$P = y_{n+1} - y_n$$

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

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

S40. Given: $y = \frac{\lambda D}{3d}$

As $\Delta p = \frac{yd}{D}$

$$\Delta p = \frac{\lambda}{3}$$

or $\Delta \phi = \frac{2\pi}{3}$

we know $I = I_0 \cos^2 \Delta\phi$

$$I = I_0\left(\cos\frac{2\pi}{3}\right)^2 = \frac{I_0}{4}.$$

S41. Position of the n^{th} bright fringe is given by $\frac{n\lambda D}{d}$ from the central bright. So the separation between two consecutive bright fringes is $\frac{\lambda D}{d}$.

With $\lambda_1 = 630\,\text{nm}$,

we have $\frac{\lambda_1 D}{d} = 8.1\,\text{mm}$ ... (i)

With λ_2, $\frac{\lambda_2 D}{d} = 7.2\,\text{mm}$ ... (ii)

From Eq. (i) ÷ (ii), we get, $\frac{\lambda_1}{\lambda_2} = \frac{8.1}{7.2}$

$\Rightarrow$ $\lambda_2 = \frac{7.2}{8.1} \times \lambda_1 = \frac{8}{9} \times 630$ = **560 nm**.

When the monochromatic light is replaced by a white light,

(a) the central bright remains white and

(b) all the other colours will form individual maximas with the least wavelength violet forming its bright close to the central bright.

S42. Given: $d = 0.15\,\text{mm} = 0.15 \times 10^{-3}\,\text{m}$, $\lambda = 450 \times 10^{-9}\,\text{m}$ and $D = 1.0\,\text{m}$

(a) (i) Distance of the second bright fringe,

$$y_2^{\max} = \frac{2\lambda D}{d}$$

$$\therefore \qquad y_2^{max} = \frac{2 \times 450 \times 10^{-9} \times 1.0}{0.15 \times 10^{-3}} = 6 \text{ mm}$$

(ii) Distance of the second dark fringe

$$y_2^{min} = \frac{3\lambda D}{d} = \frac{3 \times 450 \times 10^{-9} \times 1.0}{2 \times 0.15 \times 10^{-3}} = 4.5 \text{ mm}$$

(b) Linear width of a fringe, $\beta = \frac{\lambda D}{d}$

Angular width of a fringe, $\Delta\theta = \frac{\lambda}{d}$

So, with increase in the value of D linear width will increase, while the angular width will remain the same.

S43. The phenomenon of non-uniform distribution of energy in a medium due to superposition of two light waves is called interference of light.

$$d = 10^{-3} \text{ m}$$

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

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

$$\omega = \frac{\lambda D}{d} \qquad \omega' = \frac{\lambda D'}{d}$$

$$\omega - \omega' = \frac{\lambda}{d}(D - D')$$

$$\lambda = \frac{(\omega - \omega')d}{D - D'} = \frac{3 \times 10^{-5} \times 10^{-3}}{5 \times 10^{-2}}$$

$$= 6 \times 10^{-7} \text{ m}$$

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

S44. (a) The size reduces by half according to the relation λ/d. Intensity increases four fold.

(b) As width of central maximum, $\beta = \frac{2\lambda D}{d}$.

On increasing λ, width also increases. Intensity remains same.

(c) As $\beta \propto D$.

On reducing the distance D, Width decreases. Intensity increases.

S45. Total path difference between the rays reacting the point 'P' from main source 'S' is.

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

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

$$(S_2P - S_1P) = \Delta P - \lambda/4 \qquad (\because \; SS_2 - SS_1 = \lambda/4)$$

(a) For constructive interference $\Delta P = n\lambda$

$$S_2P - S_1P = n\lambda - \lambda/4$$

(b) For destructive interference $\Delta P = \frac{(2n-1)\lambda}{2}$

$$S_2P - S_1P = (2n-1)\frac{\lambda}{2} - \frac{\lambda}{4}$$

S46. Conditions for obtaining sustained interference pattern.

(a) Waves producing interference must have same frequency.

(b) There should be a constant phase difference between the waves producing interference.

Given: for an interference pattern $\frac{I_{max}}{I_{min}} = \frac{25}{9}$

To find: $\frac{I_1}{I_2} = ?$

Here $$\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} \quad \text{and} \quad \frac{I_{max}}{I_{min}} = \frac{\left(\frac{a_1}{a_2}+1\right)^2}{\left(\frac{a_1}{a_2}-1\right)^2}$$

So $$\frac{\left(\frac{a_1}{a_2}+1\right)^2}{\left(\frac{a_1}{a_2}-1\right)^2} = \frac{25}{9}; \quad \frac{\frac{a_1}{a_2}+1}{\frac{a_1}{a_2}-1} = \frac{5}{3}$$

$\Rightarrow$ $$3\left(\frac{a_1}{a_2}+1\right) = 5\left(\frac{a_1}{a_2}-1\right)$$

$\Rightarrow$ $$\frac{a_1}{a_2} = 4$$

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

S47. Coherent sources of light

(a) emit light waves continuously.

(b) emit waves having either a zero phase difference or a constant phase difference.

(c) emit preferably waves of same wavelength or same frequency.

In Young's double slit experiment.

Given: $d = 3\text{ mm} = 3 \times 10^{-3}\text{ m}$,

$$\lambda = 480\text{ nm} = 480 \times 10^{-9}\text{ m}, \quad D = 2\text{ m}$$

To calculate: Separation between 8th bright fringe and 3rd dark fringe from the central bright fringe.

