Wave Optics

Newton's Corpuscular Theory of Light

Characteristics of the theory

(i) Extremely minute, very light and elastic particles are being constantly emitted by all luminous bodies (light sources) in all directions which are known as corpuscles.
(ii) These corpuscles travel with the speed of light (3×10^8 m/s in vacuum).
(iii) When these corpuscles strike the retina of our eye then they produce the sensation of vision.
(iv) The different colours of light are due to different size of these corpuscles.
(v) The rest mass of these corpuscles is zero.
(vi) The velocity of these corpuscles in an isotropic medium is same in all directions but it changes with the change of medium.
(vii) These corpuscles travel in straight lines.
(viii) These corpuscles are invisible.

The phenomena explained by this theory

(i) Reflection and refraction of light.
(ii) Rectilinear propagation of light.
(iii) Existence of energy in light.

The phenomena not explained by this theory

(i) Interference, diffraction, polarisation, double refraction and total internal reflection.
(ii) Velocity of light being greater in rarer medium than that in a denser medium.
(iii) Photoelectric effect.

Wave Nature of Light

- It is based on wave theory of light put forward by Christiaan Huygen (a Dutch Physicist : 1629-95) in 1678 .
- According to wave theory, a body emits light in the form of waves. Each point source of light is a centre of disturbance from which waves spread in all directions.
  Huygens coined a term 'Wavefront'.

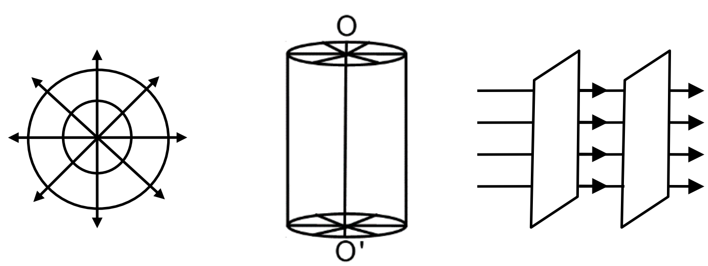
Wave-Fronts

The continuous locus of all particles in a medium which are vibrating in same phase at a given instant is called a wavefront.

Shape of Wavefront

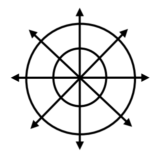
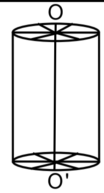
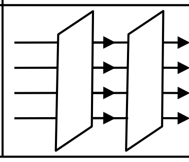
The shape of wavefront depends on the source producing the wave. It is usually of three types :
Spherical, Cylindrical or Plane.

(i) For a point source of light, the wavefront is spherical in shape with source lying at its centre.
(ii) When the source of light is linear, then the wavefront takes the cylindrical shape.
(iii) For a source of light situated far away, the wavefront may be considered to be a plane wavefront.



Point Source   Line Source   Source at ∞

Comparative Study of Three Types of Wavefront

Wavefront	Shape of light source	Diagram of shpae of wavefront	Variation of amplitude with distance	Variation of intnesity with distance
Spherical	Point source		$A \propto \frac{1}{d}$ or $A \propto \frac{1}{r}$	$I \propto \frac{1}{r^2}$
Cylindrical	Linear or slit		$A \propto \frac{1}{\sqrt{d}}$ or $A \propto \frac{1}{\sqrt{r}}$	$I \propto \frac{1}{r}$
Plane	Extended large		$A = \text{constant}$	$I = \text{constant}$

- The shape or orientation of a wavefront may change when it undergoes reflection or refraction.
- A wavefront travels parallel to itself and perpendicular to the rays.
- A ray of light represents the direction along which light energy travels.
- Wavefront always travels in the forward direction in a medium.

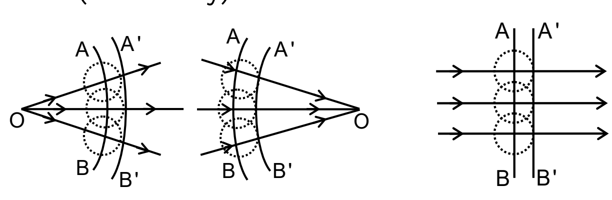
Huygen's Principle

Huygen's Principle provides geometrical method of finding the successive positions of the wavefront. It states :

(i) Every point on given wavefront (called primary wave front) acts as fresh source of new disturbance, (called secondary wavelets).

(ii) The secondary wavelets travel in all the directions with the speed of light in the medium.

(iii) A surface touching these secondary wavelets tangentially in the forward direction at any instant gives the new (secondary) wavefront at the instant.

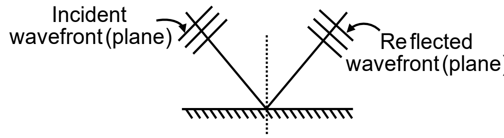


- Huygen's wave theory could explain reflection, refraction, interference and diffraction of light.
- It failed to explain polarisation of light and photoelectric effect.

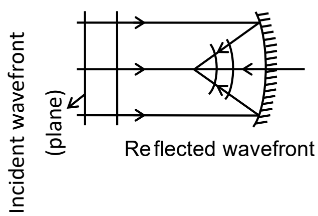
Shape of Wavefronts of Reflected & Refracted Wave

Here we are going to draw the shapes of wavefronts associated with reflected as well as refracted waves.

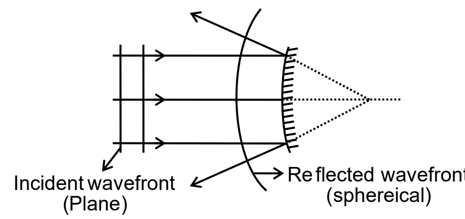
(A) Reflection from Plane Mirror



(B) Reflection from Curved Mirror

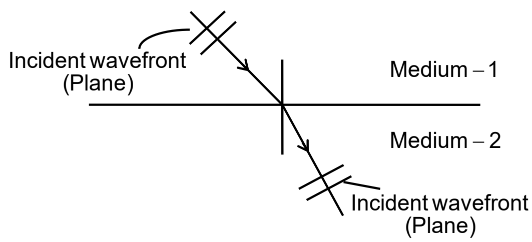


Reflection from concave mirror

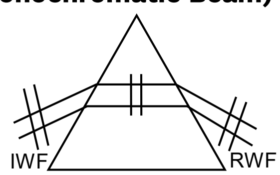


Reflection from convex mirror

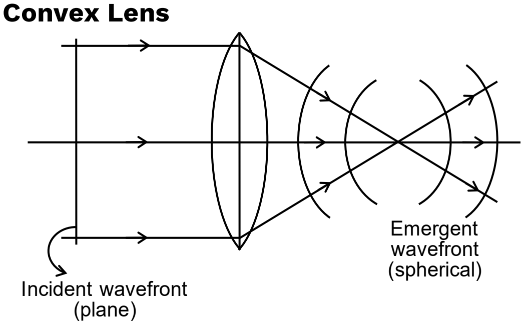
(C) Refraction from Plane Surface



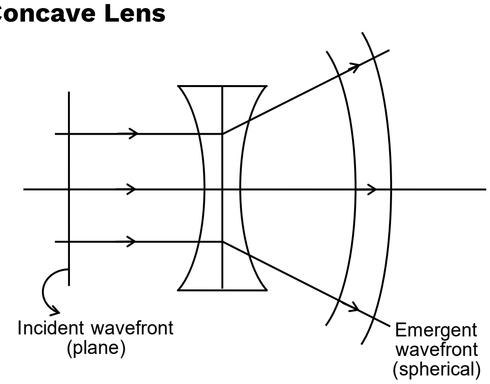
(D) Refraction Through Prism (Monochromatic Beam)



(E) Refraction Through Convex Lens



(F) Refraction Through Concave Lens



Example 1:

A plane wavefront is incident at angle of 37° with horizontal a boundary of refractive surface from air ($\mu = 1$) to a medium of refractive index $\mu = \frac{3}{2}$. Find the angle of refracted wavefront with horizontal.

Solution:

It has been given that incident wavefront makes 37° with horizontal. Hence incident ray makes 37° with normal as the ray is perpendicular to the wavefront.

Now normal as the ray is perpendicular to the wavefront.

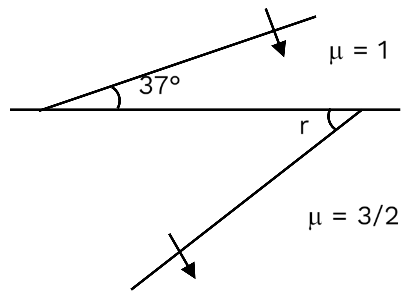
Now, by Snell's law

$$\frac{\sin 37^\circ}{\sin r} = \frac{3}{2}$$

$$\sin r = \frac{2}{3} \times \frac{3}{5} = \frac{2}{5}$$

$$r = \sin^{-1}\left(\frac{2}{5}\right)$$

which is same as angle of refractive wavefront with horizontal



Example 2:

Yellow light with wavelength 0.5 μm in air undergoes refraction in a medium in which velocity of light is 2×10^8 m/s. Then the wavelength of the light in the medium would be.

Solution:

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$$

Here, $\lambda_1 = 0.5$ μm, $v_1 = 3 \times 10^8$ m/s

$\lambda_2 = ?$ (x), $v_2 = 2 \times 10^8$ m/s

$$\frac{0.5}{x} = \frac{3 \times 10^8}{2 \times 10^8}; \qquad x = 0.33 \text{ μm}$$

Note : The frequency remains unchanged.

Concept Builder-1

Q.1 Which of the following prediction of corpuscular theory was proved wrong by Huygens's wave model ?

(1) Frequency of the wave remains same during refraction

(2) Speed of the light increases in denser medium

(3) Angle of incidence is equal to angle of reflection

(4) All of these

Q.2 A ray of light with wavelength 5000 Å travelling in a medium of refractive index $\left(\frac{3}{2}\right)$ suffers partial reflection and refraction in a medium refractive index $\left(\frac{4}{3}\right)$. Find the wavelength of reflected and refracted ray.

Interference

- The phenomenon of non-uniform distribution of energy in the medium due to superposition of two or more light waves originated from coherent sources, is called **interference** of light.
- The interference pattern in which the position of maxima and minima of intensity of light remain fixed all along on the screen is called **sustained or permanent interface pattern.**
- At the points where resultant intensity (amplitude, energy) is maximum, interference is said to be **constructive (CI)** and fringes are **Bright**.
- At the points where the resultant intensity (amplitude, energy) is minimum, interference is said to be **destructive (DI)** and fringes are **Dark**.

Condition for Coherent Sources

- The two sources are said to be coherent if
  (i) they emit light waves have **same frequency.**
  (ii) the emitted waves are either in **same phase** or a **constant phase difference**.
  (iii) the emitted waves may or may not have same amplitude.
- Two independent light sources can never be coherent.
- They are produced from a single source of light.

Condition for Sustained Interference

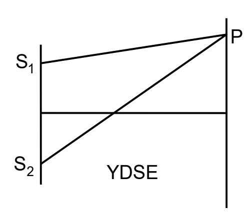
- The two sources must emit waves continuously
- The two sources should be **coherent,**
- The separation between two coherent sources should be small.
- The distance of the screen from the two sources should be large.
- For good contrast between maxima and minima,
  (i) the amplitudes of the two interfering waves should be as nearly equal as possible and
  (ii) the background should be dark.
- For a large number of fringes in the field of view,
  the source should be narrow and monochromatic.

Method of Producing Coherent Sources

Two coherent sources are produced from a single source of light by two methods namely :

(A) Division of Wave Front

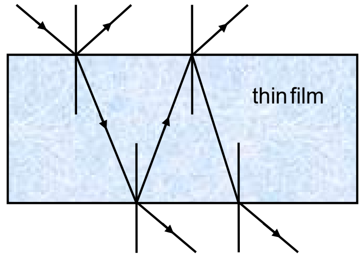
- In this method, the wavefront is divided into two or more parts by reflection or refraction with the help of mirrors, lenses or prisms.
- The Light source is narrow.
- The coherent sources obtained are imaginary.
- Example : Young's double slit experiment.



(B) Division of Amplitude

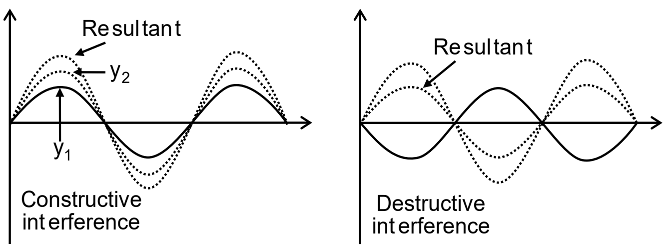
- In this method, the amplitude of incoming beam is divided into two or more parts by partial reflection or refraction.
- These divided parts travel different paths and finally brought together to produce interference.

- Example : Colour of thin films.



