CLASS – 12

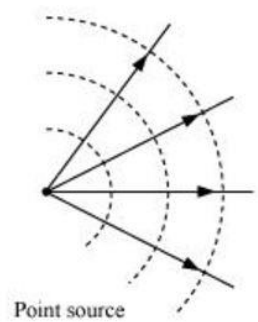
WORKSHEET- WAVE OPTICS

A. HUYGEN'S PRINCIPLE AND WAVE NATURE OF LIGHT

(1 Mark Question)

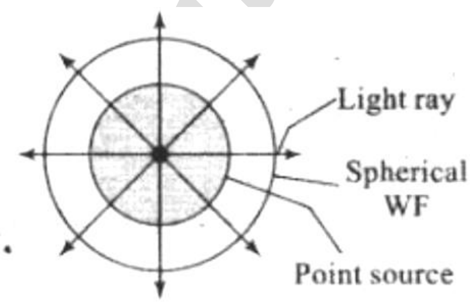
1. Draw the type of wavefront that corresponds to a beam of light coming from a very far off source.

Sol.



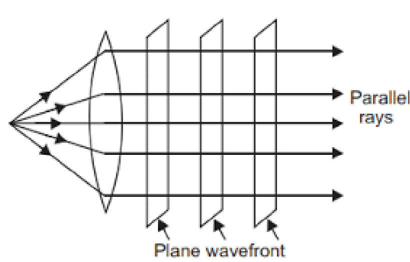
2. Sketch wave from emerging from a point source of light

Sol.



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

Sol.



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

____
____
____
____

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

Sol. When refracting, light doesn't change its frequency, but since it changes its speed, it must also change its wavelength. When light undergoes refraction, its frequency remains the same.

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

Sol. When light enters from one medium to another, its speed changes, so the wavelength changes in such a way that the ratio speed wave length = frequency remains unchanged. Therefore the frequency of UV light does not change when it goes from air to glass.

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?

Sol. (i) Energy of the wave decreases because a part of the light wave is reflected back into air. (ii) Frequency of the wave remains unchanged.

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

Ans. (a)
Corpuscular theory fails to explain the velocity of light in air and water because it predicted light to have more velocity in denser medium where as the fact is just the opposite.

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

Sol. The formation of wavefront is in accordance with Huygens' principle. So, Huygens' principle is valid for longitudinal sound waves also.

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

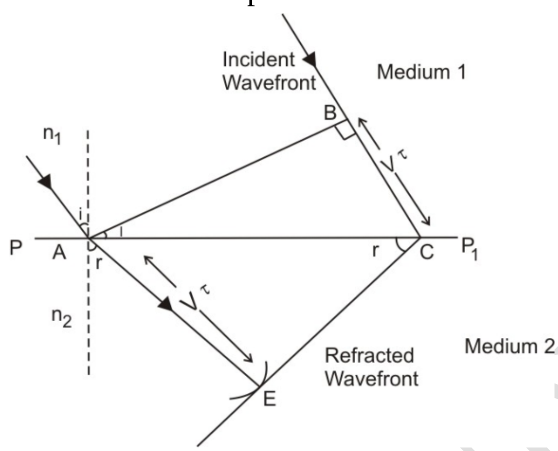
Sol. Spherical with huge radius as compared to the earth's radius so that it is almost a plane.

(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.

Sol. A source of light sends the disturbance in all the directions an continuous locus of all the particles vibrating in same phase at any instant is called wavefront.

Given figure shows the refraction of a plane wavefront at a rarer medium i.e. $v_2 > v_1$.



The incident and refracted wavefronts are shown in figure.

Let the angles of incidence and refraction be i and r respectively

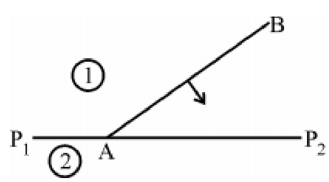
From right ΔABC, we have, ∠BAC = sin i = $\frac{BC}{AC}$

From right ΔADC, we have, ∠DCA = $\frac{AD}{AC}$

$\therefore \frac{\sin i}{\sin r} = \frac{BC}{AD} = \frac{v_1 t}{v_2 t}$ or $\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = 1_{\mu_2}$ (a constant)

This verifies Snell's law of refraction. The constant $^1\mu_2$ is called the refractive index of the second medium with respect to first medium.

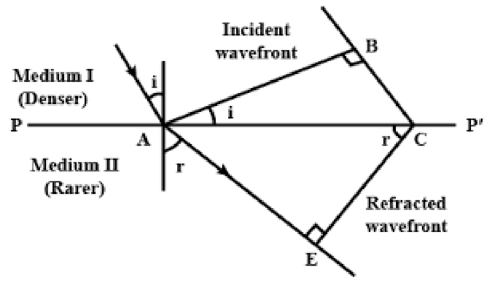
12. Define the term 'wave-front of light'. A plane wave front AB propagating from a denser medium (1) into a rarer medium (2) is incident on the source P_1P_2 separating the two media as shown in figure.



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

Sol. Refer to Q 11

Let P_1P_2 represents the surface separating medium 1 and medium 2 as shown in figure.



Let v_1 and v_2 represents the speed of light in medium 1 and 1 respectively. We assume a plane wavefront AB propagating in the direction AA' incident on the interface at and alone i. Let t be the tiem taken by the wavefront to travel the distance BC.

Therefore BC = v_1t [since distance = speed × time]

In order to determine the shape of the refracted wavefront, we draw a sphere of radius v_2t from point A in the second medium (the sped of the wave in second medium is v_2).

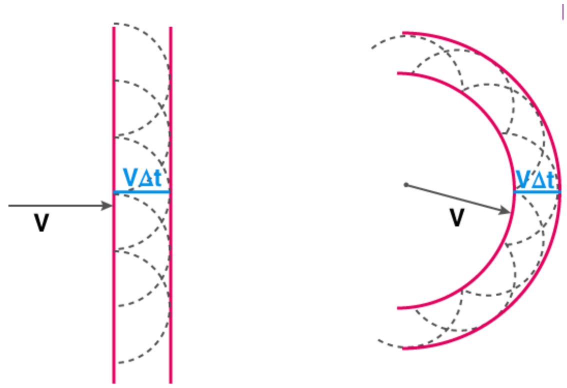
Let CE represents a tangent plane drawn from the point C. Then

AE = v_2t.

Therefore CE would represent the refracted wavefront.

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

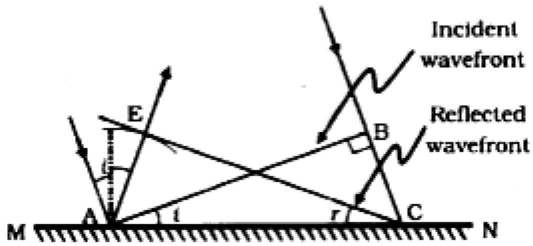
Sol. The Huygens–Fresnel principle, called after Dutch physicist Christiaan Huygens and French physicist Augustin-Jean Fresnel is a process of summary referred to difficulties of wave proliferation both in the far-field boundary and in near-field diffraction and also appearance. It states that all limit on a wavefront is itself the cause of astronomical wavelets, and the trivial wavelets radiating from various points together intervene. The amount of certain round wavelets makes the wavefront.



A simplistic example of the work of the system can be seen at an accessible doorway joins two rooms and a sound is formed in a distant corner of one of them. A person in the other room will catch the noise as if it started at the doorway. As far as the next room is disturbed, the vibrating air in the doorway is the reference of the noise.

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.

Sol. Law of reflection of light: Angle of incidence = angle of reflection i = r



In above figure, MN in reflecting surface AB in the incident wave front FC in the reflected wave front. i in the angle of incidence. r in the angle of reflection.

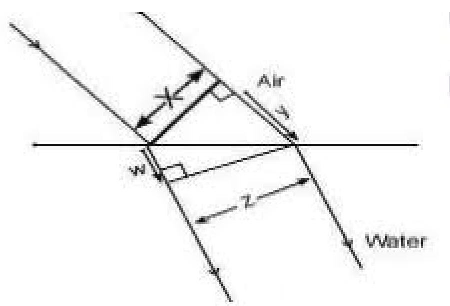
Let 'v' be the speed of the light wave in the medium and 't' be the time taken by the secondary wavelets to move from the point B to C Then the distance. BC = vt

In order to construct the reflected wave front, Let us draw a sphere of radium AE vt, CE represents the tangent drawn from the point e to this sphere, This tangent represents the position of the new reflected wave front.

From the figure it is observed that AE = BC vt. the triangles EAC and BAC are congruent

∴ i = r. This is the Law 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.



Sol. ${}^{a}\mu_{w} = \frac{\sin i}{\sin r} = \frac{y/AB}{w/AB} = \frac{y}{w}$

Therefore ${}^{w}\mu_{a} = \frac{w}{y}$

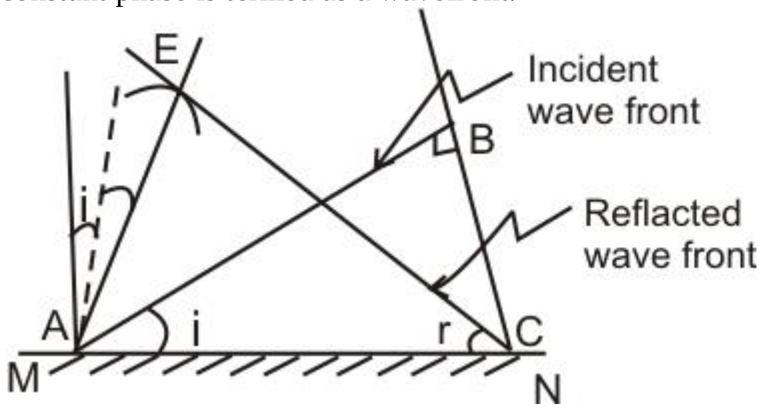
(3 Marks Questions)

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

Sol. Wave theory of light was introduced by Christian Huygens. According to Snell's law the ratio of sine of angle of incidence to the sine of angle of refraction is equal to the ratio of refractive index of second medium to the first medium.
Same as Q11.