Formula: $$\beta = \frac{\lambda D}{d} = \frac{480 \times 10^{-9} \times 2}{3 \times 10^{-3}} = 32 \times 10^{-5}\text{ m}$$

We know for bright fringes

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

For dark fringes $$x = (2n-1)\frac{\lambda}{2}\frac{D}{d}$$

Thus, separation between 8th bright and 3rd dark fringe is

$$= \left(8 - \frac{5}{2}\right) \times 32 \times 10^{-5}\text{ m}$$

$$= +\frac{11}{2} \times 32 \times 10^{-5} = 1.76 \times 10^{-3}\text{ m.}$$

S48. **Coherent Sources:** Sources are said to be coherent if:

(a) They emit light waves continuously.

(b) Waves from the sources are either having a zero phase difference or a constant phase difference.

(c) Waves are of same wavelength or same frequency. Consider two coherent sources of light emitting waves.

$$Y_1 = a \sin \omega t \qquad \text{... (i)}$$

$$Y_2 = b \sin (\omega t - \varphi) \qquad \text{... (ii)}$$

Where a and b are amplitudes and φ is the constant phase difference. According to superposition principle resultant wave is

$$Y = Y_1 + Y_2 = a \sin \omega t + b \sin (\omega t - \varphi)$$

On solving, we get

$$Y = \sin \omega t\,(a + b \cos \varphi) + \cos \omega t \,.\, b \sin \varphi$$

Put $$a + b \cos \varphi = R \cos \theta \qquad \text{... (iii)}$$

$$b \sin \varphi = R \sin \theta \qquad \text{... (iv)}$$

We get $$Y = R \sin (\omega t + \theta)$$

This is the resultant wave. It is a harmonic wave of amplitude R.

Squaring and adding equations (iii) and (iv)

$$R = \sqrt{a^2 + b^2 + 2ab\cos\varphi}$$

As intensity is directly proportional to the square of the amplitude.

$$I \propto R^2$$

$$I \propto (a^2 + b^2 + 2ab\cos\varphi)$$

In case $\quad a = b$

$$I \propto \cos^2 \varphi/2$$

Phase difference between the two interfering waves at a point at any time is

$$\varphi = \varphi_1 + \varphi_2$$

φ_1 = initial phase difference

φ_2 = phase difference due to path difference

S49. Order of size of obstacle/aperture should be comparable to the wavelength of light.

$$\lambda = 600 \times 10^{-9}\,\text{m}$$

$$a = 0.5 \times 10^{-3}\,\text{m}, \quad D = 2\,\text{m}$$

(a) Angular width = $\dfrac{\lambda}{a} = 1.2 \times 10^{-3}$ rad.

(b) Linear width of 1st order maximum = Position of 2nd minimum – Position of 1st minimum.
Linear width of 1st maximum $\Delta Y = Y_2 - Y_1$

$$\Delta Y = \frac{2\lambda D}{a} - \frac{\lambda D}{a} = \frac{\lambda D}{a} = 2.4 \times 10^{-3}\,\text{m}$$

S50.

Given $\quad \left(\dfrac{\mu'}{\mu} - 1\right) \times 100 = 2\%$

So $\quad \dfrac{\mu'}{\mu} = \dfrac{102}{100}$

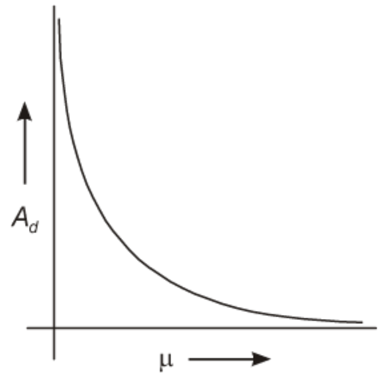
We know $\mu = \dfrac{R_d}{A_d}$

So $\quad \dfrac{\mu'}{\mu} = \dfrac{A_d}{A'_d}$

% change in apparent depth is

$$\left(1-\frac{A_d}{A_d'}\right) \times 100 = \left(1-\frac{102}{100}\right) \times 100 = 1.96\%$$

Variation in apparent depth with refractive index



S51. Given: $\lambda_1 = 650$ nm; $\lambda_2 = 520$ nm' $D = 120$ cm; $d = 2$ mm

(a) Position of third bright fringe, $x_3 = \dfrac{3\lambda D}{d}$

$$x_3 = \frac{3 \times (6500 \times 10^{-9}) \times 1.2}{2 \times 10^{-3}}$$

$$x_3 = 1.17 \times 10^{-3}\,\text{m}$$

(b) Let N be at least number of fringes for λ_1 which coincide with $N + 1$ fringes for λ_2.

$$x = N\beta = (N + 1)\,\beta'$$

$$\frac{\beta}{\beta'} = \frac{N+1}{N} \qquad \left(\because \quad \beta = \frac{\lambda D}{d}\right)$$

$$\frac{\lambda_1}{\lambda_2} = \frac{N+1}{N}$$

$$N = \frac{\lambda_1}{\lambda_1 - \lambda_2} = \frac{5200}{6500 - 5200} = 4$$

$$x = n\beta = 4\,\frac{\lambda_1 D}{d}$$

S52. We have

$$\frac{w_1}{w_2} = \frac{9}{1}$$

$$\frac{w_1}{w_2} = \frac{I_1}{I_2} = \frac{a_1^2}{a_2^2}$$

$$r = \sqrt{\frac{w_1}{w_2}} = \frac{3}{1}$$

$$I_{max} = k(a_1 + a_2)^2$$

$$I_{min} = k(a_1 - a_2)^2$$

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

$$= \frac{2(a_1^2 - a_2^2)}{4(a_1 a_2)} = \frac{\left(\frac{a_1^2}{a_2^2} + 1\right)}{2\left(\frac{a_1}{a_2}\right)}$$

$$= \frac{r^2 + 1}{2r} = \frac{5}{3}$$

Date: 21/10/2021

Q1. Sketch the wavefronts corresponding to converging rays.

Q2. Name the shape of a wavefront originating from (a) a point source (b) a line source.

Q3. Differentiate between a ray and a wavefront?

O4. What is a wavefront?

Q5. 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?