Principle of Superposition

When two or more waves superimpose over each other at a common point of the medium then the resultant displacement $(\vec{y})$ of the particle is equal to the vector sum of the displacement $(\vec{y}_1 \text{ and } \vec{y}_2)$ produced by individual waves $\vec{y} = \vec{y}_1 + \vec{y}_2$



Resultant Amplitude and Intensity

Consider two waves with same frequency and different amplitudes

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

where a_1, a_2 are individual amplitudes

and ϕ is constant phase difference between the waves.

- After superposition, the resultant wave can be written as

  $y = A \sin (\omega t + \delta)$
- The resultant amplitude (A) is

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

  $A_{max} = a_1 + a_2$ & $A_{min} = a_1 - a_2$

  For two identical sources

  $a_1 = a_2 = a_0$

  $\therefore \quad A = \sqrt{a_0^2 + a_0^2 + 2a_0a_0 \cos\phi}$

  or $A = 2a_0 \cos \frac{\phi}{2}$ $\therefore$ $A_{max} = 2a_0$ & $A_{min} = 0$
- The Resultant intensity (I) is

  $I = I_1 + I_2 + 2\sqrt{I_1I_2} \cos \phi$ $\qquad (\because I \propto (A)^2)$

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

  For two identical sources

  $I_1 = I_2 = I_0$ $\therefore$ $I = I_0 + I_0 + 2\sqrt{I_0I_0} \cos \phi$

  or $I = 4I_0 \cos^2 \frac{\phi}{2}$ $\therefore$ $I_{max} = 4I_0$ & $I_{min} = 0$

- comparison of Intensities

$$\frac{I_{max}}{I_{min}} = \frac{\left(\sqrt{I_1}+\sqrt{I_2}\right)^2}{\left(\sqrt{I_1}-\sqrt{I_2}\right)^2} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2}$$

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

Relationship Between Path Difference, Phase Difference and Time Difference

Symbol of path difference = x
Symbol of phase difference = ϕ
Symbol of time difference = t

$$\frac{2\pi}{\text{Phase diff.}} = \frac{\lambda}{\text{Path diff.}} = \frac{T}{\text{Time diff.}}$$

$$\Rightarrow \frac{2\pi}{\phi} = \frac{\lambda}{x} = \frac{T}{t}$$

The phase difference (2π) is equivalent to path difference (λ) or time difference (T).

Example 3:

If two waves represented by $y_1 = 4 \sin \omega t$ and $y_2 = 3 \sin \left(\omega t + \frac{\pi}{3}\right)$ interfere at a point. Find out the amplitude of the resulting wave.

Solution:

Resultant amplitude

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

$$= \sqrt{(4)^2 + (3)^2 + 2.(4)(3)\cos\frac{\pi}{3}} \Rightarrow A \simeq 6$$

Example 4:

Two beams of light having intensities I and 4I interfere to produce a fringe pattern on a screen. The phase difference between the beam is $\pi / 2$ at point A and 2π at point B. Then find out the difference between the resultant intensities at A and B.

Solution:

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

Resultant intensity at point A is

$$I_A = I + 4I + 2\sqrt{I_1}\sqrt{4I}\cos\frac{\pi}{2} = 5I$$

Resultant intensity at point B,

$$I_B = I + 4I + 2\sqrt{I}\sqrt{4I}\cos 2\pi = 9I$$

(Ans= $9I - 5I \Rightarrow 4I$)

Example 5:

Two coherent sources each emitting light of intensity I_0 interfere in a medium at a point where phase difference between them is $2\pi / 3$. Then the resultant intensity at that point would be

Solution:

Given here, $\phi = \dfrac{2\pi}{3}$ and $I_{res} = 4I_0 \cos^2\left(\dfrac{\pi}{3}\right) = I_0$

Example 6:

Consider interference between waves from two sources of Intensities I & 4I. Find intensities at points where the phase difference is π.

(1) I (2) 5I (3) 4I (4) 3I

Solution:

$I = a_1^2 + a_2^2 + 2a_1 a_2 \cos\delta$

$= I + 4I + 4I \cos\pi$

$I = 5I - 4I = I$

Example 7:

The intensity ratio of two waves is 9 : 1. These waves produce the event of interference. The ratio of maximum to minimum intensity will be

(1) 1 : 9 (2) 9 : 1 (3) 1 : 4 (4) 4 : 1

Solution:

$$\frac{I_1}{I_2} = \frac{9}{1} \Rightarrow \frac{I_{max}}{I_{min}} = \left[\frac{\sqrt{\frac{I_1}{I_2}}+1}{\sqrt{\frac{I_1}{I_2}}-1}\right] = \left[\frac{\sqrt{9}+1}{\sqrt{9}-1}\right]^2 \Rightarrow \frac{I_{max}}{I_{min}} = \frac{4^2}{2^2} = \frac{4}{1}$$

Example 8:

Two sources with intensity I_0 and $4I_0$ respectively interfere at a point in a medium. Then the maximum and minimum possible intensity would be

Solution:

$I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$

Here, $I_1 = I_0$ and $I_2 = 4I_0$

$\therefore\ I_{max} = \left(\sqrt{I_0} + \sqrt{4I_0}\right)^2 = 9I_0$ and $I_{min} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2 = I_0$

Example 9:

Waves emitted by two identical sources produces intensity of K unit at a point on screen where path difference between these waves is λ, calculate the intensity at that point on screen at which path difference is $\dfrac{\lambda}{4}$.

Solution:

$\phi_1 = \dfrac{2\pi x}{\lambda} = \dfrac{2\pi}{\lambda} \times \lambda = 2\pi$ and $\phi_2 = \dfrac{2\pi}{\lambda} \times \dfrac{\lambda}{4} = \dfrac{\pi}{2}$

$I_1 = I_0 + I_0 + 2\sqrt{I_0}\sqrt{I_0}\ \cos 2\pi = 4I_0$

and $I_2 = I_0 + I_0 + 2\sqrt{I_0}\sqrt{I_0}\ \cos\dfrac{\pi}{2} = 2I_0$

$\therefore\ \dfrac{I_1}{I_2} = \dfrac{4I_0}{2I_0} = 2 \Rightarrow I_2 = \dfrac{I_1}{2} = \dfrac{K}{2}$ unit

[$\because$ I_1 = K unit]

Concept Builder-2

Q.1 Find phase difference if path difference between the waves is

(a) $\lambda/2$ (b) $\lambda/3$

Q.2 If two light rays have intensity I_0 and $4I_0$ then find out the intensity at points where the phase difference between the waves is π, 2π and $\pi / 3$

Q.3 Two incoherent sources of light emitting intensity I_0 and $3I_0$ interfere in a medium. Then the resultant intensity at any point will be.

Q.4 If two waves of intensity I_0 interfere in a medium. Then find out the intensity when phase difference between them is

(a) 2π (b) π (c) $\frac{\pi}{3}$

Q.5 Two light sources with intensity I_0 each interfere in a medium where phase difference between them is $\frac{\pi}{2}$. Resultant intensity at the point would be.

Q.6 The equation of two light waves are $y_1 = 6\cos\omega t$, $y_2 = 8\cos(\omega t + \phi)$. The ratio of maximum to minimum intensities produced by the superposition of these waves will be

(1) 49 : 1 (2) 1 : 49 (3) 1 : 7 (4) 7 : 1

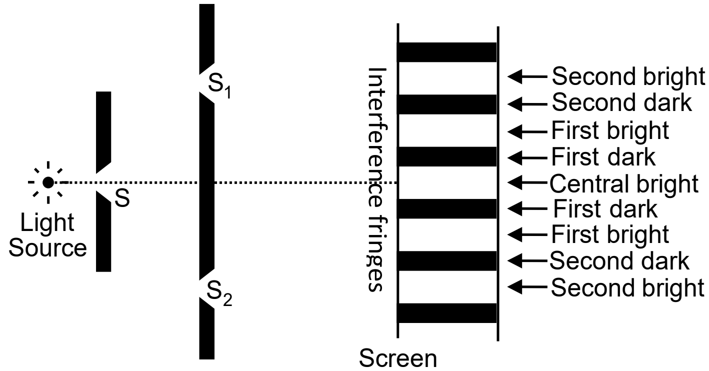
Q.7 Two sources with intensity $9I_0$ and $4I_0$ interfere in a medium. Then find the ratio of maximum to the minimum intensity in the interference pattern.

Q.8 Two incoherent sources of light each with equal intensity I_0 interfere in a medium. Will any interference pattern be observed? If no, then why? Also what would be resultant intensity then?

Q.9 If two light rays of equal intensity superimposes, find out the ratio of maximum intensities when sources are coherent and when sources are incoherent.

Young's Double-Slit Experiment

- Double-slit experiment is a simple technique to produce interference fringes.
- This experiment was first performed with light by Thomas Young (British scientist : 1773-1829) in 1801.
- In 1927, Davisson and Germer demonstrated that electrons show the same behavior, which was later extended to atom and molecules.
- A monochromatic (single wavelength) light from a source S falls on two narrow slits S_1 and S_2 which are very close together. The light waves are very close together.
- The light waves passing through the two slits are coherent, superpose on each other and form an interference pattern on the screen.
- The pattern consists of alternate bright and dark fringes. The central fringe at point O is always bright.



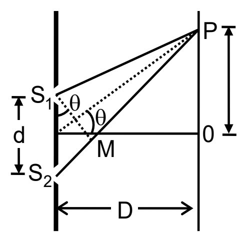
- At a point P on screen to find dark or bright fringe, it depends upon path difference between S_1P & S_2P light waves.

  Path difference, $S_2P - S_1P = x = d \sin\theta$
- If the point P on the screen, situated at a distance y from central point O, is given by

  Point position, $y = D \tan \theta$

  For small angle or D >> d, $(\sin\theta \approx \tan\theta \approx \theta)$

  $x.D = d.y \Rightarrow y = \dfrac{xD}{d}$



Condition for CI-Bright

- Amplitude: $A_{max} = a_1 + a_2$
- Intensity: $I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$
- Phase difference:

  $\phi = 2n\pi$ Here n = 0, 1, 2, 3, ...

  For CB(ϕ=0), for B_1(ϕ=2π), for B_2(ϕ=4π),..... (where B_1 is 1st Bright fringe, B_2 is 2nd Bright fringe...)
- Path difference:

  $x = n\lambda$ Here n = 0, 1, 2, 3, ...

  For CB(x=0), for B_1(x=λ), for B_2(x=2λ),.....
- Fringe position:

  $y = \dfrac{xd}{D} = \dfrac{n\lambda d}{D}$ Here n = 0, 1, 2, 3, ...

  For CB(y = 0), for B_1(y = λd/D),

  for B_2(y = 2λd/D),...

Condition for DI-Dark

- Amplitude: $A_{min} = |a_1 - a_2|$
- Intensity: $I_{min} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$

- Phase difference:
  $\phi = (2n-1)\,\pi$ Here n = 1, 2, 3, ...
  For $D_1(\phi=\pi)$, for $D_2(\phi=3\pi)$, for $D_3(\phi=5\pi)$,... (where D_1 is 1st Dark fringe, D_2 is 2nd Dark fringe...)
- Path difference:
  $x = (2n-1)\,\lambda/2$ Here n = 1, 2, 3, ...
  For $D_1(x=\lambda/2)$, for $D_2(x=3\lambda/2)$, for $D_3(x=5\lambda/2)$, ...
- Fringe position:
  $$y = x\frac{d}{D} = (2n-1)\frac{\lambda d}{2D} \quad \text{Here } n = 1, 2, 3, \ldots$$
  For D_1 $(y = \lambda D/2d)$, for $D_2(y = 3\lambda D/2d)$, for D_3 $(y = 5\lambda D/2d)$, ...

Average Intensity

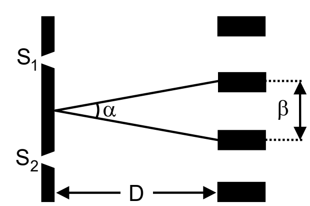
$$I_{average} = \frac{(I_{max} + I_{min})}{2} = 2\,I_0 = I_1 + I_2$$

This shows that **energy is simply redistributed in interference.** i.e., Energy is conserved in interference

Slit Width & Intensity

- If W_1 and W_2 represents width of two slits, then
  $$\frac{W_1}{W_2} = \frac{I_1}{I_2} = \left(\frac{a_1}{a_2}\right)^2.$$

Fringe Width



The distance between the centers of two consecutive bright or dark fringes is called the fringe width.
In Young's double-slit experiment, all the fringes are of equal width, where

Linear width: $\beta = \dfrac{\lambda D}{d}$ and

Angular fringe width: $\alpha = \dfrac{\beta}{D} = \dfrac{\lambda}{d}$

- If YDSE set-up is immersed in a liquid of refractive index μ_L, then the fringe width changes to
  $$\beta_L = \frac{\beta}{\mu_L} = \frac{\lambda}{\mu_L}\cdot\frac{D}{d}$$

Shapes of Fringes

- The interference fringes are usually hyperbolic in shape.
- Locus of path difference between light waves from two slits is a hyperbola.
- When distance of screen (D) is very large compared to the distance between the slits (d), then fringes are straight.