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

Sol. Surface of constant phase is termed as a wavefront.



Let us consider a plane wave AB be incident on a reflecting surface and MN at an angle of incidence (i). Let τ be the time taken by the wavefront to advance from B to C. Let v be the speed of the wave. Then,

$BC = v\tau$

Now, to draw the reflected wavefront. Let's draw a sphere of the radius centred at A. Now, In accordance with Huygen's principle, the tangent plane to this sphere passing through point c will give the refracted wavefront.

Remember that,

$\angle BAC = i \;\; and \;\; \angle ACE = r$

Let us consider the triangles EAC and BAC,

$\because \angle AEC = \angle CBA$

$AE = BC = V\tau$

$AC = AC$

So, by RHS, $\Delta EAC \cong \Delta BCA$

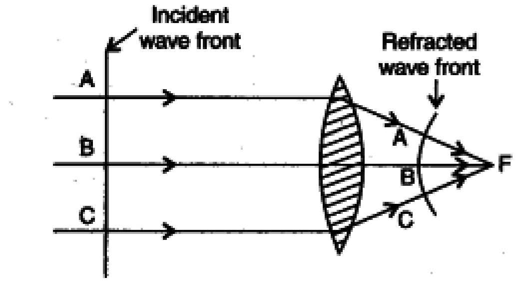
Thus, $i = r$

Hence, the angle of reflection and angle of incidence are equal, by Huygen's wave theory.

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

Sol. Wavefront: The continuous locus of all the particles of a medium, which are vibrating in the same phase is called a wavefront.

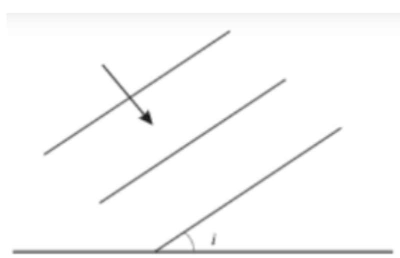
According to Huygens' principle, each point on a wavefront is a source of secondary waves, which add up to give a wavefront at any alter time.



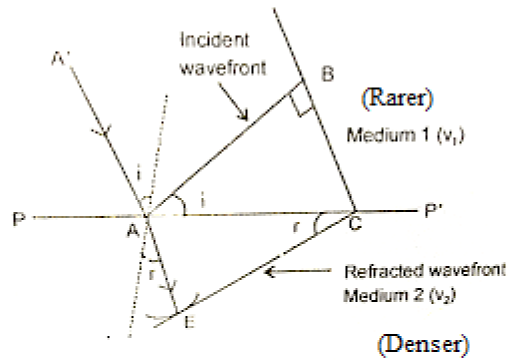
19. Explain the following, giving reasons:
(i) When monochromatic light is incident on a surface separating two media, the reflected and refracted light both have the same frequency as the incident frequency.
(ii) When light travels from a rarer medium, the speed decreases. Does this decrease in speed 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?

Sol. (i) Reflection and refraction arise through interaction of incident light with atomic constituents of matter which vibrate with the same frequency as that of the incident light. Hence frequency remains unchanged.
(ii) Energy carries by a wave depends on the frequency of the wave, not on the speed of wave propagation.
(iii) For a given frequency, intensity of light in the photon picture is determined by
$I = \frac{\text{Energy ofphotons}}{\text{area}\times\text{time}} = \frac{n\times h\upsilon}{A\times t}$ where n is the number fo photons incident normally on the crossing area A in time t.

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.



Sol. Snells' law of refraction" Let P_1P_2 represents the surface separating medium 1 and medium 2 as shown in figure.



Let v_1 and v_2 represents the speed of light in medium 1 and medium 2 respectively. We assume a plane wavefront AB propagating in the direction A'A incident on the surface at an angle i. Let i be the time taken by the wavefront to travel the distance BC.

Therefore BC = v_1t [since distance = speed × time]

In order to determine the shape of the refracted wavefront, we draw a sphere of radius v_2t from point A in the second medium (the sped of the wave in second medium is v_2).

Let CE represents a tangent plane drawn from the point C. Then

AE = v_2t.

Therefore CE would represent the refracted wavefront.

In ΔABC and ΔAEC, we have

$\sin i = \frac{BC}{AC} = \frac{v_1 t}{AC}$ and $\sin r = \frac{AE}{AC} = \frac{v_2 t}{AC}$ where i and r are the angles of incident and refraction respectively.

$\therefore \frac{\sin i}{\sin r} = \frac{v_1 t}{AC} \cdot \frac{AC}{v_2 t}$

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

If c represents the speed of light in vacuum, then $\mu_1 = \frac{c}{v_1}$ and $\mu_2 = \frac{c}{v_2}$

$\Rightarrow v_1 = \frac{c}{\mu_1}$ and $v_2 = \frac{c}{\mu_2}$

Where μ_1 and μ_2 are the refractive indices of medium 1 and medium 1.

Therefore $\frac{\sin i}{\sin r} = \frac{\frac{c}{\mu_1}}{\frac{c}{\mu_2}} \Rightarrow \frac{\sin i}{\sin r} = \frac{\mu_2}{\mu_1} \Rightarrow \mu_1 \sin i = \mu_2 \sin r$.

This is 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 $\angle i = \angle r$

Sol. Same as 14

Therefore incident angle i = incident angle r

Or $\angle i = \angle r$

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.

Sol. Here $\mu = 1.33$.

(a) For reflected light: Since the speed of light in a given medium is fixed and the frequency of light does not change when it is reflected from a surface, therefore its wavelength should also remain unchanged,

Therefore speed of reflected light = speed of (incident) light in air

Or $c = 3.0\times10^{6}\ ms^{-1}$

Wave length of reflected light = Wavelength of incident light

$\lambda = 589nm = 589\times10^{-9}m$

Frequency of reflected light, $v = c/\lambda = 3.0\times10^{8}/589\times10^{-9} = 5.09\times10^{14}Hz.$

(b) For refracted light: Frequency v remains unchanged. Both wavelength and speed get changed.

Speed of light in water, $v_w = c/\mu = 3.0\times10^{8}/1.33 = 2.26\times10^{8}\ ms^{-1}$

Wavelength of light in water, $\lambda_w = v_w/v = 2.26\times10^{8}/5.09\times10^{14}$

$= 444\times10^{-9}m = 444nm.$

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

Sol. (a) Spherical. The point source emits the spherical wavefront as the light diverges from a point source in all directions.

(b) Planar. Light emerging from a convex lens when a point source is placed at its focus :- 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 plane.

(c) Planar. The portion of the wavefront of light from a distance star intercepted by the earth :- Since a small area on the surface of a large sphere is nearly planar, so the portion of the wavefront of light from a distance star intercepted by the earth is a plane wavefront.

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

(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?

Sol. (a) Here $\mu = 1.5$, $c = 3.0\times10^{8}\ ms^{-1}$

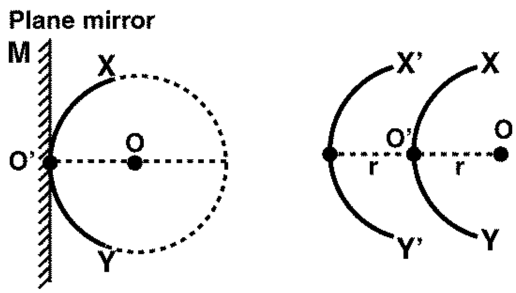
As $\mu = c/v$

Therefore speed of light in glass, $v = c/\mu = 3.0\times10^{8}/1.5 = 2.0\times10^{8}ms^{-1}$

(b) No, speed of light is not independent of the colour (wavelength) of the light. The violet colour travels slower than the red light in glass prism. This is because $\mu_v > \mu_R$ and $v = c/\mu$.

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

Sol.



Consider an item O placed at a distance r in front of the plane mirror MO'. The object is designated as point O, and a circle is drawn around it, just touching the plane mirror at point O'.

The wavefront of incident light, according to Huygens' Principle, is XY. If the mirror was absent, a wavefront X'Y' (as XY) would form behind O' at a distance of r. For the plane mirror, X'Y' can be thought of as a virtual reflected ray. As a result, putting a point object in front of a plane mirror produces a virtual picture with the same distance from the mirror as the object distance (r).

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 of light in vacuum as 3×10^8 ms^{-1}.

Sol. Here $v = 5\times10^{14}$Hz, $\lambda_i = 450\text{nm} = 450\times10^{-9}$m, velocity in liquid, $v_i – v\lambda_i = 2.25\times10^8\text{ms}^{-1}$.

Refractive index, $\mu = \frac{c}{v_i} = \frac{3\times10^8}{2.25\times10^8} = 1.33$

Wavelength in vacuum, $\lambda = m\lambda_i = 1.22 = 600$nm.

(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.

Sol. Same as Q 17

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.

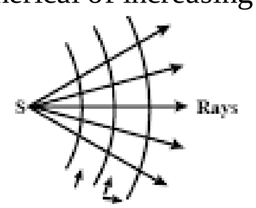
(ii) Light emerging out of a convex lens when a point source is placed at its focus.

(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.