Q6. 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.

Q7. 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?

Q8. In what way is diffraction from each slit related to the interference pattern in a double-slit experiment?

Q9. What is the Brewster angle for air to glass transition? (Refractive index of glass = 1.5.)

Q10. What is the geometrical shape of the wavefront of the light diverging from a point source? Sketch the wavefronts corresponding to diverging rays.

Q11. Given one basic difference between diffraction and interference of light.

Q12. How does resolving power of a telescope change on decreasing the aperture of its object lens? Justify your answer.

Q13. Define resolving power of a telescope.

Q14. For a given single slit, the diffraction pattern is obtained on a fixed screen, first by using red light and then with blue light. In which case, will the central maxima, in the observed diffraction pattern, have a larger angular width?

Q15. State the condition for diffraction of light to occur.

Q16. What is diffraction of light?

Q17. Will ultrasonic waves show any polarisation? Give reasons for your answer.

Q18. What evidence is there that sound is not electromagnetic in nature?

Q19. How is a wavefront to the direction of corresponding rays?

Q20. The 6563 Å H_a 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.

Q21. A slit of width a is illuminated by monochromatic light at normal incidence. Draw the intensity distribution curve observed on the screen due to diffraction.

Q22. Why is diffraction of sound waves easier to observe than diffraction of light waves?

Q23. In Example 10.3, what should the width of each slit be to obtain 10 maxima of the double slit pattern within the central maximum of the single slit pattern?

Q24. 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.

Q25. 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?

Q26. 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.

Q27. In the diffraction of a single slit experiment, the width of the slit is made double the original width. How does this affect the size and intensity of central diffraction band?

Q28. In the diffraction of a single slit experiment, how would the width of and the intensity of central maximum change, if

(a) slit width is halved and

(b) visible light of longer wavelength is used?

Q29. Two convex lenses of same focal length but of aperture D_1 and D_2 ($D_2 < D_1$), are used as the objective lenses in two astronomical telescopes having identical eyepieces. What is the ratio of their resolving powers?

Q30. How does the resolving power of a compound microscope change on

(a) decreasing the wavelength of light used, and

(b) decreasing the diameter of its object lens?

Q31. What is the basic difference between a source of light and source of radiowaves?

Q32. How will the resolving power of a compound microscope be affected, when (a) the frequency of light used to illuminate the object is increased, and (b) the focal length of the objective is increased. Justify your answer in each case.

Q33. Give two differences between fringes formed in single slit diffraction and Young's double slit experiment.

Q34. Define Resolving power of a telescope. How does diffraction limit its resolving power?

Q35. Define (a) resolving power and (b) magnifying power of a telescope.

Q36. 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?

Q37. 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.

Q38. A parallel beam of monochromatic of wavelength 500 nm falls normally on a narrow slit and the resulting diffraction pattern is obtained 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

(a) the width of the slit

(b) the distance of the second maximum from the centre of the screen.

(c) the width of the central maximum.

Q39. In a single slit diffraction pattern, how is the width of central bright maximum changed, when

(a) the slit width is decreased,

(b) the distance between the slit and the screen is increased and

(c) light of smaller wavelength is used. Justify your answer.

Q40. (a) Why do we not encounter diffraction effects of light in everyday observations?

(b) In the observed diffraction pattern due to a single slit, how will the width of central maximum be affected if

(i) the width of the slit is doubled;

(ii) the wavelength of the light used is increased?

Justify your answer in each case.

Q41. Two wavelengths of sodium light 590 nm, 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 maximum of the diffraction pattern obtained in the two case.

Q42. (a) A plane wavefront 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 wavefront is constructed.

(b) Hence verify Snell's law.

(c) When a light wave travels from a rarer to a denser medium, the speed decreases. Does it imply reduction in its energy? Explain.

Q43. 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:

(a) the width of the slit is decreased?

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

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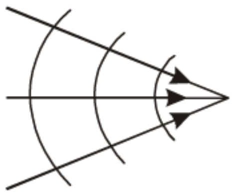
S1.



S2. (a) Spherical wave front (b) Cylindrical wavefront.

S3. **A ray:** An arrow drawn normal to the wavefront and pointing in the direction of propagation of the disturbance is called a ray of light.

A wavefront: A source of light sends out disturbance in all directions in a homogeneous medium, the disturbance reaches all those particles of the medium in phase, which are located at the same distance from the source of light.

S4. A source of light sends out disturbance in all directions in a homogeneous medium, the disturbance reaches all those particles of the medium in phase, which are located at the same distance from the source of light.

The locus of all the particles of the medium, which at any instant are vibrating in the same phase, is called the wavefront.

S5. The justification is that in ordinary optical instruments, the size of the aperture involved is much larger than the wavelength of the light used.

S6. On the one hand, the wavelength of the light waves is too small in comparison to the size of the obstacle. Thus, the diffraction angle will be very small. Hence, the students are unable to see each other. On the other hand, the size of the wall is comparable to the wavelength of the sound waves. Thus, the bending of the waves takes place at a large angle. Hence, the students are able to hear each other.

S7. 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. This is because light waves are diffracted from the edge of the circular obstacle, which interferes constructively at the centre of the shadow. This constructive interference produces a bright spot.

Bending of waves by obstacles by a large angle is possible when the size of the obstacle is comparable to the wavelength of the waves.

S8. The interference pattern in a double-slit experiment is modulated by diffraction from each slit. The pattern is the result of the interference of the diffracted wave from each slit.

S9. Refractive index of glass, $\mu = 1.5$

Brewster angle = θ

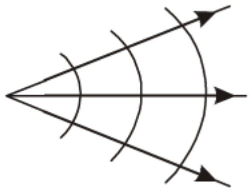
Brewster angle is related to refractive index as:

$$\tan\theta = \mu$$

$$\theta = \tan^{-1}(1.5) = 56.31°$$

Therefore, the Brewster angle for air to glass transition is 56.31°.