YDSE With White Light

- If white light is used in place of monochromatic light in young's double slit experiment.
  (a) central fringe is white
  (b) Coloured fringe around the central white fringe
  (c) Adjacent to centre of screen is red and edge of the CB is violet.

Fringe Visibility

- It is defined by the relation $V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$.

  The fringe visibility is maximum
  when $I_1 = I_2 = I_0$ or $I_{min} = 0$,
  i.e.,
  when both slits are of equal width,
  the fringe visibility is best, equal to 1.

Example 10:

In YDSE wavelength of light is 5000Å, distance between screen & slits is 2m, distance between two slits is 1mm, then calculate.

(i) fringe width
(ii) Angular fringe width
(iii) Position of 4^{th} bright fringe
(iv) Position of 4^{th} dark fringe

Solution:

$\lambda = 5 \times 10^{-7}$ m; $D = 2$ m

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

(i) fringe width $\beta = \frac{\lambda D}{d} = 10^{-3}$ m

(ii) Angular fringe width $\theta = \frac{\lambda}{d} = 5 \times 10^{-4}$ rad

(iii) Position of 4^{th} bright fringe

$= 4\beta = 4 \times 10^{-3}$ m (from central maxima)

(iv) Position of 4^{th} dark fringe

$= \frac{\beta}{2} + 3\beta = \frac{7}{2}\beta = 3.5 \times 10^{-3}$ m

Example 11:

In a Young's slit experiment, the separation between the slits is 0.10 mm, the wavelength of light used is 600 nm and the interference pattern is observed on a screen 1.0 m away. Find the separation between the successive bright fringes.

(1) 6.6 mm
(2) 6.0 mm
(3) 6 m
(4) 6 cm.

Solution:

The separation between the successive bright fringes is-

$\beta = \frac{D\lambda}{d} = \frac{1 \times 600 \times 10^{-9}}{1 \times 10^{-3}}$; $\beta = 6.0$ mm.

Example 12:

In Young's experiment the wavelength of red light is 7.5×10^{-5} cm. and that of blue light 5.0×10^{-5} cm. The value of n for which $(n + 1)^{th}$ the blue bright band coincides with n^{th} red band is-

(1) 8
(2) 4
(3) 2
(4) 1

Solution:

$n_1 \lambda_1 = n_2 \lambda_2$ for bright fringe

$n(7.5 \times 10^{-5}) = (n + 1)(5 \times 10^{-5})$

$n = \frac{5.0 \times 10^{-5}}{2.5 \times 10^{-5}} = 2.$

Example 13:

A beam of light consisting of two wavelength 6500 Å & 5200 Å is used to obtain interference fringes in a young's double slit experiment. The distance between the slits is 2.0 mm and the distance between the plane of the slits and the screen is 120 cm. What is the least distance from the central maximum where the bright fringes due to both the wave length coincide ?

(1) 0.156 cm (2) 0.152 cm (3) 0.17 (4) 0.16 cm.

Solution:

Suppose the m^{th} bright fringe of 6500 Å coincides with the n^{th} bright fringe of 5200 Å

$$X_n = \frac{m\lambda_1 D}{d} = \frac{n\lambda_2 D}{d}$$

$$\Rightarrow \frac{m \times 6500 \times D}{d} = \frac{n \times 5200 \times D}{d}$$

$$= \frac{m}{n} = \frac{5200}{6500} = \frac{4}{5}$$

$\therefore$ distance y is

$$y = \frac{m\lambda_1 D}{d} = \frac{4 \times 6500 \times 10^{10} \times 1.2}{2 \times 10^{-3}} = 0.156 \text{ cm.}$$

Example 14:

A double slit is illuminated by light of wave length 6000Å. The slit are 0.1 cm apart and the screen is placed one meter away. Calculate :

(i) The angular position of the 10^{th} maximum in radian and

(ii) Separation of the two adjacent minima.

Solution:

(i) λ = 6000 Å = 6 × 10^{-7} m, d = 0.1 cm = 1 × 10^{-3} m, D = 1m, n = 10

Angular position

$$\theta_n = \frac{n\lambda}{d} = \frac{10 \times 6 \times 10^{-7}}{10^{-3}}$$

(ii) Separation between two adjacent minima = fringe width β

$$\beta = \frac{\lambda D}{d} = \frac{6 \times 10^{-7} \times 1}{1 \times 10^{-3}} = 6 \times 10^{-4} \text{ m} = 0.6 \text{ mm}$$

Example 15:

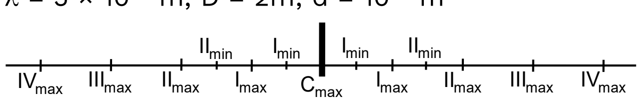
In YDSE, λ = 5000 Å, D = 2m, d = 1mm, Find distance between 4^{th} bright fringe and 2^{nd} dark fringe

(i) If these fringes light on the same side of central maxima

(ii) If these fringes lie on either side of central maxima

Solution:

λ = 5 × 10^{-7} m, D = 2m; d = 10^{-3} m



The separation between any two consecutive maxima or any two consecutive minima (x)

$$x = \frac{\lambda D}{d} = 10^{-3} \text{ m}$$

The separation between two consecutive maxima and minima (y)

$$y = \frac{\lambda D}{2d} = 0.5 \times 10^{-3} \text{ m}$$

(i) Distance between 4th bright and 2nd dark fringe on the same side = $4x - (x + y) = 2.5 \times 10^{-3}$ m

(ii) Distance between 4th bright and 2nd dark fringe on either side = $4x + (x + y) = 5.5 \times 10^{-3}$ m

Example 16:

Find the percentage decrease in fringe width when YDSE experiment is performed in water $(\mu = \frac{4}{3})$

Solution:

$$\beta_0 = \frac{\lambda_0 D}{d} \quad \text{In water } \lambda_w = \frac{\lambda_0}{\mu}$$

$$\Rightarrow \beta_w = \frac{\beta_0}{\mu} = \frac{3}{4}\beta_0 = 75\%\beta_0$$

So, percentage decrease in fringe width = 25%

Example 17:

In YDSE experiment λ = 5000Å; D = 2m, d = 1mm, find total no. of bright fringes on screen

Solution:

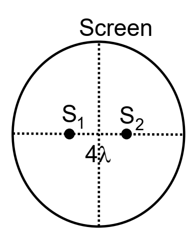
$\Delta x = d \sin\theta$ $\quad$ $n\lambda = d \sin\theta$ $\quad$ $(\theta = 90°, \sin 90° = 1)$

$$n = \frac{d}{\lambda} = \frac{10^{-3}}{5 \times 10^{-7}} = 2000$$

no. of bright fringes = 2n +1 = 4001

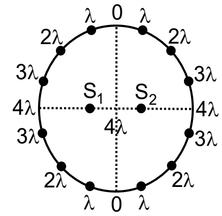
Example 18:

Find the total no. of bright fringes formed on the screen.



Solution:

as shown in the diagram total no. of bright fringes will be 16.



Concept Builder-3

Q.1 Two waves originating from source S_1 and S_2 having zero phase difference and common wavelength λ will show completely destructive interference at a point P if $(S_1P - S_2P)$ is-

(1) 5λ (2) $3\lambda/4$ (3) 2λ (4) $11\lambda/2$

Q.2 In Young's double slit experiment, carried out with light of wavelength λ = 5000 Å, the distance between the slits is 0.2 mm and the screen is at 200 cm from the slits. The central maximum is at x = 0. The third maximum will be at x equal to.

(1) 1.67 cm (2) 1.5 cm (3) 0.5 cm (4) 5.0 cm.

Q.3 In an interference pattern, at a point we observe the 16^{th} order maximum for λ_1=6000Å. What order will be visible here if the source is replaced by light of wavelength λ_2 = 4800 Å.

(1) 40 (2) 20 (3) 10 (4) 80

Q.4 Two slits separated by a distance of 1mm are illuminated with red light of wavelength 6.5×10^{-7} m. The interference fringes are observed on a screen placed 1m from the slits. The distance between third dark fringe & the fifth bright fringe is equal to.

(1) 0.65 mm (2) 1.63 mm (3) 3.25 mm (4) 4.87 mm.

Q.5 In YDSE light of wavelength λ_1 & λ_2 is used find λ_1 / λ_2 if 5^{th} bright fringe of λ_1 coincides with 6^{th} dark fringe of λ_2

Q.6 The young's double slits experiment is performed with blue and with green light of wavelength 4360 Å and 5460 Å respectively. It x is the distance of the 4^{th} maxima from the central one, then

(1) $x_{blue} = x_{green}$ (2) $x_{blue} > x_{green}$ (3) $x_{blue} < x_{green}$ (4) Insufficient information

Q.7 In Young's double slit experiment the fringes are formed at a distance of 1m from double slit of separation 0.12 mm. Calculate

(i) The distance of 3rd dark band from the centre of the screen.

(ii) The distance of 3rd bright band from the centre of the screen, given λ = 6000Å

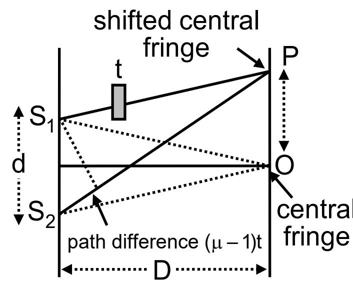
Q.8 In Young's double slit experiment the two slits are illuminated by light of wavelength 5890Å and the distance between the fringes obtained on the screen is 0.2°. The whole apparatus is immersed in water, then find out angular fringe width, (refractive index of water = $\frac{4}{3}$).

Thin Slab in Front of Slit

- If a thin glass plate or mica sheet is placed in front of one of the slits, then the central fringe shifts towards the slit in front of which the glass plate is placed.
- If t is the thickness of glass of mica sheet and is the refractive index of the material of sheet, then extra path difference introduced by the sheet is
  $\Delta x = (\mu - 1)\,t$.

- In this situation, the fringe pattern shifts by

  $y_{shift} = \frac{D}{d}(\mu - 1)t = \frac{\beta}{\lambda}(\mu - 1)t$



- If the shift is equivalent to n fringes, then

  $N = \frac{y_{shift}}{\beta} = \frac{(\mu - 1)t}{\lambda}$

- If the central fringe now appears at the location of previously formed nth bright fringe, then

  $\Delta x = (\mu - 1)t = n\lambda$

- If the central fringe appears at the position of previously formed nth dark fringe, then

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

Example 19:

In YDSE λ = 5000 Å, D = 2m, d = 1mm, A thin sheet of refractive index 1.5 and thickness 100 μm is placed on the upper source find.

(i) Path diff. introduced by sheet

(ii) Shift in the fringe pattern

(iii) No. fringes crossing the central point

Solution:

(i) Path difference

$\Delta x = (4 - 1)t = \frac{1}{2} \times 100 \times 10^{-6} = 0.5 \times 10^{-4}$ m

(ii) Shift in fringe pattern

$\Delta y = \frac{D}{d}\Delta x = \frac{2m}{1 \times 10^{-3}} \times 0.5 \times 10^{-4} = 10^{-1}$ m

(iii) $\frac{\Delta y}{\beta} = \frac{10^{-1} \times 10^{-3}}{5000 \times 10^{-10} \times 2} = 10^{2}$ m

Example 20:

Interference fringes were produced in young's double slit experiment using light of wave length 5000 Å. When a film of material 2.5×10^{-3} cm thick was placed over one of the slits, the fringe pattern shifted by a distance equal to 20 fringe width. The refractive index of the material of the film is-

(1) 1.25 (2) 1.33 (3) 1.4 (4) 1.5

Solution:

$n = \frac{(\mu - 1)tD}{d}$

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

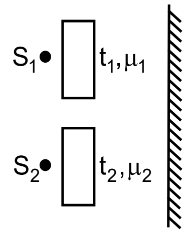
$n = (\mu - 1)\, t\, \beta/\lambda$

$20\beta = (\mu - 1)\, 2.5 \times 10^{-3}\, \{\beta/5000 \times 10^{-8}\}$

$\mu - 1 = \frac{20 \times 5000 \times 10^{-8}}{2.5 \times 10^{-3}} = 0.4 \Rightarrow \mu = 1.4$

Example 21:

Find the relation between t_1 & t_2 if their is no shift in the pattern



Solution:

because of the first slab shift will be upward

and because of the second slab shift will be downward

for no shift upward shift = downward shift $(\mu_1 - 1)\, t_1 = (\mu_2 - 1)t_2$

Interference Due to Thin Films

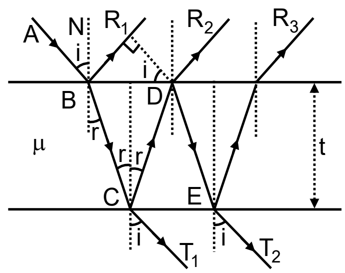
Consider a thin transparent film of thickness t and refractive index μ .