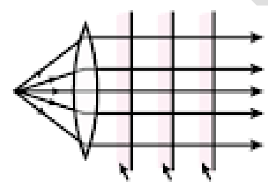
Sol. (a) A wavefront is defined as the locus of all the particles vibrating in same phase at any instant.

A little perpendicular to the wavefront in the direction of propagation of light wave is called a ray.

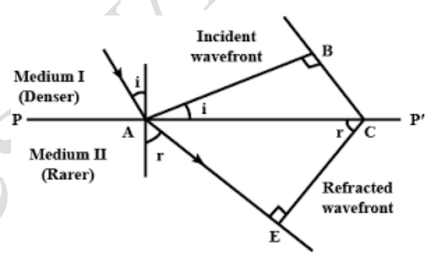
(b) (i) The wavefront will be spherical of increasing radius as shown in figure.



(ii) When source is at the focus, the rays coming out of the convex lens are parallel, so wavefront in plane as shown in figure.



(iii)



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

Sol. (i) Refer Q 11

(ii) Refer Q 11

(iii) No because energy of wave depends on its frequency and not on its speed.

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

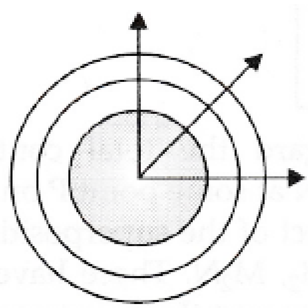
Sol. (a) A wavefront is defined as a surface of constant phase.

[Alternatively : A wavefront is the locus of all points in the medium that have the same phase.]

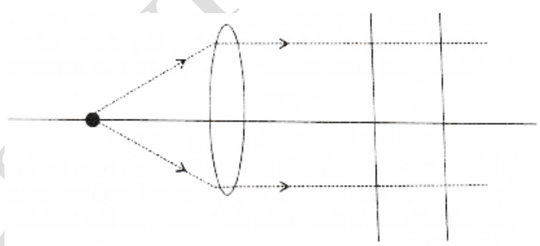
Difference from a ray : (i) The ray, at each point of a wavefront, is normal to the wavefront at that point. (ii) The ray indicates the direction of propagation of wave while the wavefront is the surface of constant phase.

The shape of the wavefront, in the three cases, are as shown.

(i)



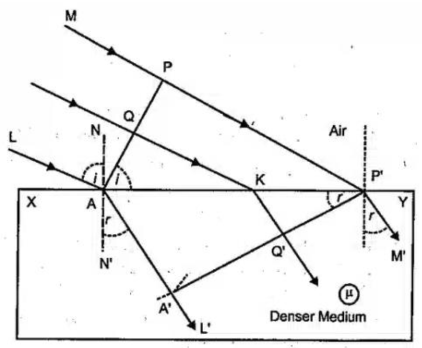
(ii)



(b) Refer Q 11

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

Sol. Huygens principle: Huygens' principle states that every point on a wave front may be considered as a source of secondary waves. The word interference is used to describe the superposition of two waves, whereas diffraction is interference produced by several waves.



Each point on the primary wave acts as a source of secondary wavelets. The new wavefront at any instant is the envelope of secondary wavelets at that instant.

Time taken for light to go from Q to Q'

$t = \frac{QK}{c} + \frac{Q'K}{\nu}$................$(i)$

In right angled triangle $\Delta AQK, \angle QAK = i$

$\therefore QK = AK sin\, i$............$(ii)$

In right angled triangle $\Delta P'Q'K, \angle Q'P'K = r$ and $Q'K = KP' sin\, r$.................(iii)

Using (i),(ii) and (iii) we get

$t = \frac{AK sin\, i}{c} + \frac{KP' sin\, r}{\nu}$

$t = \frac{AK sin\, i}{c} + \frac{(AP' - AK) sin\, r}{\nu} (\because KP' = AP' - AK)$

$t = \frac{AP' sin\, r}{\nu} + AK(\frac{sin\, i}{c} - \frac{sin\, r}{\nu})$

The incident rays will fall at the same time at corresponding points of the refracted wavefront if it is independent of AK

i.e. $\frac{sin\, i}{c} - \frac{sin\, r}{\nu} = 0$

$\frac{sin\, i}{sin\, r} = \frac{c}{\nu} \Rightarrow n = \frac{sin\, i}{sin\, r}$ which is the Snell's Law for refraction of light.

(b)(i) The frequency of incident,reflected and refracted light are all same as it only depends on the source of light.

(ii)There is no reduction in energy since frequency remains constant.

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?

Sol. (a) The speed 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.

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

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.

Sol. Two sources of light are said to be coherent if the waves emitted from them have the same frequency and are 'phase-linked', i.e they have a zero or constant phase difference.

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

Ans. 2.

For destructive interference, $\Delta x = \left(n+\frac{1}{2}\right)\lambda \Rightarrow \left(n+\frac{1}{2}\right)\lambda = \frac{5}{2}\lambda \Rightarrow n = 2$

Therefore the second dark fringe will be 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.

Ans. In Young's double slit experiment, if one slit is fully closed, the new pattern has larger 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.

Sol. (i) For constructive interference path difference must be an integer multiple of wavelength of light, λ, (lambda). (ii) For destructive interference path difference must be an odd multiple of halt wavelength.

5. What is meant by interference of light?

Sol. When two light waves from different coherent sources meet together, then the distribution of energy due to one wave is disturbed by the other. This modification in the distribution of light energy due to super- position of two light waves is called "Interference of light".

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

Sol. Two independent sources of light are unable to have coherence as they will never have the same phase and it is not possible to maintain the same phase difference within a similar interval of time.

7. State two conditions for sustained interference of light.

Sol. (i) The two sources of light must be coherent which means the two light waves emitted by them must have a constant phase difference or in the same phase. (ii) The two sources must emit light of the same wavelength but the amplitudes between them should differ as little as possible.

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

Sol. Angular separation of interference fringes in Young's experiment if distance between the slits 'd' is increased the angular separation decreases.

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?

Sol. Fringe width, $\beta = D\lambda/d \Rightarrow \beta \propto \lambda$ for same D and d. When the whole apparatus is immersed in a transparent liquid of refractive index n =1×3, the wavelength decreases to $\lambda = \lambda/n = \lambda/1.3$. so, fringe width decreases to 1/1.3 time.

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?

Sol. In visible spectrum, red light has greatest wavelength. As fringe width is directly proportional to wavelength of light, so, the fringe width will be maximum for red light.

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.

Sol. Here, $I_1 = I_2 = I_0$

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

At a point of constructive interference, $\phi = 0$

$\therefore I_R = I_0 + I_0 + 2\sqrt{(I_0 I_0)} \cos 0° = 4 I_0$

At a point of destructive interference, $\phi = 180°$

$\therefore I_R = I_0 + I_0 + 2\sqrt{(I_0 I_0)} \cos 180°$

$= 2I_0 - 2I_0 = 0$

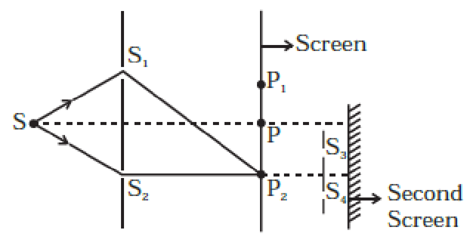
12. In a Young's double slit experiment, the source is white light. One of the holes is covered by a red filter and another by a blue filter. In this case
(a) there shall be alternate interference patterns of red and blue.

(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.

Sol. (c)

For sustained interference pattern to be formed on the screen, the sources must be coherent and emits lights of same frequency and wavelength.
In a Young's double slit experiment, when one of the holes is covered by a red filter and another by a blue filter. In the case due to filtration only red and blue lights are present which has different frequency. In this moochromatic light is used for the formation of fringes on the screen. So, in that case there shall be no interference fringes.

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).



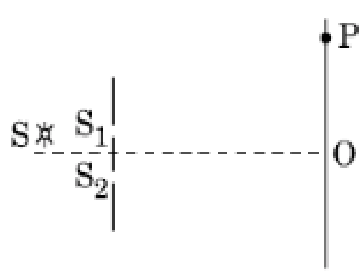
At P_2 on the screen, there is a hole and behind P_2 is a second 2- slit arrangement with slits S_3, S_4 and a second screen behind them.
(a) There would be no interference pattern on the second screen but it would be lighted.
(b) The second screen would be totally dark.
(c) There would be a single bright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

Sol. (d)

Consider the given figure there is a hole at point P_2,. By Huygen's principle wave will propagates from these sources S_1 and S_2. Each point on the screen will acts as sources of secondary wavelets.
Wavefront starting from P_2 reaches at S_3 and S_4 which will again act as two monochromatic or coherent sources.
Hence, there will be always 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 $SS_2 - SS_1 = \lambda/4$.



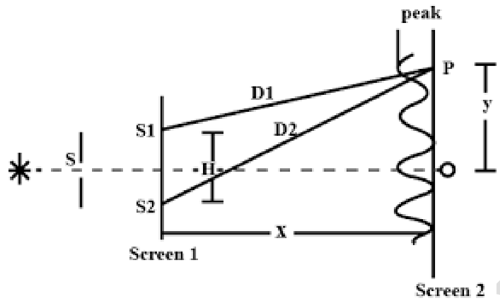
(a) Write the condition for constructive interference.
(b) Obtain an expression for the fringe width.

Sol. (a) Given $SS_2 - SS_1 = \frac{\lambda}{4}$

Now path difference between two waves from slit S_1 and S_2 on reaching P on screen is

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

Or $\Delta x = \frac{\lambda}{4} + \frac{yd}{D}$, where d is the slit separation.