S10.



S11. Interference is the result of interaction of light coming from two different wavefronts originating from two coherent sources, whereas diffraction pattern is the result of interaction of light coming from different parts of the same wavefront.

S12. Resolving power of a telescope = $\dfrac{D}{1.22\,\lambda}$

Therefore, on decreasing aperture (D) of the objective lens, the resolving power of the telescope decreases.

S13. It is defined as the reciprocal of the smallest angular separation between two distant objects, so that they appear just separated, when seen through the telescope.

S14. The angular width of the central maxima,

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

i.e., $\beta_0 \propto \lambda$

Since $\lambda_r > \lambda_b$, the central maximum will have larger angular width for red light.

S15. The size of the obstacle should be of the order of the wavelength used.

S16. The phenomenon of bending of light round the sharp corners and its spreading into the regions of the geometrical shadow is called diffraction.

S17. No it is because, ultrasonic waves are longitudinal in nature.

S18. Because, sound waves can not be polarised.

S19. The wavefront is perpendicular to the direction of rays.

S20. Wavelength of H_a line emitted by hydrogen,

$$\lambda = 6563\ \text{Å}$$

$$= 6563 \times 10^{-10}\ \text{m}.$$

Star's red-shift, $(\lambda' - \lambda) = 15\,\text{Å} = 15 \times 10^{-10}\,\text{m}$

Speed of light, $c = 3 \times 10^{8}\,\text{m/s}$

Let the velocity of the star receding away from the Earth be v.

The red shift is related with velocity as:

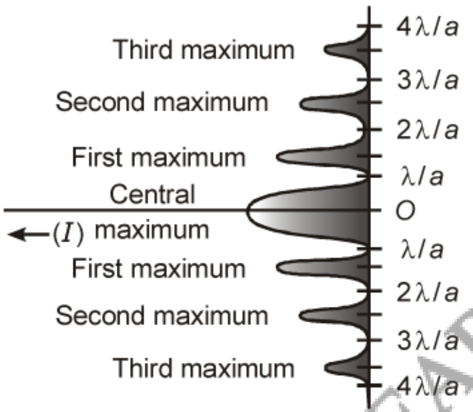
$$\lambda' - \lambda = \frac{v}{c}\lambda$$

$$v = \frac{c}{\lambda} \times (\lambda' - \lambda)$$

$$= \frac{3 \times 10^{8} \times 15 \times 10^{-10}}{6563 \times 10^{-10}} = 6.87 \times 10^{5}\,\text{m/s}$$

Therefore, the speed with which the star is receding away from the Earth is 6.87×10^{5} m/s.

S21.



S22. For diffraction to take place, the size of the obstacle/aperture should be of the order of the wavelength of the waves. Since the wavelength of light ($\approx 10^{-6}$ m) is very small as compared to the size of the obstacle/aperture around us, light cannot be diffracted readily. On the other hand, as wavelength of sound is of the order of such objects, it gets diffracted easily.

S23. We want $a\theta = \lambda, \quad \theta = \dfrac{\lambda}{a}$

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

Notice that the wavelength of light and distance of the screen do not enter in the calculation of a.

S24. Consider that a single slit of width d is divided into n smaller slits.

$\therefore$ Width of each slit, $f' = \dfrac{d}{n}$

Angle of diffraction is given by the relation,

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

Now, each of these infinitesimally small slit sends zero intensity in direction θ. Hence, the combination of these slits will give zero intensity.

S25. (a) In each diffraction order, the diffracted image of the slit gets dispersed into component colours of white light..

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

S26. The bright spot seen at the centre of the shadow of the obstacle is due to constructive interference of light waves diffracted from the edge of the circular obstacle.

S27. It follows that the size (width) of central maximum band will become ***one half***.

It follows that the intensity of central maximum band will become ***four times***.

S28. (a) The intensity of central maximum will become one fourth.

(b) The intensity of central maximum will decrease.

S29. The resolving power of a telescope ,

$$\text{R.P.} = \frac{D}{1.22\,\lambda}$$

$$\therefore \qquad \frac{(\text{R.P.})_1}{(\text{R.P.})_2} = \frac{D_1}{1.22\,\lambda} \times \frac{1.22\,\lambda}{D_2} = \boldsymbol{\frac{D_1}{D_2}}$$

The telescope having objective lens of aperture D_1 will be preferred. It is because, such a telescope will have greater resolving power and greater light gathering power.

S30. Resolving power of a microscope

$$= \frac{2\mu \sin\theta}{\lambda}.$$

(a) On decreasing wavelength of light, resolving power will increase.

(b) On decreasing diameter of objective lens, semi-vertical angle θ will decrease and hence resolving power will decrease.

S31. In a source of visible light, the atoms act as oscillators producing oscillations independent of each other. Due to this, oscillations produced are randomly oriented (unpolarised) .

In a radio wave source, the charges oscillate in a plane perpendicular to the direction of propagation of radio waves (polarised).

S32. Resolving power of a microscope

$$= \frac{2\mu \sin\theta}{\lambda} = \frac{2\nu\mu \sin\theta}{c} \qquad (\because\ c = \nu\lambda)$$

(a) When the frequency of light is increased, resolving power will increase.

(b) When the focal length of objective is increased, distance between object and objective will increase. It will lead to a decrease in the value of angle θ and hence resolving power will decrease.

S33. (a) In Young's experiment, all the bright fringes formed are of the same intensity, whereas in single slit diffraction experiment, the bright fringes are of varying intensity.

(b) In Young's experiment, fringes of minimum intensity are perfectly dark, whereas in slit diffraction experiment, fringes of minimum intensity are not perfectly dark.

S34. **Resolving power:** Resolving power of a telescope is defined as the reciprocal of the smallest angular separation between two distant objects, so that they appear just separated, when seen through the telescope.