Let a ray of light AB incident on the film at B. At B, a part of light is reflected along BR_1, and a part of light refracted along BC.

At C a part of light is reflected along CD and a part of light transmitted along CT_1.

At D, a part of light is refracted along DR_2 and a part of light is reflected along DE.

Thus interference in this film takes place due to reflected light in between BR_1 and DR_2 also in transmitted light in between CT_1 and ET_2.



Reflected Beam

Condition for constructive Interference (film appear bright)

$$\mathbf{2\,\mu t \cos r = (2n + 1)\,\lambda/2} \quad \textbf{(Here, n = 0, 1, 2, 3 .....)}$$

Condition for destructive Interference (film appear dark)

$$\mathbf{2\,\mu\, t \cos r = n\,\lambda} \quad \textbf{(Here, n = 1, 2, 3 .....)}$$

Transmitted Beam

Condition for constructive Interference (film appear bright)

$$\mathbf{2\,\mu\, t \cos r = n\,\lambda} \quad \textbf{(Here, n = 0, 1, 2, ...)}$$

Condition for distructive Interference (film appear dark)

$$\mathbf{2\,\mu t \cos r = (2n +1)\,\lambda\,/\,2} \quad \textbf{(Here, n = 0, 1, 2, ...)}$$

Note:

- If film is very thin then there will be destructive interference of all colours and the film will appear black.
- Thin layer of oil on water and soap bubbles show different colours due to interference of waves reflected from two surfaces of their films.

Diffraction

- Italian scientist **F.M. Grimaldi** coined the word "diffraction".
- It was the first to record accurate observations of the phenomenon in 1660.
- Diffraction refers to various phenomena that occur when a wave encounters an obstacle or a slit.
- It is defined as the bending of waves around the corners of an obstacle/aperture in the path of light into the region of geometrical shadow of the obstacle.
- Diffraction occurs with all waves, including sound waves, water waves, visible light , X-rays and radio waves.
- Condition : The linear dimension 'a' of obstacle/aperture is comparable to the wavelength 'λ' of wave.
- Diffraction effects become more prominent when (λ/a) increases.
- It is further observed that greater the wavelength of waves, higher is the degree of diffraction.

  As $\lambda_{sound} > \lambda_{light}$, diffraction is more easily observed in sound as compared to light.
- The basic arrangement for observing diffraction effects, three things needed - a source of light, a diffracting element (an obstacle/aperture-an opening), and a screen.

Diffraction Pattern

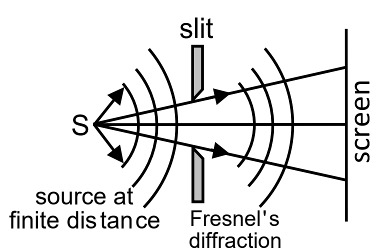
- The illuminated region above the shadow of the object contains alternating bright and dark fringes. Such a display is called a diffraction pattern.
- In the diffraction pattern, the intensity of successive maxima decreases rapidly.

Type of Diffraction

The phenomenon of diffraction is divided mainly in the following two classes

(i) Fresnel Diffraction

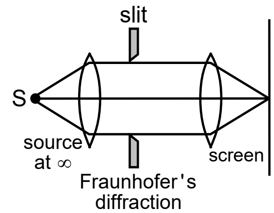
- If source and screen are at finite distance from the obstacle/aperture, then diffraction observed is known as Fresnel diffraction.
- It is also known as **near-field** diffraction.
- The wave passing through a narrow slit are non-plane (spherical) wavefronts,
- It is named in honor of A. J. Fresnel (1788-1827) , a French physicist.



(ii) Fraunhofer Diffraction

- It is named in honor of J.V. Fraunhofer (1787-1826), a German physicist.
- Fraunhofer diffraction deals with wavefronts that are plane on arrival and an effective viewing distance of infinity.
- This can be achieved experimentally by using two convex lens to focus the rays before and after they pass through the opening.
- It is also known as **far-field** diffraction.

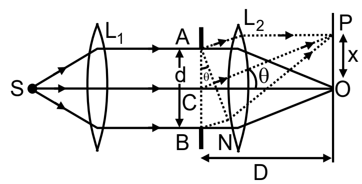
- If follows that fraunhofer diffraction is an important special case of fresnel diffraction.



Diffraction at a Single Slit

Suppose a plane wavefront is incident on a slit AB (of width 'a'). Each and every point of the exposed part of the plane wavefront acts as a source of secondary wavelets spreading in all directions.

The diffraction is obtained on a screen placed at the focal plane of convex lens placed just after the slit.



The diffraction pattern consists of a central bright fringe (central maxima- CB) surrounded by dark (D) and bright fringes (secondary maxima -SM).

Central Maxima (CM)

At point O on the screen, the central maxima is obtained. The wavelets originating from points A and B meets in the same phase at this point, hence at O, intensity is maximum.

Minima(D)

- For obtaining nth minima at point P on the screen, path difference between the diffracted waves

  $a \sin \theta = n\lambda$, where n = 1, 2, 3, ...
- Angular position of nth dark,

  $$\sin\theta \approx \theta = \frac{n\lambda}{a}$$
- Distance of nth dark from CM on screen,

  $$y_n = D.\theta = \frac{n\lambda D}{a} = \frac{n\lambda f}{a}$$

  where, D = f = focal length of convex lens.

Secondary Maxima (SM)

- For obtaining nth secondary maxima at point P on the screen, path difference between the diffracted waves

  $a\sin\theta = (2n+1)\frac{\lambda}{2}$, where n = 1, 2, 3, ...
- Angular position of nth SM,

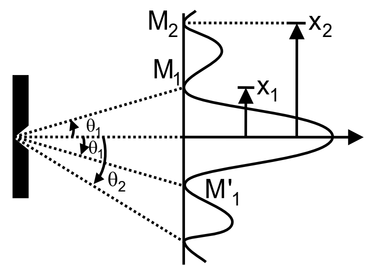
  $$\sin\theta \approx \theta = \frac{(2n+1)\lambda}{2a}$$
- Distance of nth SM from CM on screen,

  $$y_n = D.\theta = \frac{(2n+1)\lambda D}{2a} = \frac{(2n+1)\lambda f}{2a}$$

Fringe Width

The distance between two minima formed on two sides of central maximum is known as the width of central maximum, So

Linear width of CM:



$$W_{CM} = 2y_{D1} = \frac{2\lambda D}{a} = \frac{2\lambda f}{a}$$

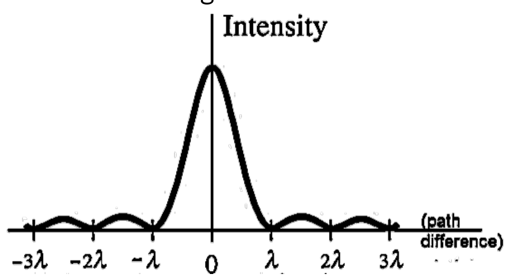
Angular width of CM : $\theta_{CM} = 2\theta_{SD} = \frac{2\lambda}{a}$

Linear width of SB : $W_{SD} = \frac{\lambda D}{a} = \frac{\lambda f}{a}$

Angular width of SB : $\theta_{SD} = \frac{\lambda}{a}$

Intensity Distribution Curve

The intensity distribution is shown is figure.



- Diffraction pattern due to a single slit consists of a central maxima flanked by alternate minima and secondary maxima.
- If I_0 be the intensity of central maxima, then intensity of first three secondary maxima is

  $I_1 = \frac{I_0}{22}, I_2 = \frac{I_0}{62}$ and $I_3 = \frac{I_0}{121}$
- The diffraction fringes are of unequal width and unequal intensities.

Example 22:

In single slit diffraction experiment, width of slit is 1mm and wavelength of light is 5000 Å; distance of slit is 2m from screen find

(i) Position of 1st minima

(ii) Width of central maxima

Solution:

(i) $d \sin\theta = n\lambda$

$\sin\theta = \frac{\lambda}{d} = \frac{5 \times 10^{-7}}{1 \times 10^{-3}} = 5 \times 10^{-4}$

$\theta = 5 \times 10^{-4}$ rad.

(ii) $w = \frac{2\lambda D}{d} = \frac{2 \times 5 \times 10^{-7}}{10^{-3}} = 20 \times 10^{-4}$

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

Example 23:

Light of wavelength 6000Å is incident normally on a slit of width 24 × 10^{-5} cm. Find out the angular position of second minimum from central maximum?

Solution:

a sinθ = 2λ

given λ = 6 × 10^{-7} m, a = 24 × 10^{-5} × 10^{-2} m

$$\sin\theta = \frac{2\lambda}{a} = \frac{2\times6\times10^{-7}}{24\times10^{-7}} = \frac{1}{2} \quad \therefore \ \theta = 30°$$

Example 24:

Light of wavelength 6328Å is incident normally on a slit of width 0.2 mm. Calculate the angular width of central maximum on a screen distance 9 m?

Solution:

given λ = 6.328 × 10^{-7} m, a = 0.2 × 10^{-3} m

$$w_\theta = \frac{2\lambda}{a} = \frac{2\times6.328\times10^{-7}}{2\times10^{-4}} \text{ radian}$$

$$= \frac{6.328\times10^{-3}\times180}{3.14} = 0.36°$$

Example 25:

The first diffraction minima due to a single slit diffraction is at θ = 30^0 for a light of wavelength 5000 Å. The width of the slit is-

(1) 5 × 10^{-5} cm (2) 1.0 × 10^{-4} cm (3) 2.5 × 10^{-5} cm (4) 1.25 × 10^{-5} cm

Solution:

The distance of first diffraction minimum from the central principal maximum x = λD/d

$$\therefore \ \sin\theta = \frac{x}{D} = \frac{\lambda}{d} \Rightarrow d = \frac{\lambda}{\sin\theta}$$

$$\Rightarrow d = \frac{5000\times10^{-8}}{\sin 30°} = 2 \times 5 \times 10^{-5} \qquad \Rightarrow d = 1.0 \times 10^{-4} \text{ cm,}$$

Example 26:

The fraunhofer diffraction pattern of a single slit is formed at the focal plane of a lens of focal length 1m. The width of the slit is 0.3 mm. If the third minimum is formed at a distance of 5 mm from the central maximum then calculate the wavelength of light.

Solution:

$$x_n = \frac{nf\lambda}{a} \quad \Rightarrow \quad \lambda = \frac{ax_n}{fn} = \frac{3\times10^{-4}\times5\times10^{-3}}{3\times1} = 5000Å \qquad [\because \ n = 3]$$

Example 27:

A screen is placed 2m away from the single narrow slit. Calculate the slit width if the first minimum lies 5mm on either side of the central maximum. Incident plane waves have a wavelength of 5000 Å.

(1) 2 × 10^{-4} m (2) 2 × 10^{-3} cm (3) 2 × 10^{-2} m (4) None

Solution:

Here distance of the screen from the slit,

D = 2m, a = ?, x = 5 mm

$= 5 \times 10^{-3}$ m, $\lambda = 5000$ Å

$= 5000 \times 10^{-10}$ m

for the first minima,

$\sin\theta = \lambda/a = x/D$,

$a = D\lambda/x = \dfrac{2 \times 5000 \times 10^{-10}}{5 \times 10^{-3}} = 2 \times 10^{-4}$ m.

Hence correct answer is (1)

Example 28:

Fraunhofer diffraction pattern is observed at a distance of 2m on screen, when a plane-wavefront of 6000 Å is incident perpendicularly on 0.2 mm wide slit. Width of central maxima is:

(1) 10 mm (2) 6 mm (3) 12 mm (4) None of these

Solution:

Width of central maxima = $\dfrac{2f\lambda}{a}$

$= \dfrac{2 \times 2 \times 6000 \times 10^{-10}}{0.2 \times 10^{-3}} = 12$ mm Hence correct answer is (3)

Example 29:

Find the half angular width of the central bright maximum in the Fraunhofer diffraction pattern of a slit of width 12×10^{-5} cm when the slit is illuminated by monochromatic light of wavelength 6000 Å.

Solution:

$\because \sin\theta = \dfrac{\lambda}{a}$

θ = half angular width of the central maximum.

$a = 12 \times 10^{-5}$ cm, $\lambda = 6000$ Å $= 6 \times 10^{-5}$ cm

$\therefore \sin\theta = \dfrac{\lambda}{a} = \dfrac{6 \times 10^{-5}}{12 \times 10^{-5}} = 0.50 \Rightarrow \theta = 30°$

Concept Builder-4

Q.1 In single slit experiment width of slit is 10^{-3} mm wavelength of light is 5000Å, distance of screen is 2m, Find

(i) Angular position of 1st minima (ii) width of principal maxima

Q.2 Light of wavelength 5000Å is incident on a slit of width 0.1 mm. Find out the width of the central bright line on a screen distance 2m from the slit?