For consecutive interference at point P, path difference, $\Delta x = \frac{yd}{D} = \left(n - \frac{1}{4}\right)\lambda$ …(i)

where n = 0, 1, 2, 3, …

(b) From equation (i), $y_n = \left(n - \frac{1}{4}\right)\frac{\lambda D}{d}$ and $y_{n-1} = \left(n - 1 - \frac{1}{4}\right)\frac{\lambda D}{d}$

The fringe width is given by separation of two consecutive bright fringes.

$\beta = y_n - y_{n-1} = \left(n - \frac{1}{4}\right)\frac{\lambda D}{d} - \left(n - 1 - \frac{1}{4}\right)\frac{\lambda D}{d} = \frac{\lambda D}{d}$

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.

Sol. (a) The essential conditions, which must satisfied sources to be coherent are: (i) the two light waves should be of same wavelength. (ii) the two light waves should either be in phase or should have a constant phase difference.

(b) For bright fringes (maxima),

Path difference, $\frac{xd}{D} = n\lambda$

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

For dark fringes (maxima),

Path difference, $\frac{xd}{D} = (2n - 1)\frac{\lambda}{2}$

Therefore $x = 2n - 1)\frac{\lambda}{2}\frac{D}{d}$ where n = 1m, 2, 3, ….

The separation between the centre of two consecutive bright fringes is the width of a drak fringe.

The fringe width, $\beta = x_n - x_{n-1}$

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

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

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.

Sol. Fringe width, $\beta = \frac{D\lambda}{d}$; $\beta \propto \lambda$

$\therefore \frac{\beta_1}{\beta_2} = \frac{\lambda_1}{\lambda_2}$ or $\lambda_2 = \frac{\beta_2}{\beta_1}\lambda_1 = \frac{8.1}{7.2} \times 640$nm or $\lambda_2 = 72$ nm.

As $x = n_1\beta_1 = n_2\beta_2$

Or $\frac{n_1 D\lambda_1}{d} = \frac{n_2\lambda_2 D}{d}$ or $n_1\lambda_1 = n_2\lambda_2$

Therefore bright fringes coincides at least distance x, if $n_1 = n_2 + 1$, $\Rightarrow n_1 \times 640 = (n_1 - 1) \times 720$

$\frac{n_1 - 1}{n_1} = \frac{640}{720}$ or $n_1 = 9$

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?

Sol. Here $d = 1\text{mm} = 1\times10^{-3}$m, D = 1m, $\lambda = 500\text{nm} = 5\times10^{-7}$m

Fringe spacing, $\beta = \frac{\lambda D}{d} = \frac{5\times10^{-7}\times1}{1\times10^{-3}} = 5\times10^{-4}$m= 0.5mm.

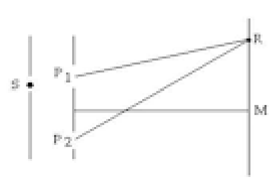
18. Laser light of wavelength 630 nm incident on a pair of slits produces an interference pattern in which the bright fringes are separated by 7.2 mm. Calculate the wavelength of another source of laser light which produces interference fringes separated by 8.1 mm using same pair of slits.

Sol. Fringe width, $\beta = \frac{\lambda D}{d}$

When D and d are kept fixed, $\frac{\beta}{\beta_1} = \frac{\lambda}{\lambda_1}$

Or $\lambda_1 = \frac{\lambda\beta_1}{\beta} = \frac{630\times8.1}{7.2} = \frac{5103}{7.2} = 708.75$ nm.

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?



Sol. The condition for dark fringe is $P_2R - P_1R = (2n-1)\frac{\lambda}{2}$ where n = 1,2, 3, ….

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.

Sol. Here, $\Delta D = 5 \times 10^{-2}$ m, $\Delta\beta = 3 \times 10^{-5}$ m, d = 10-3 m, λ = ?

We know that fringe width in Young's double slit experiment is given by $\beta = \lambda\frac{D}{d}$

Here, since λ and d are constant, we can write

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

$$\therefore \lambda = \frac{\Delta\beta}{\Delta D}d = \frac{3\times10^{-5}\times10^{-3}}{5\times10^{-2}}$$

$$= 0.6\times10^{-6}\text{m} = 6\times10^{-7}\text{m} = 6000\text{ Å}$$

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 0 and $\lambda/4$.

Sol. Let I_0 be intensity of light emitted from the source,

then Resultant intensity $I = 4I_0\cos^2\phi/2$

$$\therefore \quad I_1 = 4I_0\cos^2 0/2 = 4I_0 \quad [\because \phi = 0]$$

Now, $\Delta x = \lambda/4$

$$\therefore \quad \phi = \frac{2\pi}{\lambda}\times\Delta x = \frac{2\pi}{\lambda}\times\frac{\lambda}{4}$$

$$\Rightarrow \quad \phi = \frac{\pi}{2}$$

and $I_2 = 4I_0\cos^2\frac{\pi}{4} = 2I_0\left[\because \phi = \frac{2\pi}{\lambda}\Delta x\right]$

$$\therefore \quad I_1 : I_2 = 2 : 1$$

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.

Sol. If monochromatic light source is replaced by a source of white light, the interference patterns due to difference component colours of white light will overlap. The central bright fringes for all colours are at same point, hence the central fringe is white. but all other fringes are coloured.

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.

Sol. Young's double slit experiment the bandwidth (B.W) is calculated as:

Bandwidth $= \frac{D}{d}\lambda$ where D = distance between the screen and slits, d = distance between the slits, λ = wavelength.

When the screen is moved away from the plane of the slits the distance between the slits is increased from equation

Therefore if D is increased, and it is given that remaining parameters remain same so bandwidth (B.W) is increased.

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.

Sol. The fringe width in air is given by

$$\beta = \frac{D\lambda}{2d} \qquad \ldots(i)$$

where D = distance of screen from slits = 2.5 m λ = wavelength of light used = 6000 Å, 2d = separation between slits fringe width β = 0.8 mm When the whole apparatus is dipped in water, then

$$\lambda_w = \frac{\lambda}{\mu} \qquad \ldots(ii)$$

μ = refractive index of medium = 1.6

So, that $\beta' = \frac{D\lambda_w}{2d}$

or $\beta' = \frac{D\lambda}{2d\mu}$ [from (ii)]

or $\beta' = \frac{\beta}{\mu}$ [from (i)]

Hence, $= \frac{0.8}{1.6} = 0.5$ mm

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.

Sol. Here λ = 600nm = 600×10^{-9}m, d= 0.5 mm = 0.5×10^{-3}, D = 2m

Distance between first dark fringe and wither side of centred bright fringe,

$x = \frac{2\lambda D}{d} = \frac{2\times600\times10^{-9}\times2}{0.5\times10^{-3}}$ = 12 ×10^{-4}m = 1.2mm

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°. What is the spacing between the two slits?

Sol. Wavelength of light used, λ = 6000 nm = 600×10^{-9}m

Angular width of fringe,

$$\theta = 0.1° = 0.1\times\frac{\pi}{180} = \frac{3.14}{1800} \text{ rad}$$

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

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

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

$$= \frac{600\times10^{-9}}{\frac{3.14}{1800}} = 3.44\times10^{-4} \text{ m}$$

∴ the spacing between the two slits is 3.44×10^{-4}m.

(3 Marks Questions)

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

Sol. We know, intensity of wave depends on amplitude of wave. e.g., intensity of wave is directly proportional to square of amplitude of wave.

mathematically, I = KA², where K is proportionality constant, I is intensity and A is amplitude.

if two waves, $y_1 = A_1 sin\omega t$

and $y_2 = A_2 sin(\omega t + \delta)$

Resultant amplitude, $A = \sqrt{A_1^2 + A_2^2 + 2A_1A_2cos\delta}$

so, $A^2 = A_1^2 + A_2^2 + 2A_1A_2cos\delta$

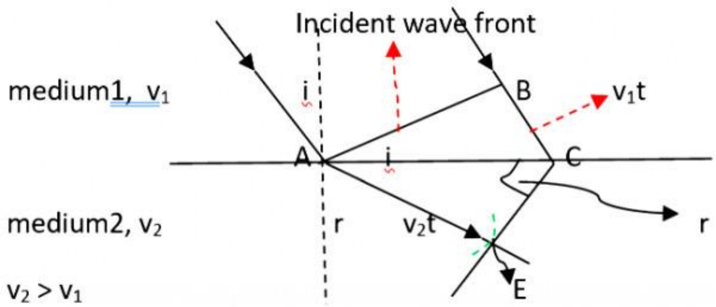
or, $\boxed{\mathbf{I = I_1 + I_2 + 2\sqrt{I_1I_2}cos\delta}}$

This is the expression for the intensity at any point on the observation screen in Young's Double slit experiment.

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.

Sol. Refractive index of a medium : The ratio of the sine of the angle of incidence to the sine of angle of refraction is constant and is called the refractive index of the second medium w.r.t the first medium.

$\therefore$ $\boxed{\frac{\sin i}{\sin r} = n_{21}}$



Sin i = $\frac{BC}{AC} = \frac{v_1 t}{AC}$

Sin r = $\frac{AE}{AC} = \frac{v_2 t}{AC}$

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

Also,

$n_1 = C/v_1$,

$n_2 = C/v_2$

Or, $\boxed{n_1 \sin i = n_2 \sin r}$

which is Snell's law.

If we define, $\sin i_C = n_2/n_1$ then we have $i = i_c$ and $r = 90°$. Obviously for $i > i_c$,

There cannot be any refracted wave and wave will undergo what is known as total internal reflection. 'i_c' is called the critical angle.

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?