The smallest separation (linear or angular) between the two point objects at which they appear just separated is called the ***limit of resolution*** of an optical instrument and the reciprocal of the limit of resolution is called its ***resolving power***.

S35. (a) **Resolving power:** Resolving power of a telescope is defined as the reciprocal of the smallest angular separation between two distant objects, so that they appear just separated, when seen through the telescope.

(b) **Magnifying power:** Magnifying power of a telescope is defined as the ratio of the angle subtended at the eye by the image formed at the least distance of distinct vision to the angle subtended at the eye by the object lying at infinity, when seen directly.

S36. Distance between the towers, $d = 40$ km

Height of the line joining the hills, $d = 50$ m.

Thus, the radial spread of the radio waves should not exceed 50 km.

Since the hill is located halfway between the towers, Fresnel's distance can be obtained as:

$$Z_P = 20 \text{ km} = 2 \times 10^4 \text{ m}$$

Aperture can be taken as: $a = d = 50$ m

Fresnel's distance is given by the relation,

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

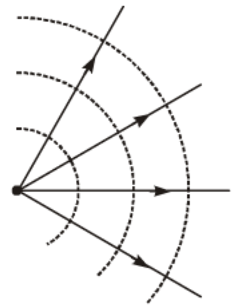
Where, λ = Wavelength of radio waves

$$\therefore \quad \lambda = \frac{a^2}{Z_p}$$

$$= \frac{(50)^2}{2 \times 10^4} = 1250 \times 10^{-4} = 0.1250 \text{ m} = 12.5 \text{ cm}$$

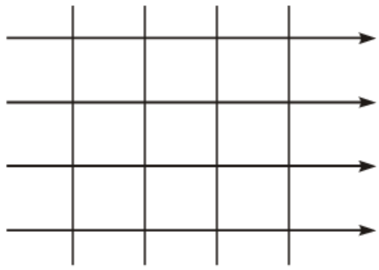
Therefore, the wavelength of the radio waves is 12.5 cm.

S37. (a) The shape of the wavefront in case of a light diverging from a point source is spherical. The wavefront emanating from a point source is shown in the given figure.



Point source

(b) The shape of the wavefront in case of a light emerging out of a convex lens when a point source is placed at its focus is a parallel grid. This is shown in the given figure.



Wavefront

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

S38. Given: $\lambda = 500\,\text{nm} = 500 \times 10^{-9}\,\text{m}$; $D = 1\,\text{m}$; $y_1^{\min} = 2.5 \times 10^{-3}\,\text{m}$

(a) We have that

$$y_1^{\min} = \frac{\lambda D}{d} \qquad (\because\ n = 1)$$

Width of the slit, $$d = \frac{\lambda D}{y_1^{\min}}$$

$$= \frac{500 \times 10^{-9} \times 1}{2.5 \times 10^{-3}}$$

$$d = 0.2\,\text{mm}.$$

(b) Distance of the second maximum from the centre of the screen

$$y_2^{\max} = (2 \times 2 + 1)\frac{\lambda D}{2d}$$

$$y_2^{\max} = \frac{5\lambda D}{2d} = \frac{5 \times 500 \times 10^{-9} \times 1}{1 \times 0.2 \times 10^{-3}}$$

$$y_2^{\max} = 0.625\,\text{mm}.$$

(c) Width of the central maximum

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

$$W = 2 \times y_1^{\text{min}} = 2 \times 2.5 \times 10^{-3}\,\text{m} \qquad \left(\because \quad \frac{\lambda D}{d} = 2.5 \times 10^{-3}\,\text{m}\right)$$

$$\therefore \qquad W = 5.0\,\text{mm}.$$

S39. The width of central maximum is given by

$$\beta_0 = \frac{2D\lambda}{a} \qquad \text{... (i)}$$

where the letters have their usual meanings.

(a) **Effect of slit width:** From the equation (i), it follows that $\beta_0 \propto \frac{1}{a}$. Therefore, as the slit width is decreased, the width of the central maximum will ***increase***.

(b) **Effect of distance between slit and screen:** From the equation (i), it follows that $\beta_0 \propto D$. Therefore, as the distance between slit and the screen is increased, the width of the central maximum will also ***increase***.

(c) **Effect of wavelength of light:** From the equation (i), it follows that $\beta_0 \propto \lambda$. Therefore, as the light of smaller wavelength is used, the width of the central maximum will ***decrease***.

S40. (a) For diffraction effects to be observed, the width of the slits should be of the order of wavelength.

(b) Width of central maxima $\beta = \frac{2\lambda D}{d}$.

(i) On doubling the slit width (d), the width of central maxima will become half as $\beta \propto \frac{1}{d}$.

(ii) On increasing the wavelength, the width increases as $\beta \propto \lambda$.

S41. Given: $\alpha = 2 \times 10^{-6}$ m; $\lambda = 590 \times 10^{-9}$ m; $\lambda' = 596 \times 10^{-9}$ m; $D = 1.5$ m

Formula: $$Y_{\text{maxi}} = \frac{3\lambda D}{a}; \qquad Y'_{\text{maxi}} = \frac{3\lambda' D}{a}$$

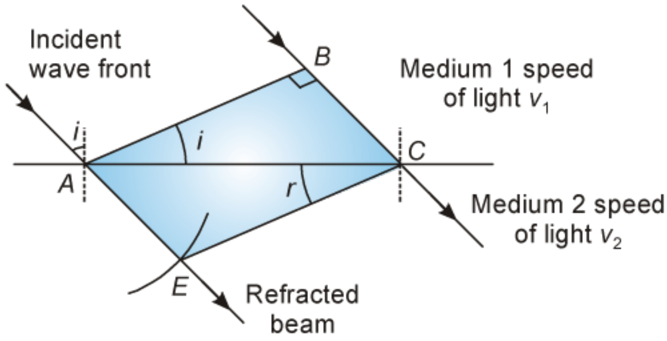
$$\Delta Y = Y'_{\text{maxi}} - Y_{\text{maxi}} = \frac{3D}{a}(\lambda' - \lambda)$$

Calculation: $$\Delta Y = 3 \times 1.5 \times (596 - 590) \times 10^{-9}$$

$$\Delta Y = 13.5 \times 10^{-3}\,\text{m}.$$

S42. (a) As soon as incident wavefront strikes the surface at 'A' a wavefront is generated (Huygen's principle). It begins to travel into the second medium. Refracted wavefront acquires radius. $AE = v_2 t$.