Q.3 Width of slit is 0.3mm. Fraunhofer diffraction is observed at 1 m focal length in focus placed lens. If third minima is at 5 mm distance from central maxima, then wavelength of light is-

(1) 7000Å (2) 6500Å (3) 6000Å (4) 5000Å

Q.4 Wavelength of light is 500 nm and width of each slit is 4μm if slits are separated by 20 μm then find no. of interference fringes inside central maxima of diffraction pattern.

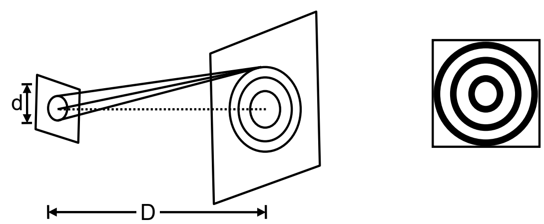
Q.5 A diffraction pattern is produced by a single slit of width 0.5mm with the help of a convex lens of focal length 40cm. If the wave length of light used is 5896 Å. then the distance of first dark fringe from the axis will be-

(1) 0.047 cm (2) 0.047 m (3) 0.047 mm (4) 47 cm

Diffraction at a Circular Aperture

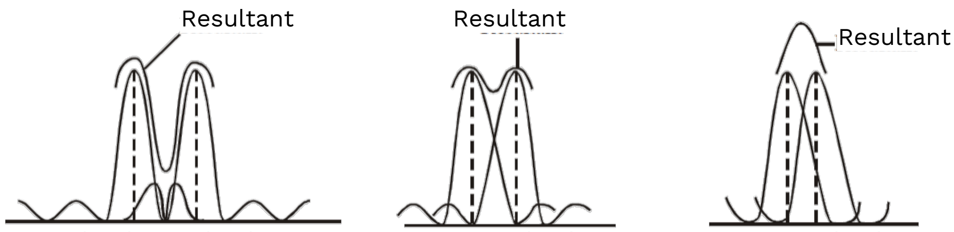
- When monochromatic light of wavelength λ is used to illuminate a circular aperture of diameter d, then
  the angular radius of the first dark ring is given by:
  $d \sin\theta = 1.22\lambda$ or $\sin\theta = (1.22\ \lambda/d)$
  and θ also represents the radius of the CB disc.
- Angular radius of central maximum is given by:

$$\sin\theta \approx \theta = \frac{1.22\lambda}{d}$$, When θ is small



Rayleigh's Criterion for Resolution

Two points are just resolved by an optical system when the central maximum of the diffraction pattern due to one falls on the first minimum of the diffraction pattern of the other.



Resolving Power (R.P.)

- If two sources are separated such that their central maxima do not overlap, their images can be distinguished and are said to be resolved.
- R.P. of an optical instrument is its ability to distinguish two neighbouring points.
- Limit of Resolution : It is the smallest distance - Linear or angular between two objects.
- The resolving power is defined as the reciprocal to limit of resolution.
  Linear R.P. = dD/λ
  Angular R.P. = d/λ
  D = Observed distance
  d = Distance between two points

(A) Telescope

Limit of resolution = $\theta = \sin^{-1}\frac{1.22\lambda}{a}$;

For small angles $\theta = \frac{1.22\lambda}{a}$

Resolving power = $\frac{1}{\text{limit of resolution}}$

(B) Microscope

Limit of resolution (the smallest distance between two object) = $x_{min} = \frac{1.22\lambda}{2\mu\sin\theta}$

Here "$\mu \sin\theta$" is known as numerical aperture

(C) Eye

The limit of resolution of human eye is 1' of arc (One minute of arc)

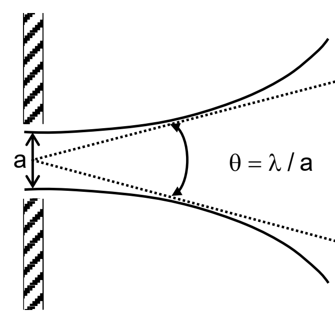
Validity of Ray Optics

- When a slit or hole of size a is illuminated by a parallel beam, then it is diffracted into an angle of $\approx \lambda / a$
- When travelling a distance Z, the size of image is $Z\lambda / a$.

  So, taking $\frac{Z\lambda}{a} \geq a \Rightarrow Z \geq \frac{a^2}{\lambda}$

  Now, distance Z_F is called Fresnel's distance. $Z_F = a^2/\lambda$
- Spreading due to diffraction is comfortable upto distance $Z_F/2$ and
- Spreading due to diffraction is prominent, for distance much greater than Z_F,
- So, image formation can be explained by ray optics for distance less than Z_F.

  Fresnel's distance is given by $\frac{a^2}{\lambda}$,



Differences Between Interference & Diffraction

INTERFERENCE	DIFFRACTION
It due to superposition of waves from two coherent source.	It due to superposition of wavelets from same wavefront.
All bright fringes are of same intensity.	Intensity decreases with the increase in the order of maxima.
The bright fringes are of same intensity.	Intensity decreases with the increase in the order of maxima.
Fringes are of same width.	Fringes are not of same width.

The number of bands is large.	The number of bands is small.
Bands are equally spaced.	Bands are unequally spaced.

Example 30:

What should be the size of the aperture of the objective of telescope which can just resolve the two stars of angular width of 10^{-3} degree by light of wavelength 5000 Å?

(1) 3.5 cm (2) 3.5 mm (3) 3.5 m (4) 3.5 km

Solution:

$d\theta = \frac{1.22\lambda}{a}$ or $a = \frac{1.22\lambda}{d\theta}$

According to question

$d\theta = 10^{-3}$ degree $= \frac{10^{-3} \times \pi}{180}$ Radian,

$\lambda - 5 \times 10^{-5}$

$a = \frac{1.22 \times 5 \times 10^{-5} \times 180}{10^{-3} \times 3.14}$ a = 3.5 cm

Example 31:

How far in advance can one detect two headlights of a car if they are separated by a distance of 1.57 m ?

Solution:

The human eye can resolve two objects when the angle between them is 1 minute of arc. Thus, we have

$D = \frac{x}{\theta}$

Here x = 1.57 m, q = 1' = $\frac{1}{60} \times \frac{\pi}{180}$ rad,

Thus,

$D = \frac{157}{\frac{1}{60} \times \frac{\pi}{180}} = \frac{10800 \times 1.57}{3.14}$ =5400m = 5.4 km

Example 32:

The numerical aperture of a microscope is 0.12, and the wavelength of light used is 600 nm. Then its limit of resolution will be nearly –

(1) 0.3 μm (2) 1.2 μm (3) 2.3 μm (4) 3.0 μm

Solution:

The limit of resolution of a microscope is given by

$x = \frac{0.61\,\lambda}{\mu \sin\theta}$

It is given that $\lambda = 6 \times 10^{-7}$ m, and the numerical aperture $\mu \sin\theta = 0.12$. Therefore,

$x = \frac{0.61 \times 6 \times 10^{-7}}{0.12}$ $= 3.05 \times 10^{-6}$ m ≈ 3μm

Concept Builder-5

Q.1 Diameter of objective of astronomical telescope is 10 cm, λ = 5000 Å. 2 objects are located at a distance of 1km from telescope. Find minimum distance between objects if the objective of telescope is just able to resolve them.

Q.2 A person wants to resolve two thin poles standing near each other at a distance of 1 km. Then the minimum separation between them should be nearly –

(1) 3 cm (2) 30 cm

(3) 3 m (4) cannot be predicted

Q.3 Focal length of objective of compound microscope is f wavelength of light is λ find minimum distance between 2 points to resolve them. (diameter of objective = a)

Q.4 Radius of lens is 0.1 mm & wavelength of light is 2000Å. Find distance from the lens upto which ray optics is valid.

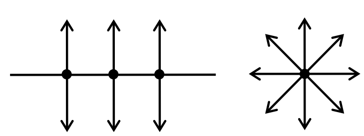
Polarisation

Light is an electromagnetic wave in which Electric and Magnetic field vectors vary sinusoidally perpendicular to each other as well as perpendicular to the direction of propagation of light.
The magnitude of electric field vector is much larger as compared to the magnitude of magnetic field vector.
Thus, we prefer to describe light in terms of electric field oscillations.

Unpolarised Light

- In ordinary light, the electric field vectors are distributed uniformly in all the possible directions perpendicular to the direction of propagation of light.
  Such light is known as the "**unpolarised light**".
- The unpolarised light is symmetrical about the direction of propagation.
- An unpolarised light is equivalent to superposition of two mutually perpendicular identical plane polarised light.

Ray Diagram of UPL & PL



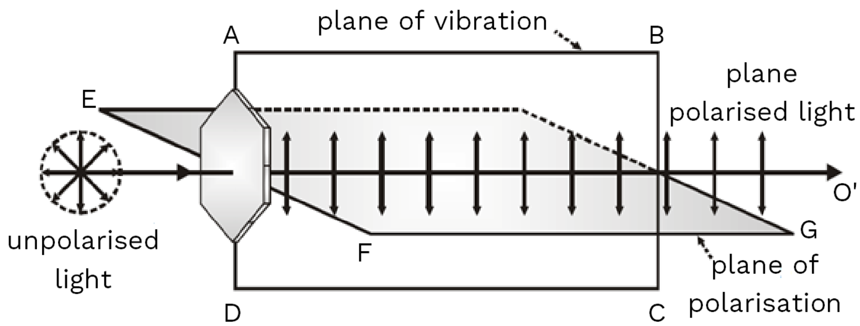
Unpolarised Light

Polarised Light

Polarization / Plane polarised Light

- If vibrations of electric field vector are limited in one direction in a plane perpendicular to the direction of propagation of light wave, then this light is called the "**plane polarised light**".
- The phenomenon of the restriction of the vibrations to a particular direction is called **"polarization"**.

- The crystal doing polarization known as **"polarizer"**.
- **Tourmaline crystal** acts as polariser.
- The lack of symmetry of vibration around the direction of wave propagation is called **polarisation**.
- Polarisation of light waves shows that they are **transverse waves.**
- The plane is which vibrations of polarised light are confined is called **plane of vibration** (ABCD).
- A plane perpendicular to the plane of vibration is called **plane of polarisation** (EFGH).
- The angle between plane of vibration and direction of propagation of wave is 90°.
- The angle between plane of polarisation and direction propagation of wave is 90°.
- If an unpolarised light is converted into plane polarised light, its intensity reduces to half.



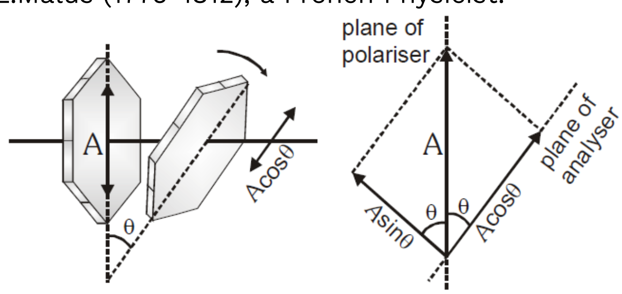
Malus's Law

When a beam of completely plane polarised light (intensity I_0) is incident on an analyser, the resultant intensity of light (I) transmitted from the analyser varies directly as the square of the cosine of the angle between plane of transmission of analyser and polariser.

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

This law is called **Malus's law**.

It is named after E.L.Malus (1775-1812), a French Physicist.



- If light of intensity I_1 emerging from one polaroid (called **polariser)** is incident on a second polariod (usually called **analyser**) the intensity of the light emerging from the second polaroid will be given by

  $I_2 = I_1 \cos^2\theta'$

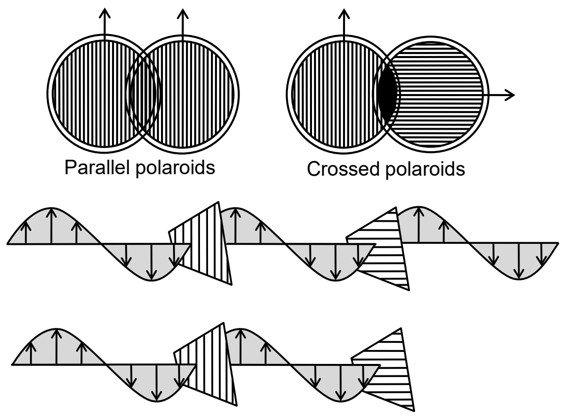
  where θ' is the angle between the transmission axis of the two polariods.

  (i) if the two polaroids have their transmission axes parallel to each other, i.e., $\theta' = 0°$,

  $I_2 = I_1 \cos^2 0° = I_1$

  (ii) if the two polaroids are crossed, (transmission axes perpendicular to each other), i.e., $\theta' = 90°$.