Sol (a) We know, $\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2}$

According teo question, I_2 = 50% of I_2

$I_2 = 0.5I_1$; $a_2^2 = 0.5a_1^2$

$a_2 = \frac{a_1}{\sqrt{2}}$

Hence, $\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2/\sqrt{2})^2}{(a_1-a_2/\sqrt{2})^2} = \frac{(1+1/\sqrt{2})^2}{(1-1/\sqrt{2})^2} = \left(\frac{\sqrt{2}+1}{\sqrt{2}+1}\right)^2 \approx 34$

(b) The central fringes are white. On the either side of the central white fringe the coloured bands (few coloured maxima and minima) will appear. This is because fringes of different colours overlap.

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?

Sol. (a) Angular width, $\theta = \frac{\lambda}{d}$ or $d = \frac{\lambda}{\theta}$

Here λ = 600nm = 6×10^{-7} m

$\theta = 0.1° = \frac{0.1\times\pi}{180}$ rad $= \frac{\pi}{1800}$ rad, d = ?

Therefore $d = \frac{6\times10^{-7}\times1800}{\pi} = 3.44\times10^{-4}$m

(b) Frequency of a light depends on its source only. So the frequencies of reflected and refracted light will be same as that of incident light.

Reflected light is in the same medium (air) so its wavelength remains same as 500Å.

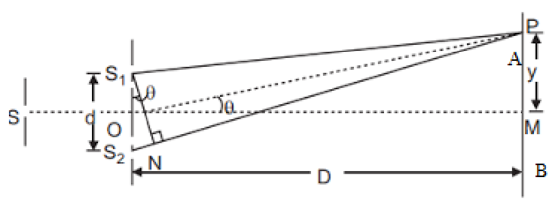
Wavelength of refracted light, $\lambda_r = \lambda/\mu_w$ where μ_w = refractive index of water.

So wavelength of refracted wave will be decreased.

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.

Sol. (i) Two independent monochromatic sources cannot produce sustained interference pattern because the phase difference between the light waves from two independent sources keep on changing.

(ii)



Consider a point P on the screen at distance x from the centre O. The nature of the interference at point P depends on path difference, $p = S_2P - S_1P$

From right angled ΔS_2BP and ΔS_1AP,

$(S_2P)^2 - (S_1P)^2 = [S_{2B}^2 + PB^2] - [S_1A^2 + PA^2]$

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

Or $(S_2P - S_1P)(S_2P + S_1P) = 2xd$

Or $S_2P - S_1D = \frac{2xd}{S_2P + S_1P}$

In practice the point P lies very close to O, therefore $S_1P = S_2P = D$. Hence

$P = S_2P - S_1P = \frac{2xd}{2D}$ or $P = \frac{xd}{D}$

Positions of bright fringes: For constructive interference, $P = \frac{xd}{D} = n\lambda$ or $x = \frac{nD\lambda}{d}$ where n = 0, 1, 2, 3, ….

Positions of dark fringes: For destructive interference, $P = \frac{xd}{D} = (2n-1)\frac{\lambda}{2}$ or $x = (2n-1)\frac{D\lambda}{2d}$ where n = 1, 2, 3, …

Width of dark fringe = separation between two consecutive bright fringes

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

Width of bright fringe= separation of two consecutive dark fringes

$= x'_n = x'_{n-1} = (2n-1)\frac{D\lambda}{d} - [2(n-1)-1]\frac{D\lambda}{2d} = \frac{D\lambda}{d}$

Clearly both the bright and dark fringe are of equal width.

Hence the expression for the fringe width in Young's double slit experiment can be written as $\beta = \frac{D\lambda}{d}$

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.

Sol. (a) The intensity of light due to slit is directly proportional to width of slit.

$\therefore \frac{I_1}{I_2} = \frac{w_1}{w_2} = \frac{4}{1} \Rightarrow \frac{a_1^2}{a_2^2} = \frac{4}{1}$ or $\frac{a_1}{a_2} = \frac{2}{1}$ or $a_1 = 2a_2$

$\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \frac{(2a_2+a_2)^2}{(2a_2-a_2)^2} = \frac{9a_2^2}{a_2^2} = 9:1$

(b) No the appearance of bright and dark fringes in the interference pattern does not violate the law of conservation of energy.

When interference takes place, the light energy which disappears at the regions of destructive interference appears at regions of constructive interference so that the average intensity of light remains the same. Hence, the law of conservation of energy is obeyed in the phenomenon of interference of light.

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.

Sol. (a) The resultant displacement is given by

$$y = y_1 + y_2$$
$$= a \cos \omega t + a \cos (\omega t + \phi)$$
$$= a \cos \omega t (1 + \cos \phi) - a \sin \omega t \sin \phi$$
$$\text{Put } R \cos \theta = a (1 + \cos \phi)$$
$$R \sin \theta = a \sin \phi$$
$$\therefore \quad R^2 = a^2(1 + \cos^2 \phi + 2 \cos \phi) + a^2 \sin^2 \phi$$
$$= 2a^2 (1 + \cos \phi) = 4a^2 \cos^2 \frac{\phi}{2}$$
$$\therefore \quad I = R^2 = 4a^2 \cos^2 \frac{\phi}{2} = 4 I_0 \cos^2 \frac{\phi}{2}$$

(b)

For constructive interference,

$$\cos \frac{\phi}{2} = \pm 1 \text{ or } \frac{\phi}{2} = n\pi \text{ or } \phi = 2n\pi$$

For destructive interference,

$$\cos \frac{\phi}{2} = 0 \text{ or } \frac{\phi}{2} = (2n + 1) \frac{\pi}{2} \text{ or } \phi = (2n + 1)\pi$$

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 $\lambda/3$.

Sol. (a) Coherent sources are necessary to produce a sustained interference pattern otherwise the phase difference changes very rapidly with time and hence no interference will be observed.

(b) Intensity at a point, $I = 4I_0\cos^2(\phi/2)$

Phase difference = $2\pi/\lambda \times$path difference

At path difference λ, phase difference, $\phi = 2\pi/\lambda \times \lambda = 2\pi$

Therefore intensity, $K = 4I_0\cos^2(2\pi/2)$ [As given I = Kat path difference λ] …(i)

$K = 4I_0$

If the path difference is $\lambda/3$, then phase difference will be

$\phi' = 2\pi/\lambda \times \lambda/3 = 2\pi/3$

Therefore intensity, $I' = 4I_0\cos^2(2\pi/6) = K/4$ (using (i))

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

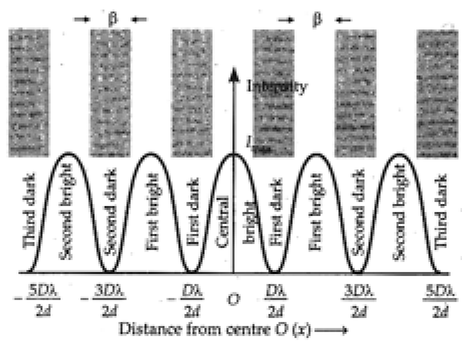
Sol. Young's performed an experiment to prove the wave nature of light by explaining the phenomenon of interference. He used two coherent sources to perform in this experiment. He used a light bulb and two small slits, S_1 and S_2 and source S.

Condition for maxima: Path difference between two waves should even multiple of half of wave length. OR The phase difference between two waves are even multiple of π radian.

Condition for Minima: Path difference between two waves is odd multiple of half of wavelength OR phase difference between two waves.

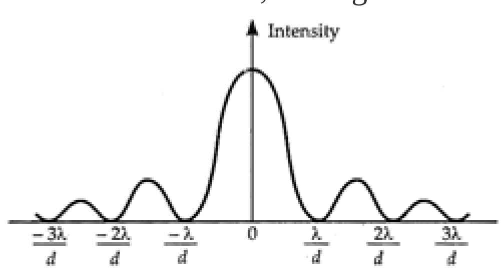
37. Two narrow slits are illuminated by a single monochromatic source. Name the pattern obtained on the screen. One of the slits is now completely covered. What is the name of the pattern now obtained on the screen? Draw intensity pattern obtained in the two cases. Also write tow differences between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

Sol. With two narrow slits, an interference pattern is obtained. When one slit is completely covered, diffraction pattern is obtained. For intensity distribution curve for interference, see Fig.



Intensity distribution curve.

For intensity distribution curve for diffraction, see Fig.



Variation of intensity with angle θ in single slit diffraction.

Interference	Diffraction
Fringes are of equal width	Fringes are of unequal width

Fringes are of equal intensity	Fringes are of decreasing intensity
Due to superposition of two different wave fronts	Due to superposition of secondary wavelets from different parts of the same wave front
Maxima occur at $\theta=\lambda/a$	Minima occur at $\theta=\lambda/a$

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.

Sol. Here d= 0.28mm = 0.28×10^{-3}m, D = 1.4m, x_4 = 1.2cm = 1.2×10^{-2}m

Position of nth bright fringe, $x_n = n\frac{D\lambda}{d}$

Or $x_4 = 4\frac{D\lambda}{d}$

Therefore $\lambda = \frac{x_4 d}{4D} = \frac{1.2\times10^{-2}\times0.28\times10^{-3}}{4\times1.4} = 6\times10^{-7}$m = 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?

Sol. Here d = 2mm = 2×10^{-3}m, D = 120cm = 1.2m, λ_1 = 650nm = 650×10^{-9}m, λ_2 = 520nm = 520×10^{-9}m.