To determine the shape of the refracted wavefront, we draw a sphere of radius $v_2 t$ from the point A in the second medium.



Tangential plane drawn from point C on the sphere gives refracted wavefront.

Here 't' is the time taken by the wave from point 'B' on the incident wavefront to reach the point 'C' on the interface. Distance travelled by the wave is

$$BC = v_1 t$$

(b) From ΔABC $\quad \sin i = \dfrac{BC}{AC}$ ... (i)

From ΔAEC $\quad \sin r = \dfrac{AE}{AC}$ ... (ii)

From equations (i) and (ii), we obtain

$$\frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{v_1}{v_2} \quad \text{... (iii)}$$

We know $\quad n_1 = \dfrac{c}{v_1}$

and $\quad n_2 = \dfrac{c}{v_2}$

Substituting in equation (iii), we get

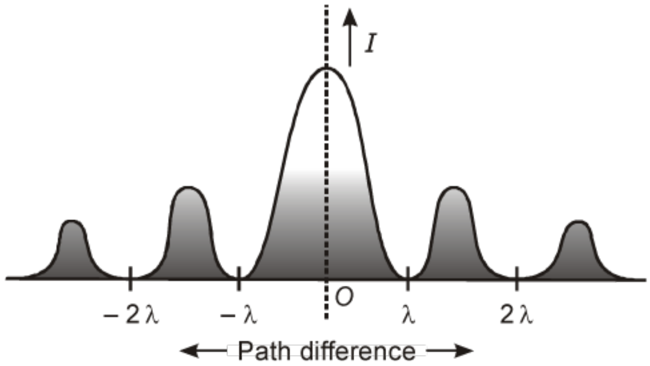
$$n_1 \sin i = n_2 \sin r$$

This is Snell's law of refraction.

(c) No, Energy carried by a wave depends on the amplitude of the wave only.

S43. Diffraction of light: Phenomenon of bending of light round the corners of an obstacles or aperture is called diffraction of light.

Graph showing th variation of intensity with angle in single alit diffraction experiment is



In diffraction pattern, the brightness of successive bright fringes from the centre goes on decreasing whereas in interference pattern all bright fringes are equally bright and have the same width.

$$\text{width of central maxima} = \frac{2\lambda D}{d}$$

(a) When the width of slit (d) is decreased, angular width increases.

(b) When the monochromatic source of light is replaced by source of white light, the diffraction pattern is coloured. The central maxima is bright but other bands are coloured.

Since band width $\propto \lambda$ and $\lambda_{red} > \lambda_{violet}$

So, $\beta_{red} > \beta_{violet}$.

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Q1. Describe a method for producing beam of plane polarized light.

Q2. What do you understand by polarization of light?

Q3. Why can light waves be polarized but sound waves cannot?

Q4. 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?

Q5. When a low flying aircraft passes overhead, we sometimes notice a slight shaking of the picture on our TV screen. Suggest a possible explanation.

Q6. Which plane is defined as the plane of polarisation in a plane polarised electromagnetic wave?

Q7. How does an unpolarised light get polarised, when it is passed through a polaroid?

Q8. The refractive index of a medium is $\sqrt{3}$. What is the angle of refraction, if the unpolarized light is incident on it at the polarizing angle of the medium?

Q9. What is the value of refractive index of a medium of polarizing angle 60°?

Q10. What is the polarization angle of a medium in which the angle of refraction is 33°?

Q11. What is the polarizing angle of a medium of refractive index 1.732?

Q12. Which out of the following can be polarized : X-rays, sound waves and radio waves?

Q13. What type of waves show the property of polarization?

Q14. At what angle of incidence should a light beam strike a glass slab of refractive index $\sqrt{3}$, such that reflected an refracted rays are perpendicular to each other.

Q15. Uppolarised light is incident on a plane surface of glass of refractive index μ at an angle of incidence *i*. If the reflected light gets completely polarised, write the relation between the angle *i* and refractive index μ.

Q16. A beam of unpolarised light is incident on the boundary between two transparent media. If the reflected light is completely plane polarised, how is its direction related to the direction of the corresponding refracted light?

Q17. When unpolarized light passes from air to transparent medium, under what condition does the reflected light get polarized?

Q18. For sound waves, the Doppler formula for frequency shift differs slightly between the two situations: (i) 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?

Q19. An unpolarised beam of light of intensity I_0 is incident on a combination of two polaroids. Find the net intensity of light of intensity transmitted by the combination, When the pass axis of the two polaroids are inclined to each other at an angle of 60°.

Q20. If the angle between the pass axis of a polariser and the analyser is 45°, write the ratio of the intensities of original light and the transmitted light after passing through the analyser.

Q21. 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.

Q22. What is the elliptically polarised light?

Q23. How can one distinguish between an unpolarised light beam and a linearly polarised beam using a polaroid?

Q24. What is an unpolarized light? Explain with the help of suitable ray diagram how an unpolarized light can be polarized by reflection from a transparent medium. Write the expression for Brewster angle in terms of the refractive index of denser medium.

Q25. 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.

Q26. Explain the following giving reason for each:

(a) How does a polaroid work to produce a linearly polarised light from an unpolarised beam of light?