  $I_2 = I_1 \cos^2 90° = 0$



So, if an analyser is rotated from 0° to 90° with respect to polariser, the intensity of emergent light changes from maximum value I_1 to minimum value zero.

Example 33:

A polariser and an analyser are oriented so that maximum light is transmitted, what will be the intensity of outcoming light when analyser is rotated through 60°.

Solution:

According to Malus Law $I = I_0 \cos^2 \theta = I_0 \cos^2 60° = I_0 \left[\frac{1}{2}\right]^2 = \frac{I_0}{4}$

Methods of Polarisation

Plane polarised light can be produced by the following methods:

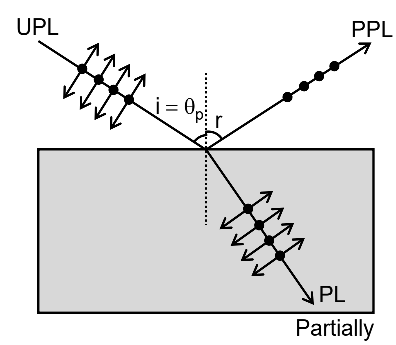
(a) by reflection
(b) by refraction (pile of plates)
(c) by dichroism
(d) by double refraction (Nicol’s prism)
(e) by scattering.

By Reflection

Brewster discovered that when light is incident at a particular angle on a transparent substance, the reflected light is completely plane polarised with vibrations in a plane perpendicular to the plane of incidence.

This specific angle of incidence is called polarising angle θ_P and is related to the refractive index μ of the material through the relation:

$\tan \theta_p = \mu$



This is known as Brewster's law.

It is named after Sir D.Brewster (1781-1868), a British Scientist.

In case of polarisation by reflection :

- For $i = \theta_p$, refracted light is plane polarised.
- For $i = \theta_p$, reflected and refracted rays are perpendicular to each other.
- For $i <$ or $> \theta_p$, both reflected and refracted light become partially polarised.

By Refraction

In this method, a pile of glass plates is formed by taking 20 to 30 microscope slides and light is made to be incident at polarising angle.

Double Refraction

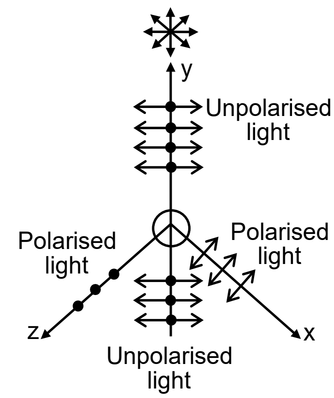
When a ray of unpolarised light incident on a calcite (or quartz) crystals, splits up into two refracted rays, the phenomenon is called double refraction.

By Dichroism

some doubly-refracting crystals have the property of absorbing strongly one of the two refracted rays and allowing the other to emerge with little loss. This selective absorption by the crystal is known as dichroism. e.g. tourmaline crystal.

By Scattering

When a beam of white light passes through a medium consisting of small particles of dust, smoke, air molecules etc. (having size of the order of wavelength of light), it is absorbed by the particle and is re-radiated in all directions. This phenomenon is called as scattering. Light scattered in a direction at right angles to the incident light is always plane-polarised.



Example 34:

If light beam is incident at polarising angle (56.3°) on air-glass interface, then what is the angle of refraction in glass?

Solution:

$\because i_p + r_p = 90°$

$\therefore r_p = 90° - i_p$

$= 90° - 56.3° = 33.7°$

Example 35:

When light of a certain wavelength is incident on a plane surface of a material at a glancing angle 30°, the reflected light is found to be completely plane polarised. Determine

(a) refractive index of given material and

(b) angle of refraction.

Solution:

Angle of incident light with the surface is 30°. Hence angle of incidence = 90° − 30° = 60°. Since reflected light is completely polarised, therefore, incidence takes place at polarising angle of incidence θ_p.

(a) $\therefore \quad \theta_p = 60°$

Using Brewster's law

$\mu = \tan\theta_p = \tan 60°$

$\therefore \quad \mu = \sqrt{3}$

(b) From Snell's law

$$\mu = \therefore = \sqrt{3} = \frac{\sin 60º}{\sin r}$$

$$\text{or} \quad \sin r = \frac{\sqrt{3}}{2} \times \frac{1}{\sqrt{3}} = \frac{1}{2}$$

$r = 30°$

Concept Builder-6

Q.1 A polariser and an analyser are oriented so that maximum light is transmitted, what will be the intensity of outcoming light when analyser is rotated through 30°.

Q.2 Two polaroids as oriented with their planes perpendicular to incident light and transmission axis making an angle of 30° with each other. What fraction of incident unpolarised light is transmitted?

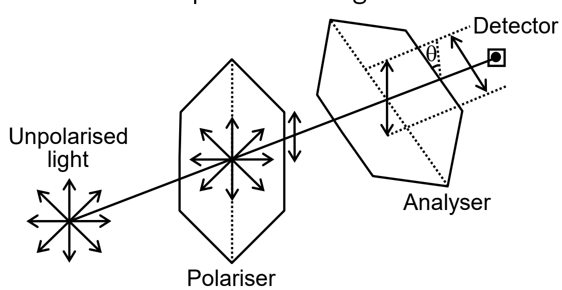
Q.3 Two polaroids P_1 & P_2 are placed with their axis perpendicular to each other. Unpolarised light I_0 is incident on P_1. A third polaroid P_3 is kept in between P_1 & P_2 such that its axis makes an angle 30° with that of P_1. Find the intensity of transmitted light through P_2 ?

Q.4 Refractive index of a medium is μ. Find the angle of incidence to polarise the incoming light after reflection.

Q.5 Image of sun formed due to reflection at air water interface is found to be very highly polarised. Refractive index of water being $\mu = 4/3$, find the angle of sun above the horizon.

Polaroids

- These are artificially prepared polarising materials (like iodosulphate of quinone) in the form of sheets or plates capable of producing strong beam of plane polarised light.
- It is a very big polarising film mounted between two glass plates and is used to obtain plane-polarised light for commercial purposes.
- Polariod allow the light oscillations parallel to the transmission axis to pass through them.
- The crystal or polaroid on which unpolarised light is incident is called **polariser**.
- The crystal or polaroid on which polaroised light is incident is called **analyser**.



If intensity of unpolarised light falling on the polariser is I_0 then only half of it $I_0/2$ is transmitted by the polariser

ANSWER KEY FOR CONCEPT BUILDERS

CONCEPT BUILDER-1

1. (2) **2.** 5000Å, 5625 Å

CONCEPT BUILDER-2

1. (a) π, (b) $\frac{2\pi}{3}$

2. I_0, $9I_0$ and $7I_0$

3. $4I_0$

4. (a) $4I_0$ (b) 0 (c) $3I_0$

5. $2I_0$ **6.** (1)

7. 25 : 1 **8.** $2I_0$

9. 2 : 1

CONCEPT BUILDER-3

1. (4) **2.** (2)

3. (2) **4.** (2)

5. $\frac{\lambda_1}{\lambda_2} = \frac{11}{10}$ **6.** (3)

7. (i) 1.25 cm (ii) 1.5 cm $[\because n = 3]$

8. 0.15

CONCEPT BUILDER-4

1. (i) $\theta = 30°$ (ii) w =2 mm.

2. 20 mm **3.** (4)

4. 10 **5.** (1)

CONCEPT BUILDER-5

1. 0.61 cm **2.** (2)

3. $\frac{1.22\lambda f}{a}$ **4.** 20 cm

CONCEPT BUILDER-6

1. $\frac{3I_0}{4}$ **2.** $\frac{3}{8}$ = 37.5 %

3. $\frac{\sqrt{3}\,I_0}{8}$ **4.** 60°

5. 37°

Exercise - I

Wave Nature of Light

1. Two sources of waves are called coherent if:-
(1) Both have the same amplitude of vibrations
(2) Both produce waves of the same wavelength
(3) Both produce waves of the same wavelength having constant phase difference
(4) Both produce waves having the same velocity

2. The light waves from two independent monochromatic light sources are given by $y_1 = 2\sin \omega t$ and $y_2 = 3\cos \omega t$
then the following statement is correct
(1) Both the waves are coherent
(2) Both the waves are incoherent
(3) Both the waves have different time periods
(4) None of the above

3. The intensity of two waves is 2 and 3 unit, then average intensity of light in the overlapping region will have the value:
(1) 2.5 (2) 6
(3) 5 (4) 13

4. Ratio of intensities of two light waves is given by 4 : 1. The ratio of the amplitudes of the waves is:
(1) 2 : 1 (2) 1 : 2
(3) 4 : 1 (4) 1 : 4

5. Two coherent monochromatic light beams of intensities I and 4I are superposed; the maximum and minimum possible intensities in the resulting beam are :
(1) 5 I and I (2) 5I and 3I
(3) 9 I and I (4) 9I and 3I

6. The energy in the phenomenon of interference:
(1) is conserved, gets redistributed
(2) is equal at every point
(3) is destroyed in regions of dark fringes
(4) is created at the place of bright fringes

7. The resultant amplitude in interference with two coherent sources depends upon:
(1) only amplitude
(2) only phase difference
(3) on both the above
(4) none of the above

8. Which of following nature of light waves is supported by the phenomenon of interference:
(1) longitudinal
(2) transverse
(3) both transverse and longitudinal
(4) None of the above

9. Phenomenon of interference is not observed by two sodium lamps of same power. It is because both waves have:
(1) not constant phase difference
(2) zero phase difference
(3) different intensity
(4) different frequencies

10. Four independent waves are represented by the equations:
$y_1 = a_1 \sin \omega t$, $y_2 = a_2 \sin \omega t$,
$y_3 = a_3 \cos \omega t$, $y_4 = a_4 \sin (\omega t + \pi/3)$
Then the waves for which phenomenon of interference will be observed are –
(1) 1 and 3 (2) 1 and 4
(3) All 1, 2, 3 and 4 (4) None

YDSE With Monochromatic Light

11. In a Young's double slit experiment, the central point on the screen is:-
(1) Bright
(2) Dark
(3) First bright and then dark
(4) First dark and then bright

12. Two coherent sources of light produce destructive interference when phase difference between them is:
(1) 2π (2) π
(3) $\pi/2$ (4) 0

13. The intensity of the central fringe obtained in the interference pattern due to two identical slit sources is I. When one of the slits is closed then the intensity at the same point is I_0. Then the correct relation between I and I_0 is:

(1) $I = I_0$

(2) $I = 2I_0$

(3) $I = 4I_0$

(4) $I = I_0/4$

14. If two line slits are illuminated by a wavelength 5×10^{-7} m and the distance between two bright fringes is 0.005 m on a screen 1 m away, then the distance between the slits is:-

(1) 10 cm (2) 1 cm

(3) 10^{-1} cm (4) 10^{-2} cm

15. The fringe width in the Young's double slit experiment is 2×10^{-4} m. If the distance between the slits is halved and the slit screen distance is double, then the new fringe width will be :-

(1) 2×10^{-4} m (2) 1×10^{-4} m

(3) 0.5×10^{-4} m (4) 8×10^{-4} m

16. The distance between two slits in a double slit experiment is 1 mm. The distance between the slits and the screen is 1 m. If the distance of 10th fringe from the central fringe is 5 mm, then the wavelength of light is:-

(1) 5000 Å (2) 6000 Å

(3) 7000 Å (4) 8000 Å

17. If the slit distance in Young's double slit experiment is reduced to $\frac{1}{3}$rd, the fringe width becomes n times. The value of n is:

(1) 3 (2) 1/3

(3) 9 (4) 1/9

18. Young's experiment is performed in air and then performed in water, the fringe width:-

(1) Will remain same

(2) Will decrease

(3) Will increase

(4) All the above types of waves

19. In Young's experiment, light wavelength 4000 Å is used, and fringes are formed at 2 metre distance and has a fringe width of 0.6 mm. If whole of the experiment is performed in a liquid of refractive index 1.5, then width of fringe will be:-

(1) 0.2 mm (2) 0.3 mm

(3) 0.4 mm (4) 1.2 mm

20. In Young's experiment, if the amplitude of interfering waves are unequal then the :

(1) contrast in the fringes decreases

(2) contrast in the fringes increase

(3) number of fringes will increase

(4) number of fringes will decrease

21. Young's experiment proves which of following fact:

(1) light is made up of particles

(2) light is made up of waves

(3) light is made up of neither waves nor particles

(4) fringe width doesn't depend upon the spacing between slits.

22. Which of following is a true statement, if in Young's experiment, separation between the slits is gradually increased :

(1) fringe width increases and fringes disappear

(2) fringe width decreases and fringes disappear

(3) fringes become blurred

(4) fringe width remains constant and fringes are more bright

23. Two beams of light having intensities I and 4I interfere to produce a fringe pattern on a screen. The phase difference between the beam is $\frac{\pi}{2}$ at point A and 2π at point B. Then find out the difference between the resultant intensities at A and B.