(a) The distance of the third fringe from the central maximum for wavelength 650nm is

$x_3 = \frac{3D\lambda_1}{d} = \frac{3\times1.2\times650\times10^{-9}}{2\times10^{-3}}$ m = 1.17×10^{-3} = 1.17m

(b) Suppose at any distance x from the central maximum, we have

$x = n_1\beta_1 = n_2\beta_2$

or $n_1.\frac{D\lambda_1}{d} = n_2.\frac{D\lambda_2}{d}$

or $n_1\lambda_1 = n_2\lambda_2$

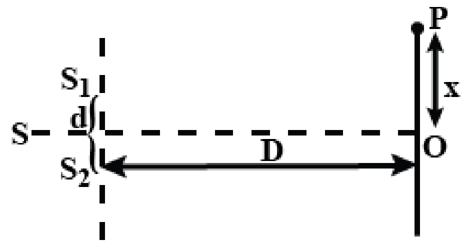
The bright fringes will coincide at the least distance x, if $n_2 = n_1+1$

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

or $n_1 \times 650 \times 10^{-9} = (n_1+1) \times 520 \times10^{-9}$ or $n_1 = 4$

Hence required distance is $x = \frac{n_1 D\lambda_1}{d} = \frac{4\times1.2\times650\times10^{-9}}{2\times10^{-3}}$ m = 1.56×10^{-3}m = 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 $I_0/4$.



Sol. Fringe width (β) = $\frac{\lambda D}{d}$

$y = \frac{\beta}{3} = \frac{\lambda D}{3d}$

Path difference (Δp) = $\frac{yd}{D} \Rightarrow \Delta p = \frac{\lambda D}{3d}.\frac{d}{D} = \frac{\lambda}{3}$

$\Delta\phi = \frac{2\pi}{\lambda}.\Delta p = \frac{2\pi}{\lambda}.\frac{\lambda}{3} = \frac{2\pi}{3}$

Intensity at point P = $I_0\cos^2 \Delta\phi = I_0\left[\cos\frac{2\pi}{3}\right]^2 = I_0\left(\frac{1}{2}\right)^2 = \frac{I_0}{4}$

Here D = 120cm = 1.20m and d = 2mm = 2×10^{-3}m

Therefore distance, $y_{min} = \frac{nD\lambda_1}{d} = \frac{4\times1.2\times650\times10^{-9}}{2\times10^{-3}}$ m = 1.56×10^{-3}m = 1.56mm

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?

Sol. The linear separation between n bright fringes n an interface pattern on the screen is given by $x_n = \frac{n\lambda D}{d}$

As x_n <<D, the angular separation between n bright fringes should be

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

For 10 bright fringes, we get $\theta_{10} = \frac{10\lambda}{d}$

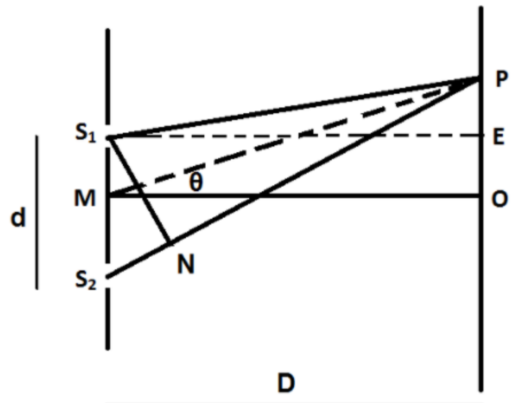
The angular width of the central maximum in the diffraction pattern due to slit of width a is $2\theta_1 = \frac{2\lambda}{a}$

We want, $10\frac{\lambda}{d} < 2\frac{\lambda}{d}$ or a $\leq \frac{d}{5} = \frac{1}{5}$mm = 0.2mm.

(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.

Sol. (a) When two light sources produce waves having the same frequency and have a constant phase difference with time, they are called to be coherent. The two conditions for two light sources to be coherent are as follows:
-The coherent sources of light must have originated from a single source and must be monochromatic (that is they have a single wavelength) in nature.
-The path difference between the light waves from the two sources must be small.
(b) Let, a monochromatic source of light with wavelength λλ is used to illuminate a narrow slit, SS therefore producing two coherent sources of light through the two slits S1S1 andS2S2.



YOUNG's DOUBLE SLIT EXPERIMENT

Now, the light waves from the slits S1 andS2 superimpose with each other and reach point P as shown in the figure and have a path difference ofS2P−S1P.
Let d= the separation between the slits, D=the distance between the screen and the slits, x= the distance between the centre of the screen to point P and θ=θthe angle between MP and MO. Now, draw a perpendicular,S1N on line S2P such that distances PS1 and PN are equal. Therefore, the path difference is S2N. Let, the point Pbe at a distance x from O. Therefore,
PE=x−d/2 and PF=x+d/2 .
Consider the right-angled triangles in the figure, we get:
$\Rightarrow (S2P)^2-(S1P)^2=[D^2+(x+d/2)^2]-[D^2+(x-d/2)^2$
Simplify the equation:
$\Rightarrow (S_2P)^2-(S_1P)^2=2xd$
$\Rightarrow (S_2P+S_1P)(S_2P-S_1P) =2xd$
$\Rightarrow S_2P-S_1P=2xd/S_2P+S_1P$

Approximate that,
$\Rightarrow S_2P \cong S_1P \cong D$
So, Path difference $=S_2P-S_1P=xd/D$

The condition for bright fringe at point P on the screen is:
$\Rightarrow S_2P - S_1P = m\lambda$
$\Rightarrow xd/D = m\lambda$
The condition for dark fringe at point P on the screen is:
$\Rightarrow S_2P - S_1P = (2m+1).\lambda/2$
$\Rightarrow xd/D = (2m+1).\lambda/2$
Where m is the order of the fringe and λ is the wavelength.
In order to find the fringe width, β subtract the distance of the two consecutive b right or dark fringes.T he fringe of m^{th} order will be seen at:
$x_m = m\lambda D/d$
The fringe of $(m+1)^{th}$ order will be seen at:
$x_{m+1} = (m+1)\lambda D/d$
So, the fringe width,ββ is given by:
$\Rightarrow \beta = x_{m+1} - x_m$
$\therefore \beta = \lambda D/d$

C. DIFFRACTION OF LIGHT

(1 Mark Question)

1. What is diffraction of sound waves more easily observed than diffraction of light waves?

Sol. Sound waves have higher wavelength and its wavelength is comparable to the dimension of opaque encounters in our daily life. Hence diffraction effects are more easily detected in the case of sound waves than light waves.

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.

Sol. Here λ = 600nm = 6×10^{-7}m, a = 3mm = 3×10^{-3}m, D = 3m, (2x) = ?

$2x = \frac{2\lambda D}{a} = \frac{2\times6\times10^{-7}\times3}{3\times10^{-3}} = 12\times10^{-4}$m = 1.2mm.

3. Diffraction is common in sound but not common in light waves? Why?

Sol. For sound wavelength is large and we get obstacles of large size easily. Hence diffraction is common in sound. In the case of light, wavelength is very small and small size obstacle is not available easily. Hence diffraction is not common in light.

4. Why is the diffraction of sound waves more evident in daily experience than that of light wave?

Sol. The reason for the diffraction of sound waves being more evident in daily experience than light waves is that sound waves have much higher wavelength compared to the visible light waves. For diffraction to occur, the slit width should be comparable to the wavelength of the light or sound waves.

(2 Marks Questions)

5. State Huygens principle of diffraction of light.

Sol. Huygens principle is a method of analysis applied to wave propagation problems both in the far-field limit and near-field diffraction and reflection. It states that: "Every point on a wavefront is in itself the source of spherical wavelets which spread out in the forward direction at the speed of light.

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.

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

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

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.

Sol. 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.

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.

Sol. Difference between interference and diffraction: Interference is due to superposition of two distinct waves coming from two coherent sources . Diffraction is produced as a result of superposition of the secondary wavelets coming from different parts of the same wavefront

Here λ = 600nm = 600×10^{-19} = 6×10^{-7}m, D = 0.8m, x = 15mm = 1.5×10^{-3}m, n = 2, a = ?

Since $a\frac{x}{D} = n\lambda$

$a = \frac{n\lambda D}{x} = \frac{2\times6\times10^{-7}\times0.8}{1.5\times10^{-3}} = \frac{9.6\times10^{-4}}{1.5} = 6.4\times10^{-4}$ mm.

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.

Sol. Divide the single slit into n smaller slits of width a' = a/n'.
Then angle, $\theta = n\lambda/a = \lambda/a'$
Each of the smaller slits sends zero intensity in the direction θ. The combination gives zero intensity as well.

(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?

Sol. If the width of each slit is comparable to the wavelength of light used, the interference pattern thus obtained in the double slit experiment is modified by diffraction from each of the two slits.

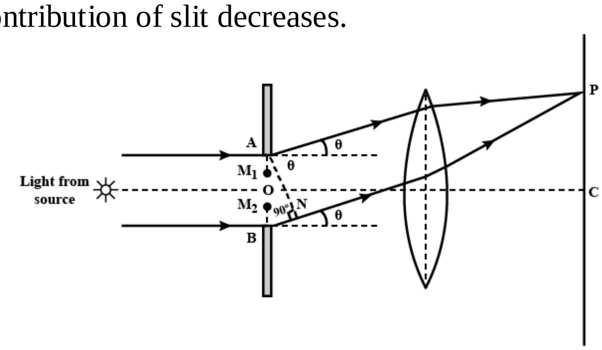
11. State the condition for diffraction of light to occur. If the diffraction in a single slit experiment, how would the width and the intensity of central maximum change if (i) slit width is halved and (ii) visible light of longer wavelength is used?