(b) Why is it that light waves can be polarised, but sound waves cannot be?

(c) Why are sun goggles made of polaroids preferred over those using coloured glasses?

Q27. The sun subtends an angle $\alpha = 0.5°$ at the pole of a concave mirror. The radius of curvature of the concave mirror is $R = 1.5$ m. Calculate the size of the image.

Q28. 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 them? Take intensity of unpolarised light as I_0.

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S1. By passing unpolarized light through nicol prism or calcite prism.

S2. The phenomenon of restricting the vibration of light (electric vector) in a particular direction, perpendicular to the direction of wave motion is called polarization of light.

S3. It is so because light waves are transverse and sound waves are longitudinal.

S4. For $i + r$ to be equal to $\pi/2$, we should have $\tan i_B = \mu = 1.5$. This gives $i_B = 57°$. This is the Brewster's angle for air to glass interface.

S5. Weak radar signals sent by a low flying aircraft can interfere with the TV signals received by the antenna. As a result, the TV signals may get distorted. Hence, when a low flying aircraft passes overhead, we sometimes notice a slight shaking of the picture on our TV screen.

S6. The plane perpendicular to the plane of vibrations in a plane polarised light is called plane of polarisation.

S7. When unpolarised light is passed through a polaroid, only those electric field vectors, which are parallel to the crystallographic axis of the polaroid, emerge out of it. As such, the emerging light possesses vibrations in one plane only and is said to be plane polarised.

S8. According to Brewster's law,

$$\tan i_p = \mu_m = \sqrt{3}$$

$$\Rightarrow \quad i_p = \tan^{-1} \sqrt{3} = 60°$$

$$\therefore \quad r = 30°.$$

S9. $\tan i_p = \mu$

$$\therefore \quad \mu = \tan 60° = \sqrt{3}$$

S10. In case of angle of incidence being equal to polarizing angle,

$$\angle r = 90° - \angle r_p$$

$$\therefore \quad \angle i_p = 90° - \angle r = 90° - 33° = 57°$$

S11. If i_p is the polarizing angle, then

$$\tan i_p = \mu = 1.732 = \sqrt{3} \text{ given.}$$

$$\therefore \quad i_p = 60°$$

S12. X-rays and radio waves can be polarized.

S13. Polaroid is a trade name for a thin transparent film containing ultramicroscopic polarizing crystals of quinine iodosulphate with optic axes lined up parallel in between two sheets of plastic.

S14. When the reflected ray and the refracted rays are perpendicular to each other, then angle of incidence is equal to polarising angle.

Here, $i = p = \tan^{-1}\mu = \tan^{-1}\sqrt{3}$ = **60°**

S15. $\mu = \tan i$

S16. The reflected ray of light is perpendicular to the refracted ray.

S17. The ray of light should be incident on the refracting medium at polarising angle. When it is done so, the reflected ray of light will be plane polarised and perpendicular to the refracted ray.

S18. No.

Sound waves can propagate only through a medium. The two given situations are not scientifically identical because the motion of an observer relative to a medium is different in the two situations. Hence, the Doppler formulas for the two situations cannot be the same.

In case of light waves, sound can travel in a vacuum. In a vacuum, the above two cases are identical because the speed of light is independent of the motion of the observer and the motion of the source. When light travels in a medium, the above two cases are not identical because the speed of light depends on the wavelength of the medium.

S19. Since the incident light is unpolarised, the intensity of light, on being transmitted through the first polaroid, will become

$$I = I_0\,\overline{\cos^2\theta} = \frac{I_0}{2} \qquad \left(\because\ \overline{\cos^2\theta} = \frac{1}{2}\right)$$

If θ is the angle between the transmission planes of the two polaroids, then the intensity of light on passing through the second polaroid is given by

$$I' = I\cos^2\theta$$

Since $I = I_0/2$ and $\theta = 60°$, we get

$$I' = \frac{I_0}{2}\cos^2 60°$$

$$= \frac{I_0}{2}\times\left(\frac{1}{2}\right)^2 = \boldsymbol{\frac{I_0}{8}}$$

S20. If I_0 is the intensity of the original light, then the intensity of the light transmitted through the analyser,

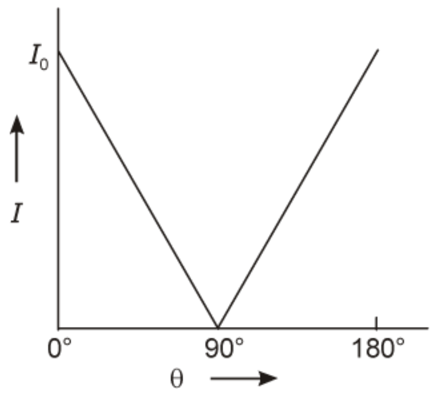
$$I = I_0\cos^2\theta$$

$$= I_0\cos^2 45° = I_0\left(\frac{1}{\sqrt{2}}\right)^2 = \frac{I_0}{2}$$

Therefore, the ratio of the intensities of original light and the transmitted light after passing through the analyser,

$$\frac{I_0}{I} = \frac{I_0}{I_0/2} = \mathbf{2}.$$

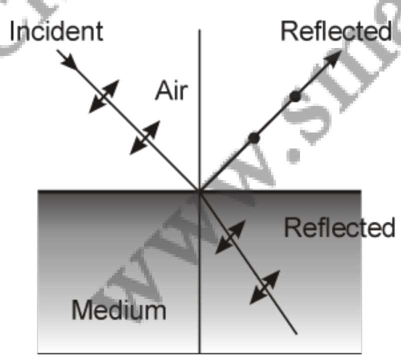
S21. Nicol prism can be used to produce plane polarised light.



S22. When the plane polarised waves are superimposed, the resultant light vector rotates in a plane perpendicular to the direction of propagation. If the resultant light vector has constant magnitude, then the tip of the light vector traces a circle and the light is said to be circularly polarised. However, if the magnitude of the resultant light vector varies periodically during its rotation, the tip of the light vector traces an ellipse and the light is said to be elliptically polarised.