(1) 2I (2) 5I

(3) I (4) 4I

24. In Young's experiment, if X_{mr} and X_{mv} denotes the distances of m^{th} red and violet fringe from the central fringe. Then:

(1) $X_{mr} > X_{mv}$ (2) $X_{mr} < X_{mv}$
(3) $X_{mr} = X_{mv}$ (4) $X_{mr} + X_{mv} = 0$

25. If ratio of amplitude of two interfering source is 3 : 5. Then ratio of intensity of maxima and minima in interference pattern will be:

(1) 25 : 16 (2) 5 : 3
(3) 16 : 1 (4) 25 : 9

26. In an interference pattern the $(n+4)^{th}$ blue bright fringe and n^{th} red bright fringe are formed at the same spot. If red and blue light have the wavelength of 7800 Å and 5200 Å then value of n should be:

(1) 2 (2) 4
(3) 6 (4) 8

27. In Young's double slit experiment, wavelength of light is 6000 Å. Then the phase difference between the light waves reaching the third bright fringe from the central fringe will be:

(1) zero (2) 2π
(3) 4π (4) 6π

28. If intensity of each wave in the observed interference pattern in Young's double slit experiment is I_0. then for some point P where the phase difference is ϕ, intensity I will be:

(1) $I = I_0 \cos\phi$ (2) $I = I_0 \cos^2 \phi$
(3) $I = I_0 (1+\cos\phi)$ (4) $I = 2I_0(1+\cos\phi)$

YDSE with Glass Slab

29. When a thin transparent plate of thickness t and refractive index μ is placed in the path of one of the two interfering waves of light, then the path difference changes by:

(1) $(\mu + 1)t$ (2) $(\mu - 1)t$
(3) $\frac{(\mu+1)}{t}$ (4) $\frac{(\mu-1)}{t}$

30. In Young's experiment, monochromatic light through a single slit S is used to illuminate the two slits S_1 and S_2. Interference fringes are obtained on a screen. The fringe width is found to be w. Now a thin sheet of mica (thickness t and refractive index μ) is placed near and in front of one of the two slits. Now the fringe width is found to be w′, then:

(1) $w' = w/\mu$ (2) $w' = w\mu$
(3) $w' = (\mu - 1)\, tw$ (4) $w' = w$

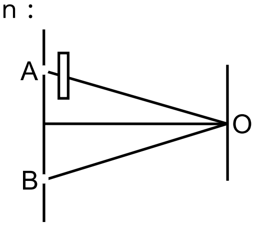
31. In Young's double slit experiment, a mica sheet of thickness t and refractive index μ is introduced in the path of ray from the first source S_1. By how much distance the fringe pattern will be displaced:

(1) $\frac{d}{D}(\mu-1)t$ (2) $\frac{D}{d}(\mu-1)t$
(3) $\frac{d}{(\mu-1)D}$ (4) $\frac{D}{d}(\mu-1)$

32. If a transparent medium of refractive index $\mu = 1.5$ and thickness $t = 2.5 \times 10^{-5}$ m is inserted in front of the slits of Young's Double slit experiment, how much will be the shift in the interference pattern? The distance between the slits is 0.5 mm and that between slits and screen is 100 cm:

(1) 5 cm (2) 2.5 cm
(3) 0.25 cm (4) 0.1 cm

33. In Young;s experiment, monochromatic light is used to illuminate the two slits A and B. Interference fringes are observed on a screen placed in front of the slits. Now if a thin glass plate is placed normally in the path of the beam coming from the slit then :



(1) The fringes will disappear
(2) The fringe width will decrease
(3) The fringe width will increase
(4) There will be no change in the fringe width

Thin Film Interference

34. Colours of thin films results from:-
(1) Dispersion of light
(2) Interference if light
(3) Absorption of light
(4) Scattering of light

35. A very thin transparent film of soap solution (thickness 0) is seen under reflection of white light. Then the colour of the film appear to be:
(1) blue (2) black
(3) red (4) yellow

Diffraction of Light

36. The bending of beam of light around corners of obstacles is called.
(1) Reflection (2) Diffraction
(3) Refraction (4) Interference

37. The waves of 600 μm wave length are incident normally on a slit of 1.2mm width. The value of diffraction angle corresponding to the first minima will be (in radian):
(1) $\frac{\pi}{2}$ (2) $\frac{\pi}{6}$
(3) $\frac{\pi}{3}$ (4) $\frac{\pi}{4}$

38. In a Fraunhofer's diffraction by a slit, if slit width is a, wave length λ, focal length of lens is f, linear width of central maxima is:
(1) $\frac{f\lambda}{a}$ (2) $\frac{fa}{\lambda}$
(3) $\frac{2f\lambda}{a}$ (4) $\frac{f\lambda}{2a}$

39. A single slit of width d is placed in the path of beam of wavelength λ. The angular width of the principal maximum obtained is:
(1) $\frac{d}{\lambda}$ (2) $\frac{\lambda}{d}$
(3) $\frac{2\lambda}{d}$ (4) $\frac{2d}{\lambda}$

40. A slit of width a is illuminated by light. For red light (λ = 6500 Å),the first minima is obtained at θ = 30° Then the value of a will be
(1) 3250 Å
(2) 6.5×10^{-4} mm
(3) 1.3 μm
(4) 2.6×10^{-4} cm

41. A slit of size 0.15 cm is placed at 2.1 m from a screen. On illuminated it by a light of wavelength 5×10^{-5} cm. The width of central maxima will be.
(1) 70 mm (2) 0.14 mm
(3) 1.4 mm (4) 0.14 cm

42. What will be the angle of diffraction for the first minimum due to Fraunhofer diffraction with sources of light of wave length 550 nm and slit of width 0.55 mm.
(1) 0.001 rad (2) 0.01 rad
(3) 1 rad (4) 0.1 rad

43. In the diffraction pattern of a single slit aperture, the width of the central fringe compared to widths of the other fringes, is :
(1) equal
(2) less
(3) little more
(4) double

44. Diffracted fringes obtained from the slit aperture are of:-
(1) same width
(2) different width
(3) uniform intensity
(4) non-uniform width & non uniform intensity

45. In a single slit diffraction pattern, if the light source is used of less wave length then previous one. Then width of the central fringe will :
(1) decrease
(2) increase
(3) remain same
(4) none of the above

Polarisation

46. Light waves can be polarised as they are
(1) Transverse
(2) Of high frequency
(3) Longitudinal
(4) Reflected

47. A polaroid is placed at 45° to an incoming light of intensity I_0. Now the intensity of light passing through polaroid after polarisation would be
(1) I_0 (2) $I_0/2$
(3) $I_0/4$ (4) Zero

48. Plane polarised light is passed through a polaroid. On viewing through the polaroid we find that when the polariod is given one complete rotation about the direction of the light one of the following is observed
(1) The intensity of light gradually decreases to zero and remains at zero.
(2) The intensity of light gradually increases to a maximum and remains at maximum.
(3) There is no change in intensity
(4) The intensity of light is twice maximum and twice zero.

49. A ray of light is incident on the surface of a glass plate at an angle of incidence equal to Brewster's angle. If represents the refractive index of glass with respect to air then the angle between reflected and refracted rays is
(1) $90 + \phi$
(2) $\sin^{-1}(\mu \cos \phi)$
(3) 90°
(4) $90° - \sin^{-1}(\sin\phi / \mu)$

50. The angle of polarisation for any medium is 60° what will be critical angle for this
(1) $\sin^{-1}\sqrt{3}$ (2) $\tan^{-1}\sqrt{3}$
(3) $\cos^{-1}\sqrt{3}$ (4) $\sin^{-1}\frac{1}{\sqrt{3}}$

51. A ray of unpolarised light is incident on a glass plate at the polarising angle 57°. Then -
(1) The reflected ray and the transmitted ray both will be completely polarised.
(2) The reflected ray will be completely polarised and the transmitted ray will be partially polarised.
(3) The reflected ray will be partially polarised and the transmitted ray will be completely polarised.
(4) The reflected and transmitted both rays will be partially polarised.

52. Electromagnetic waves are transverse in nature is evident by
(1) polarization (2) interference
(3) reflection (4) diffraction

53. When an unpolarized light of intensity I_0 is incident on a polarizing sheet, the intensity of the light which does not get transmitted is
(1) zero (2) $I_0/2$
(3) $I_0/4$ (4) $I_0/8$

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Ans.	3	2	3	1	3	1	3	4	1	4	1	3	3	4	4	1	2	2	3	1	3	2	4	1	3
Que.	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Ans.	1	4	4	2	4	2	2	4	2	2	2	2	3	3	3	3	1	4	4	1	1	2	4	3	4
Que.	51	52	53																						
Ans.	2	1	2																						

Exercise - II

1. Two coherent sources produce waves of different intensities which interfere. After interference, the ratio of the maximum intensity to the minimum intensity is 16. The intensity of the waves are in the ratio:

(1) 4 : 1
(2) 25 : 9
(3) 16 : 9
(4) 5 : 3

2. In YDSE, slits are separated by 0.5 mm, and the screen is placed 150 cm away. A beam of light consisting of two wavelengths 650 nm and 520 nm, is used to obtain interference fringes on the screen. The least distance from where the bright fringes due to both the wavelengths coincide is

(1) 9.75 mm
(2) 15.6 mm
(3) 1.56 mm
(4) 7.8 mm

3. In a Young's double slit experiment with light of wavelength λ the separation of slits is d and distance of screen is D such that D >> d >> λ. If the fringe width is β, the distance from point of maximum intensity to the point where intensity falls to half of maximum intensity on either side is:

(1) $\frac{\beta}{2}$
(2) $\frac{\beta}{4}$
(3) $\frac{\beta}{3}$
(4) $\frac{\beta}{6}$

4. Two monochromatic light beams of intensity 16 and 9 units are interfering. The ratio of intensities of bright and dark parts of the resultant pattern is:

(1) $\frac{16}{9}$
(2) $\frac{4}{3}$
(3) $\frac{7}{1}$
(4) $\frac{49}{1}$

5. This question has Statement-1 and Statement-2 of the four choices given after the Statements, choose the one that best describes the two Statements.

Statement-1: In Young's double slit experiment, the number of fringes observed in the field of view is small with longer wave length of light and is large with shorter wave length.

Statement-2: In the double slit experiment the fringe width depends directly on the wave length of light.

(1) Statement-1 is false and Statement-2 is true.
(2) Statement-1 is true, Statement-2 is true, But Statement-2 is not the correct explanation for Statement-1
(3) Statement-1 is true and Statement-2 is false.
(4) Statement-1 and Statement-2 both are true, But Statement-2 is correct explanation for Statement-1

6. At two points P and Q on a screen in Young's double slit experiment, waves from slits S_1 and S_2 have a path difference of 0 and $\lambda/4$ respectively. The ratio of intensities at P and Q will be :

(1) 2 : 1
(2) $\sqrt{2}$: 1
(3) 4 : 1
(4) 3 : 2

7. In a Young's double slit experiment, the two slits act as coherent sources of waves of equal amplitude A and wavelength λ. In another experiment with the same arrangement the two slits are made to act as incoherent sources of waves of same amplitude and wavelength. If the intensity at the middle point of the screen in the first case is I_1 and in the second case is I_2, then the ratio I_1 / I_2 is:

(1) 2
(2) 1
(3) 0.5
(4) 4

8. A mixture of light, consisting of wavelength 590 nm and an unknown wavelength, illuminates Young's double slit and gives rise to two overlapping interference patterns on the screen. The central maximum of both lights coincide. Further, it is observed that the third bright fringe of known light coincides with the 4th bright fringe of the unknown light. From this data, the wavelength of the unknown light is :

(1) 393.4 nm (2) 885.0 nm
(3) 442.5 nm (4) 776.8 nm

9. In a young's double slit experiment the intensity at a point where the path difference is $\lambda/6$ (λ being the wavelength of the light used) is I. If I_0 denotes the maximum intensity, I/I_0 is equal to

(1) $\sqrt{3}\ /\ 2$ (2) $1\ /\ 2$
(3) $3\ /\ 4$ (4) $1\ /\ \sqrt{2}$

10. The maximum number of possible interference maxima for slit–separation equal to twice the wavelength in Young's double–slit experiment is
(1) infinite
(2) five
(3) three
(4) zero

11. To demonstrate the phenomena of interference we required two sources which emits radiation of
(1) nearly the same frequency
(2) the same frequency
(3) different wavelength
(4) the same frequency and having a constant phase difference

12. Light of wavelength 550 nm falls normally on a slit of width 22.0×10^{-5} cm. The angular position of the second minima from the central maximum will be (in radians)

(1) $\pi\ /\ 4$ (2) $\pi\ /\ 8$
(3) $\pi\ /\ 12$ (4) $\pi\ /\ 6$

13. A single slit of width b is illuminated by a coherent monochromatic light of wavelength λ. If the second and fourth minima in the diffraction pattern at a distance 1 m from the slit are at 3 cm and 6 cm respectively from the central maximum, what is the width of the central maximum ? (i.e. distance between first minimum on the either side of the central maximum)

(1) 1.5 cm (2) 3.0 cm
(3) 4.5 cm (4) 6.0 cm

14. A single slit of width 0.1 mm is illuminated by a parallel beam of light of wavelength 6000Å and diffraction bands are observed on a screen 0.5 m from the slit. The distance of the third dark band from the central bright band is

(1) 3 mm (2) 9 mm
(3) 4.5 mm (4) 1.5 mm

15. If I_0 is the intensity of the principal maximum in the single slit diffraction pattern, then what will be its intensity when the slit width is doubled ?