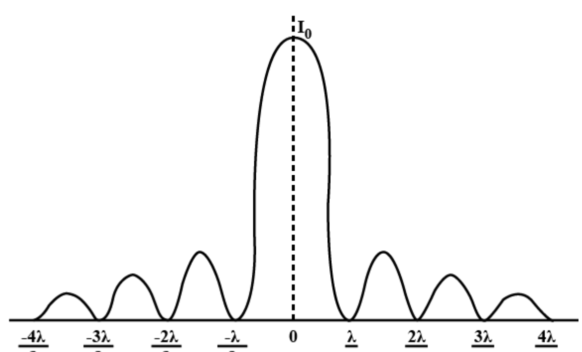
Sol. i) When slit width is halved, size of the central maxima is doubled. Hence, intensity reduces to one-fourth of it's initial value. ii) When longer wavelength is used, size of central maximum is increased. Hence, intensity reduces.

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.

Sol. Diffraction of light at a single slit: When monochromatic light is made incident on a single slit. we get diffraction pattern on a screen placed behind the slit. The diffraction pattern contains bright and dark bands. the intensity of central band is and goes on decreasing on both sides.
Explanation: Let AB be a slit of width a and a parallel beam of monochromatic light is incident on it. According to Fresnel the diffraction pattern is the result of superposition of a large number of waves. starting from different points of illuminated slit.
Let θ be the angle of diffraction for waves reaching at point P of screen and AN the perpendicular dropped from A on wave diffracted from B.
The path difference between rays diffracted at points A and B.
$\Delta = BP - AP = BN$ In ΔANB, $\angle ANB = 90°$ and $\angle BAN = \theta$
$\sin\theta = BN/AB$ or $BN = AB\sin\theta$

As AB = Width of slit = a
Path difference, $\Delta = a\sin\theta$
To find the effect of all coherent waves at P. We have to sum up their contribution. each with a different phase. This was done by Fresnel by rigorous calculations, but the main features may be explained by simple arguments given below:
At the central point C of the screen, the angle θ is zero. Hence the waves starting from all points of slit arrive in the same phase. This gives maximum intensity at the central point C.
Minima: Now we divide the slit into two equal halves AO and OA each of width 2a. Now for every point, M1 in AO, there is a corresponding point M2 in OB, such that $M_1M_2=a/2$; then path difference between waves arriving at P and starting from M_1 and M_2 will be $2a\sin\theta=2\lambda$. This means that the contributions from the two halves of slit AO and OB are opposite in phase and so cancel each other. It gives the angle of diffraction at which intensity falls to zero. Similarly it may be shown that the intensity is zero for $\sin(\theta).n\lambda/a$.
Thus the general condition of minima is $a\sin\theta=n\lambda$
Secondary Maxima: Let us now consider angle θ such that, $\sin\theta=\theta=3\lambda/2a$
Which is midway between two dark bands given by, $\sin\theta=\theta=\lambda/a$ and $\sin\theta=\theta=2\lambda/a$
Clearly there will be a maxima between first two minima. but this maxima will be of much weaker intensity than central maximum. This is called first secondary maxima. In a similar manner we can show that there are secondary maxima between any two consecutive minima: and the intensity of maxima will go on decreasing with increase of order of maxima. In general the position of nth maxima will be given by $a\sin\theta=(n+1/2)\lambda$
The intensity of secondary maxima decreases with increase of order n because with increasing n. the contribution of slit decreases.





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?

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?

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?

Sol. Here size of Fresnel zone d_F at the mdidle hill must be less than 50m.

Distance of either of the two hills from the middle hill is D = 40/2 km = 20,000m

As size of Fresnel's zone, $d_F = \sqrt{\lambda D}$. Therefore $\sqrt{\lambda D} << 50$

Or $\lambda D << 2500$ or $\lambda << 2500/D = 2500/20000 = 0.125$m = 12.5cm

Thus wavelengths longer than 12.5cm will undergo serious diffraction effects.

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

Sol. Position of first minimum in diffraction pattern, $y = \frac{D\lambda}{a}$

So, slit width, $a = \frac{D\lambda}{y} = \frac{1\times500\times10^{-9}}{2.5\times10^{-3}} = 2\times10^{-4}$m = 0.2 mm.

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?

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

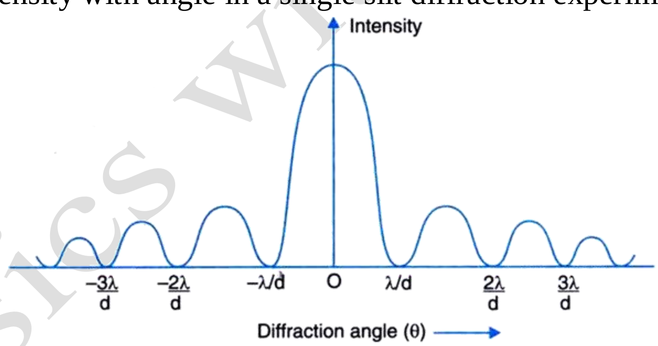
(b) Superposition principle follows from the linear character of the (differential) equation governing wave motion. If y_1 and y_2 are solutions of the wave equations, so is any linear combination of y_1 and y_2. When the amplitudes are large (e.g. high intensity laser beams) and non linear effects become important, the situation is far more complicated.

(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

Sol. Diffraction of light: Phenomenon of bending of light around the corners of an obstacle or aperture is called diffraction.

Variation of intensity with angle in a single slit diffraction experiment is as shown.



In interference all the bright fringes are of the same intensity whereas in diffraction phenomenon, the intensity of bright fringes decreases as the distance from the central bright fringe increases.

(i) The diffraction pattern of a single slit becomes narrower if the width of slit is decreased.

(ii) A coloured diffraction pattern is obtained if monochromatic source is replaced by white light. The red fringe will be wider than the white fringe because the central badn is white.

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?

Sol. (a) Width of central maximum = $2D\lambda/d$. On doubling the width 'd' of the slit the size of the central diffraction band is halved. But the amplitude of light intensity gets doubled. So the intensity becomes four time the initial intensity.
(b) The intensity of interference fringes in Young's double slit experiment is modified by the diffraction pattern of each slit.

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

(d) For diffraction to take place, size of the obstacle or aperture must be comparable to the wavelength of the wave. Wavelength of sound is of the order of height of the partition but wavelength of light is much smaller. So sound waves bend round the partition white light waves cannot bed.

(e) In ordinary optical instruments, the sizes of apertures are much larger than the wavelength of light. So the diffraction effects are negligible small. Hence the assumption that light travels in straight lines can be safely used in the optical instruments.

D. POLARISATION

(1 Mark Question)

1. What is plane polarized light?

Sol. Plane polarized light consists of waves in which the direction of vibration is the same for all waves. In circular polarization the electric vector rotates about the direction of propagation as the wave progresses.

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

Sol. Polarized light can be produced from the common physical processes that deviate light beams, including absorption, refraction, reflection, diffraction (or scattering), and the process known as birefringence (the property of double refraction).

3. What is Polaroid?

Sol. Polaroid is a material which polarizes light.

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

Sol. Polarization (also polarisation) is a property applying to transverse waves that specifies the geometrical orientation of the oscillations. In a transverse wave, the direction of the oscillation is perpendicular to the direction of motion of the wave.

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

Sol. X rays and radio waves. A sound wave cannot be polarized because the sound wave is a longitudinal wave.

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

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

Sol. According to Brewster's law, $n = \tan i_p = \tan 60° = \sqrt{3} = 1.73$.

(2 Marks Questions)

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

Sol. Polarized light can be distinguished, from unpolarized light, when it is allowed to pass through a Polaroid. Polarized light does can show the change in its intensity, on passing through a Polaroid; intensity remains same in case of unpolarized light.

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

Sol. By Brewster's law, $\tan i_p = \mu = 1.5$
So, Brewster's angle, $i_p = \tan^{-1}(1.5) = 56.3°$.

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

Sol. Here $d = 4\text{mm} = 4\times10^{-3}\text{m}$, $l = 400\text{nm} = 4\times10^{-7}\text{m}$

$D_F = \frac{d^2}{\lambda} = \frac{(4\times10^{-3})^2}{4\times10^{-7}} = 40\text{m}$

(3 Marks Questions)

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

Sol. Polaroid is the material that polarize the light. Polarization is the restriction the vibration of light in the particular plane.

Uses of Polaroid,

1) Polaroid are used on spectacles to reduce glare.

2) Plane polarized light is commonly used in chemical analysis to determine handedness of molecules.

Polarized light waves are light waves in which the vibrations occur in a single plane partially polarized light can be described as the mixture of polarized and unpolarized light. In unpolarized light, vibrations take place randomly in directions perpendicular to the direction of the wave.

(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 slits 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).

Sol. In this question use the direct formula for Band width of young's double slit experiment that is $B.W = D/d.\lambda$, where D is the distance between the screen and the slits, d is the distance the slits, $\lambda\lambda$ is the wavelength. Variations of these parameters have direct influence over band width. This will help getting the answer. Formula used = B.W=D/d.λ

As we know in a Young's double slit experiment the bandwidth (B.W) is calculated as: B.W=D/d.λ................. (1),

where D = distance between the screen and the slits, d = distance between the slits, λ = wavelength.

(a) When the screen is moved away from the plane of the slits the distance between the slits is increased from equation (1).

Therefore if D is increased, and it is given that remaining parameters remain same so bandwidth (B.W) is increased.

(b) When the monochromatic source is replaced by another monochromatic source of shorter wavelength, hence the bandwidth (B.W) is decreased as wavelength (λ)(λ) is decreased from equation (1).

(c) When the separation between the two slits is increased so the distance (d) between the slits is increased, hence the bandwidth (B.W) is decreased from equation (1).