S23. When a polaroid is rotated in the path of unpolarised light, the intensity of the light transmitted from the polaroid remains undiminished. However, when the polaroid is rotated in the path of the plane polarised light, its intensity will vary from maximum (when the vibrations of the plane polarised light are parallel to the axis of the polaroid) to minimum (when the direction of vibrations becomes perpendicular to the axis of the crystal).

S24. **Unpolarised light:** It is the light in which displacement of optical vector keeps on changing randomly with time in a direction perpendicular to the direction of propagation.



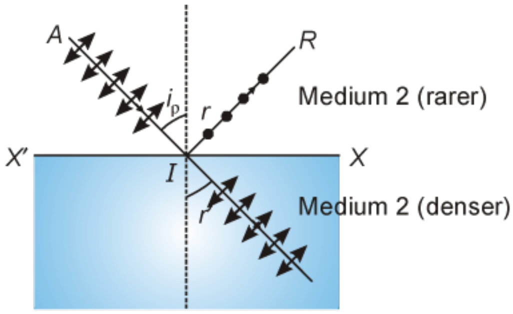
When an unpolarised light is incident on the interface of two media the reflected light get polarised with its electric vector parallel to the interface. Refracted wave makes angle of $\frac{\pi}{2}$ with reflected wave.

$$\mu = \tan i_b$$

where i_b is Brewster angle and μ is refractive index of denser medium.

S25. ***Unpolarised Light:*** A beam of light in which optical vector oscillates, in all possible planes, in a direction normal to the direction of propagation of wave .

Plane Polarised Light: A beam of light in which optical vector oscillates in a direction normal to the direction of propagation of wave on a single plane only.



When light is incident at a particular angle known as polarising angle partially reflected and partially refracted portions of light waves move in mutually perpendicular directions. Reflected wave is purely polarised while refracted wave is partially polarised.

According to the situation

$$\angle RIX + \angle XIF = 90°$$

$$(90° - r) + (90 - r') = 90°$$

$$r + r' = 90°$$

$$r' = 90° - r = 90° - i_p \qquad (\because \; r = i_p)$$

From Snell's law

$$\frac{\sin i_p}{\cos r'} = \mu$$

$$\frac{\sin i_p}{\sin (90° - i_p)} = \mu$$

$$\frac{\sin i_p}{\cos i_p} = \mu$$

$$\tan i_p = \mu$$

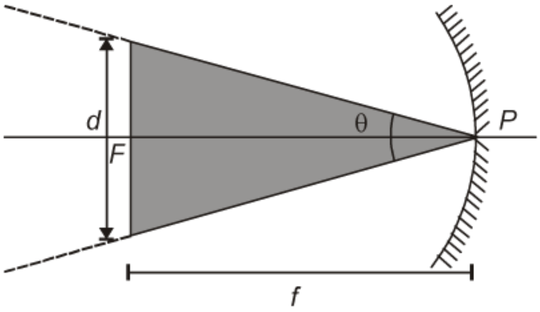
This is known as Brewster's law.

S26. (a) On passing through a polaroid, the transmitted light is linearly polarised. In the unpolarised light, the electric vector changes rapidly and randomly. When it is incident on the polaroid, only the vibration parallel to the pass axis of the polaroid pass through it and are hence confined to only one plane (polarised). The perpendicular component is cutoff.

(b) Light waves can be polarised because they are transverse in nature. Sounds waves are longitudinal in nature and hence cannot be polarised.

(c) The sun goggles are made of polaroid sheets. They polaroid sheets help to avoid glare from sunlight reflected from bright surface, water or snow etc., thus protecting our eyes.

S27. Mirror is concave and sun is in front of it at a large distance. So the image must be real and is formed at focus of the mirror.



$$R = 1.5\text{ m} = \frac{3}{2}\text{ m}$$

$$f = \frac{3}{4}\text{ m}$$

$$\alpha = 0.5° = 0.9 \times 10^{-2}\text{ rad}$$

Size of the image is

$$d = f\alpha$$

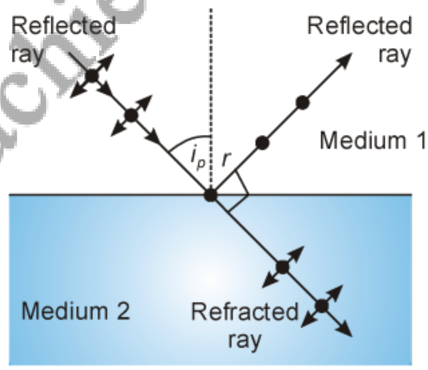
$$= \frac{3}{4} \text{ x } 0.9 \times 10^{-2}$$

$$d = 6.75 \times 10^{-3}\text{ m} = 6.75\text{ mm.}$$

S28. The light wave in which the electric vctor is confined to a single plane is said to be linearly polarised.

Only transverse waves can be polarised. Polarisation by reflection.

When unpolarised light is incident on a boundary between two transparent media, the reflected light is polarised with its electric field vector perpendicular to the plane of refracted and reflected rays makean angle of 90° with each other.



Intensity of polarised light after it comes out the first polaroid is

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

As second polaroid is at 45° w.r.t. the 1^{st}, the component of intensity coming out of the 2^{nd} polaroid is

$$I_2 = I_1 \cos^2 45° = \frac{I_0}{2} \times \frac{1}{2} \Rightarrow I_2 = \frac{I_0}{4}$$

Third polaroid at 45° w.r.t., the second one. Thus intensity of the light coming out of it is

$$I_3 = I_2 \cos^2 45°$$

$$I_3 = \frac{I_0}{4} \times \frac{1}{2} = \frac{I_0}{8}.$$