(1) $4\ I_0$ (2) $2\ I_0$
(3) $I_0\ /\ 2$ (4) I_0

16. Unpolarized light of intensity I_0 is incident on surface of a block of glass at Brewster's angle. In that case, which of the following statements is true?
(1) transmitted light is partially polarized with intensity $I_0/2$
(2) transmitted light is completely polarized with intensity less than $I_0/2$
(3) reflected light is completely polarized with intensity less than $I_0/2$
(4) reflected light is partially polarized with intensity $I_0/2$

17. Two beams, A and B, of plane polarized light with mutually perpendicular planes of polarization are seen through a polaroid. From the position when the beam A is has maximum intensity (and beam B has zero intensity), a rotation of polaroid through 30° makes the two beams appear equally bright. If the initial intensities of the two beams are I_A and I_B respectively, then I_A / I_B equals:

(1) 1 / 3 (2) 3
(3) 3/2 (4) 1

18. A beam of unpolarised light of intensity I_0 is passed through a polaroid A and then through another polaroid B which is oriented so that its principal plane makes an angle of 45° relative to that of A . The intensity of the emergent light is :

(1) I_0 (2) I_0 /2
(3) I_0 /4 (4) I_0 /8

19. **Statement - 1 :** On viewing the clear blue portion of the sky through a Calcite Crystal, the intensity of transmitted light varies as the crystal is rotated.
Statement - 2 : The light coming from the sky is polarized due to scattering of sun light by particles in the atmosphere.
The scattering is largest for blue light

(1) Statement - 1 is true, statement - 2 is false.
(2) Statement - 1 true, statement - 2 is true, statement - 2 is the correct explanation of statement - 1.
(3) Statement - 1 is true, statement - 2 is true, statement -2 is not the correct explanation of statement - 1.
(4) Statement - 1 is false, statement - 2 is true.

20. When an un-polarized light of intensity I_0 is incident on a polarizing sheet, the intensity of the light which does not get transmitted is

(1) I_0 / 4
(2) I_0 / 2
(3) I_0
(4) zero

21. The angle of incidence at which reflected light is totally polarized for reflection from air to glass (refractive index n), is

(1) $\sin^{-1}$ (n)
(2) $\sin^{-1}$ (1/n)
(3) $\tan^{-1}$ (1/n)
(4) $\tan^{-1}$ (n)

22. If two light waves having the same frequency have intensity ratio 4 : 1 and they interfere, the ratio of maximum to minimum intensity in the pattern will be

(1) 9 : 1
(2) 3 : 1
(3) 25 : 9
(4) 16 : 25

23. Red light is generally used to observe diffraction pattern from single slit. If blue light is used instead of red light, then diffraction pattern.

(1) Will be more clear
(2) Will contract
(3) Will expanded
(4) Will not be visualized

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Ans.	2	4	2	4	4	1	1	3	3	2	4	2	2	2	1	3	1	3	2	2	4	1	2

Exercise – III (Previous Year Question)

1. In Young's double slit experiment, the slits are 2mm apart are illuminated by photons of two wavelengths λ_1 = 12000 Å and λ_2 = 10000 Å. At what minimum distance from the common central bright fringe on the screen 2m from the slit will a bright fringe from one interference pattern coincide with a bright fringe from the other? **[NEET-2013]**

(1) 8 mm (2) 6 mm
(3) 4 mm (4) 3 mm

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

(1) Diffraction pattern is not observed on the screen in the case of electrons
(2) The angular width of the central maximum of the diffraction pattern will increase
(3) The angular width of the central maximum will decrease
(4) The angular width of the central maximum will be unaffected

3. A beam of light of λ = 600 nm from a distant source falls on a single slit 1mm wide and the resulting diffraction pattern is observed on a screen 2m away. The distance between first dark fringes on either side of the central bright fringe is **[NEET - 2014]**

(1) 1.2 cm (2) 1.2 mm
(3) 2.4 cm (4) 2.4 mm

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

(1) K (2) K/4
(3) K/2 (4) Zero

5. In a double slit experiment, the two slits are 1 mm apart and the screen is placed 1 m away. A monochromatic light of wavelength 500 nm is used. What will be the width of each slit for obtaining ten maxima of double slit within the central maxima of single slit pattern? **[NEET-2015]**

(1) 0.1 mm (2) 0.5 mm
(3) 0.02 mm (4) 0.2 mm

6. Two slits in Young's experiment have widths in the ratio 1 : 25. The ratio of intensity at the maxima and minima in the interference pattern $\frac{I_{Max}}{I_{min}}$ is **[NEET-2015]**

(1) $\frac{4}{9}$ (2) $\frac{9}{4}$

(3) $\frac{121}{49}$ (4) $\frac{49}{121}$

7. At the first minimum adjacent to the central maximum of a single slit diffraction pattern the phase difference between the Huygen's wavelet from the edge of the slit and the wavelet from the midpoint of the slit is **[NEET - 2015]**

(1) $\frac{\pi}{8}$ rad (2) $\frac{\pi}{4}$ rad

(3) 2π rad (4) π rad

8. For a parallel beam of monochromatic light of wavelength 'λ', diffraction is produced by a single slit whose width 'a' is of the order of the wavelength of the light. If 'D' is the distance of the screen from the slit, the width of the central maxima will be : **[NEET-2015]**

(1) $\frac{D\lambda}{a}$ (2) $\frac{Da}{\lambda}$

(3) $\frac{2Da}{\lambda}$ (4) $\frac{2D\lambda}{a}$

9. The interference pattern is obtained with two coherent light sources of intensity ratio n. In the interference pattern, the ratio $\frac{I_{max} - I_{min}}{I_{max} + I_{min}}$ will be: **[NEET-2016]**

(1) $\frac{\sqrt{n}}{(n-1)^2}$ (2) $\frac{2\sqrt{n}}{(n+1)^2}$

(3) $\frac{\sqrt{n}}{n+1}$ (4) $\frac{2\sqrt{n}}{n+1}$

10. The intensity at the maximum in a Young's double slit experiment is I_0. Distance between two slits is $d = 5\lambda$, where λ is the wavelength of light used in the experiment. What will be the intensity in front of one of the slits on the screen placed at distance D = 10d **[NEET - 2016]**

(1) I_0 (2) $\frac{I_0}{4}$

(3) $\frac{3}{4}I_0$ (4) $\frac{I_0}{2}$

11. A linear aperture whose width is 0.02 cm is placed immediately in front of a lens of focal length 60 cm. The aperture is illuminated normally by a parallel beam of wavelength 5×10^{-5} cm. The distance of the first dark band of the diffraction pattern from the centre of the screen is : **[NEET - 2016]**

(1) 0.20 cm (2) 0.15 cm
(3) 0.10 cm (4) 0.25 cm

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

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

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

13. Two Polaroids P_1 and P_2 are placed with their axis perpendicular to each other. Unpolarised light I_0 is incident on P_1. A third polaroid P_3 is kept in between P_1 and P_2 such that its axis makes an angle 45° with that of P_1. The intensity of transmitted light through P_2 is : **[NEET - 2017]**

(1) $\frac{I_0}{2}$ (2) $\frac{I_0}{4}$

(3) $\frac{I_0}{8}$ (4) $\frac{I_0}{16}$

14. Young's double slit experiment is first performed in air and then in a medium other than air. It is found that 8^{th} bright fringe in the medium lies where 5^{th} dark fringe lies in air. The refractive index of the medium is nearly : **[NEET-2017]**

(1) 1.25 (2) 1.59
(3) 1.69 (4) 1.78

15. In Young's double slit experiment the separation d between the slits is 2 mm , the wavelength λ of the light used is 5896 Å and distance D between the screen and slits is 100 cm. It is found that the angular width of the fringes is 0.20^0. To increase the fringe angular width to 0.21^0 (with same λ and D) the separation between the slits needs to be changed to **[NEET-2018]**

(1) 1.8 mm (2) 1.9 mm
(3) 2.1 mm (4) 1.7 mm

16. Unpolarised light is incident from air on a plane surface of a material of refractive index μ. At a particular angle of incidence 'i' , it is found that the reflected and refracted rays are perpendicular to each other. Which of the following options is correct for this situation ? **[NEET - 2018]**

(1) Reflected light is polarised with its electric vector parallel to the plane of incidence
(2) Reflected light is polarised with its electric vector perpendicular to the plane of incidence
(3) $i = \sin^{-1}\left(\frac{1}{\mu}\right)$
(4) $i = \tan^{-1}\left(\frac{1}{\mu}\right)$

17. Light is incident on a polarizer with intensity I_0. A second prism called analyzer is kept at a angle of 15°, from the first polarizer then the intensity of final emergent light will be **[NEET-2018]**

(1) $I_0(\sqrt{2}-1)$ (2) $I_0(\sqrt{3}-1)$

(3) $\frac{I_0}{8}(2+\sqrt{3})$ (4) $\frac{I_0}{8}(2-\sqrt{3})$

18. In a double slit experiment, when light of wavelength 400 nm was used, the angular width of the first minima formed on a screen placed 1 m away, was found to be 0.2°. What will be the angular width of the first minima, if the entire experimental apparatus is immersed in water (m_{water} = 4/3) **[NEET - 2019]**

(1) 0.266° (2) 0.15°

(3) 0.05° (4) 0.1°

19. In a Young's double slit experiment if there is no initial phase difference between the light from the two slits, a point on the screen corresponding to the fifth minimum has path difference.

[NEET-2019 (Odisha)]

(1) $5\frac{\lambda}{2}$

(2) $10\frac{\lambda}{2}$

(3) $9\frac{\lambda}{2}$

(4) $11\frac{\lambda}{2}$

20. Angular width of the central maxima in the Fraunhofer diffraction for l = 6000 Å is θ_0. When the same slit is illuminated by another monochromatic light, the angular width decreases by 30%. The wavelength of this light is, **[NEET-2019 (Odisha)]**

(1) 1800 Å (2) 4200 Å

(3) 6000 Å (4) 420 Å

21. Assume that light of wavelength 600 nm is coming from a star. The limit of resolution of telescope whose objective has a diameter of 2 m is : **[NEET-2020]**

(1) 6.00×10^{-7} rad (2) 3.66×10^{-7} rad

(3) 1.83×10^{-7} rad (4) 7.32×10^{-7} rad

22. The Brewsters angle i_0 for an interface should be : **[NEET-2020]**

(1) $i_0 = 90°$ (2) $0° < i_0 < 30°$

(3) $30° < i_0 < 45°$ (4) $45° < i_0 < 90°$

23. In a Young's double slit experiment, if the separation between coherent sources is halved and the distance of the screen from the coherent sources is doubled, then the fringe width becomes :

[NEET-2020]

(1) one-fourth (2) double

(3) half (4) four times

24. Two coherent sources of light interfere and produce fringe pattern on a screen. For central maximum, the phase difference between the two waves will be:

[NEET-2020 (Odisha)]

(1) zero (2) π

(3) $3\pi/2$ (4) $\pi/2$

25. A lens of large focal length and large aperture is best suited as an objective of an astronomical telescope since :

[NEET-2021]

(1) a large aperture contributes to the quality and visibility of the images.

(2) a large area of the objective ensures better light gathering power.

(3) a large aperture provides a better resolution.

(4) all of the above.

26. In a Young's double slit experiment, a student observes 8 fringes in a certain segment of screen when a monochromatic light of 600 nm wavelength is used. If the wavelength of light is changed to 400 nm, the number of fringes he would observe in the same region of the screen is:

[NEET-2022]

(1) 6
(2) 8
(3) 9
(4) 12

27. A linearly polarised monochromatic light of intensity 10 lumen is incident on a polarizer. The angle between the direction of polarisation of the light and that of the polariser such that the intensity of output light is 2.5 lumen is:

[NEET-2022 (Dubai)]

(1) 75°
(2) 30°
(3) 45°
(4) 60°

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Ans.	2	3	4	3	4	2	4	4	4	4	2	4	3	4	2	2	3	2	3	2	2	4	4	1	4
Que.	26	27																							
Ans.	4	4																							