(d) As the source slit width increases, fringe pattern gets less and less sharp. When the source slit is so widethen the interference pattern disappears.

(e) As the source slit width increases, fringe pattern gets less and less sharp. When the source slit is so wide then the interference pattern disappears.

(f) If we increase the slit width so the separation between the slits also increases hence d is increased, so if d is increased bandwidth (B.W) is decreased from equation (1).

(g) If monochromatic light source is replaced by a source of white light, the interference patterns due to difference component colours of white light will overlap. The central bright fringes for all colours are at same point, hence the central fringe is white. but all other fringes are coloured.

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.

Sol. Here λ = 6563 Å, Δλ = 15 Å

As $\Delta\lambda = -\frac{v}{c}\lambda$

Therefore $v = -\frac{\Delta\lambda}{\lambda}.c = -\frac{15}{6563} \times 3 \times 10^8 = -6.86\times10^5 ms^{-1}$

The negative sign shows that the star is receding away fro the earth.

F. CASE STUDY

1. **Interference and Diffraction:** Interference is due to superposition of waves from two coherent light sources. Diffraction is due to superposition of waves from various points of the same wave-front. In an interference pattern, all fringes are equally spaced. In a diffraction pattern the fringes are not equally spaced. In an interference experiment, all bright fringes have the same intensity. In a diffraction pattern, the central bright slit has the maximum intensity and the secondary maxima have rapidly decreasing intensity.

(i) Choose the correct statements from the following:

(a) Large number of interference fringe can be seen.

(b) Only a few diffraction fringes can be seen.

(c) In Young's double slit experiment, the fringes become more distinct if the width of the source slit is increased

(d) In single slit diffraction experiment, the fringes become sharper and brighter if the width of the slit is decreased.

Sol. (a, b)

The correct statements are (a) and (b). Only a few diffraction fringes are seen because the intensity of maxima falls very rapidly as we go from the central maximum to higher order maxima. Statement (c) is incorrect. If the width of the source slit is increased, the interference patterns due to various parts of the slit overlap. As a result, the minima will not be totally dark and the fringe pattern becomes indistinct. Statement (d) is also incorrect because if the width of the slit is decresed, the central maximum wil become broader.

(ii) Choose the incorrect statement from the following:

(a) Interference fringes are equally intense and equispaced.

(b) Diffraction fringes are not equally intense and are not equispaced.

(c) The diffraction at the two slits in Young's experiment has no effect on the interference pattern.

(d) Due to diffraction at thte two slits in Young's experiment, the bright fringes will not be equally intense and equally spaced.

Sol. (c)

The only incorrect statement is (c). The angle out diffraction at each slit will affect the interference pattern. However, if the slits are very narrow (i.e. if the slit width is comparable with wavelength), the diffraction effect will not substantially modify the interference pattern.

(iii) In Young's double slit experiment, the separation between the slits is 1.0mm and the width of each slit is 0.2mm. How many maxima of the two slit interference pattern the within the central maximum of the single slit diffraction pattern?

(a) 5 (b) 10 (c) 20 (d) 40

Sol. (b)

The correct choice is b.

2. **Diffraction in a hall:** A and B went to purchase a ticket of a music programme. But unfortunately only one ticket was left. They purchased the singe ticket and decided that A would be in the hall during the 1st half and B during the 2nd half.

Both of them reached the hall together. A entered the hall and found that the seat behind a pillar which created an obstacle. He was disappointed. He thought htat he would bnot be able to hear the programme properly.

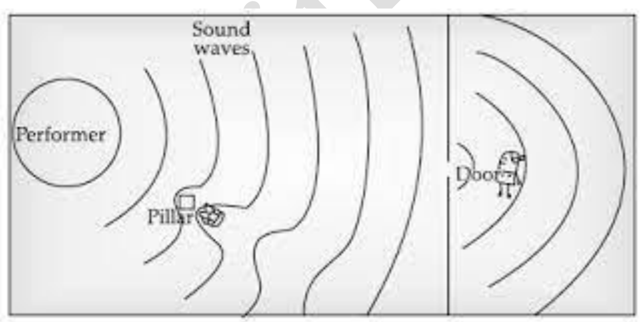
B was waiting outside closed door. The door was not fully closed. There was a little opening. But surprisingly, A could hear the music programme. This happened due to diffraction of sound.

The fact we hear such sound corners and around barriers involves both diffraction and reflection of sound.

Diffraction in such cases helps the sound to "bend around" the obstacles.

In fact, diffraction is more pronounced with longer wavelengths implies that we can hear low frequencies around obstacles better than high frequencies.

B was outside the door. He could also hear the programme. But he noticed that when the door opening is comparatively less he could hear the programme even better. This is because when the width of the opening is larger than the wavelength of the wave passing through the gap then it does the opening is smaller than the wavelength more diffraction occurs and the waves spread out greatly with semicircular wavefront. The opening in this case functions as a localized source of sound.



(i) A and B could hear the music programme due to phenomenon named

(a) interference (b) scattering (c) diffraction (d) dispersion

Sol. (c)

The fact we hear sounds around corners and around barriers involves both diffraction and reflection of sound.

(ii) Diffraction is more pronounced with ___ wavelengths.

(a) longer (b) shorter (c) fluctuating (d) all

Sol. (a)

In fact, diffraction is more pronounced with longer wavelengths

(iii) The minimum and maximum frequencies in the musical programme was 550 HZ and 10 kHz. Which frequency was better suitable around the pillar obstacle.

(a) 10kHz (b) 550 kHz (c) mid frequency (d) the complete frequency range

Sol. (a)

In fact, diffraction is more pronounced with longer wavelengths implies that we can hear low frequencies around obstacles better than high frequencies.

(iv) Diffraction of sound takes place when

(a) sound is diffracted through an opening having width equal to the wavelength of the sound.

(b) sound is diffracted through an opening having width more than the wavelength fo the sound.

(c) sound is diffracted through an opening having width less than the wavelength of the sound.

(d) diffraction of sound does not depend on the width of the opening.

Sol. (c)

When the width of opening is comparatively less than the wavelength of sound wave, the sound spread out much better i.e., better diffraction occurs.

When the width of the opening is larger than the wavelength, the wave passing through the opening dies not spread out much on the other side.

(v) How the waveform will look like outside the door of the hall?

(a) sound repeater (b) sound reflector (c) localized sound source (d) none of these

Sol. (c)

Sound spreads out well through a gap whose width is slightly smaller than the wavelength of the sound wave as if it is localized source of sound.

G. ASSERTION REASON TYPE QUESTIONS:

(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false **(d) If both assertion and reason are false**
(e) If assertion is false but reason is true.

1. Assertion: A narrow pulse of light is sent through a medium. The pulse will retain its shape as it travels through the medium.

Reason: A narrow pulse is made of harmonic wave with a large tange of wavelengths.

Ans. (e) Assertion is false but reason is true.

A narrow pulse is made of harmonic waves wit a large range of wavelengths. As speed of propagation is different for different wavelengths, the pulse cannot retain its shape while travelling through the medium.

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

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

Ans. (a) Both assertion and reason are true and reason is the correct explanation of assertion.

When d is negligibly small, fringe width β which is proportional to 1/d may become too large. Even a single fringe may occupy the whole screen. Hence the pattern cannot be detected.

3. Assertion: 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.
Reason: Wave diffracted from the edges of circular obstacle interface constructively at the centre of the shadow resulting in the formation of bright spot.

Ans. (a) Both assertion and reason are true and reason is the correct explanation of assertion.
Point of constructive interference or maxima is obtained when path difference between the two interfering was is an integral multiple of wavelength.

4. Assertion: Young's double slit experiment can be performed using a source of white light.
Reason: The wavelength of red light is less than the wavelength of other colours in white light.

Ans. (c) Assertion is true but reason is false.
When source in Young's double slit experiment is of white light, the central fringe is white as all colours meet there in phase.

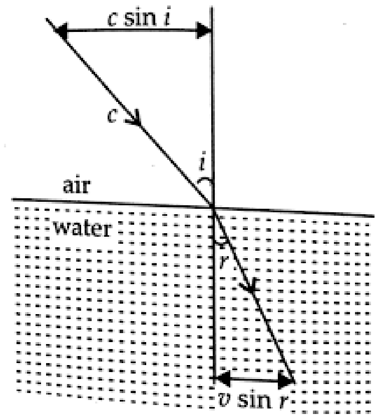
5. Assertion: When Young's double slit experiment performed with a source of white light, only black and white fringes are observed.
Reason: White light does not disperse in different colours in case of interference.

Ans. (d) Both assertion and reason are false.
When Young's double slit experiment is performed by a source of white light, the central fringe will be white, there will be not be a completely dark fringe and the fringe next to the central fringe will be violet.

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?

Sol. In Newton's corpuscular (particle) picture of refraction, particles of light incident from a rarer to a denser medium experience a force of attraction normal to the surface. This results in an increase in the normal component of velocity but the component along the surface remains unchanged.
Consider a ray of light going from a rarer medium (air) to a denser medium (water).
:et c = speed of light in vacuum, v = speed of light in water, i = angle of incidence, r = angle of refraction.



Then according to Newton's corpuscular theory, component of velocity c = Component of velocity v along the surface of separation.

Therefore c sin i = v sin r

Or $\frac{v}{c} = \frac{\sin i}{\sin r} = {}^{a}\mu_{w}$

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

Thus Newton's corpuscular theory predicts light should travel faster in water than in air. This prediction is opposite to the experiment results: v < c. The prediction of Huygens' wave theory is consistent with the experimental results.

SPACE FOR ROUGH WORK

SPACE FOR NOTES