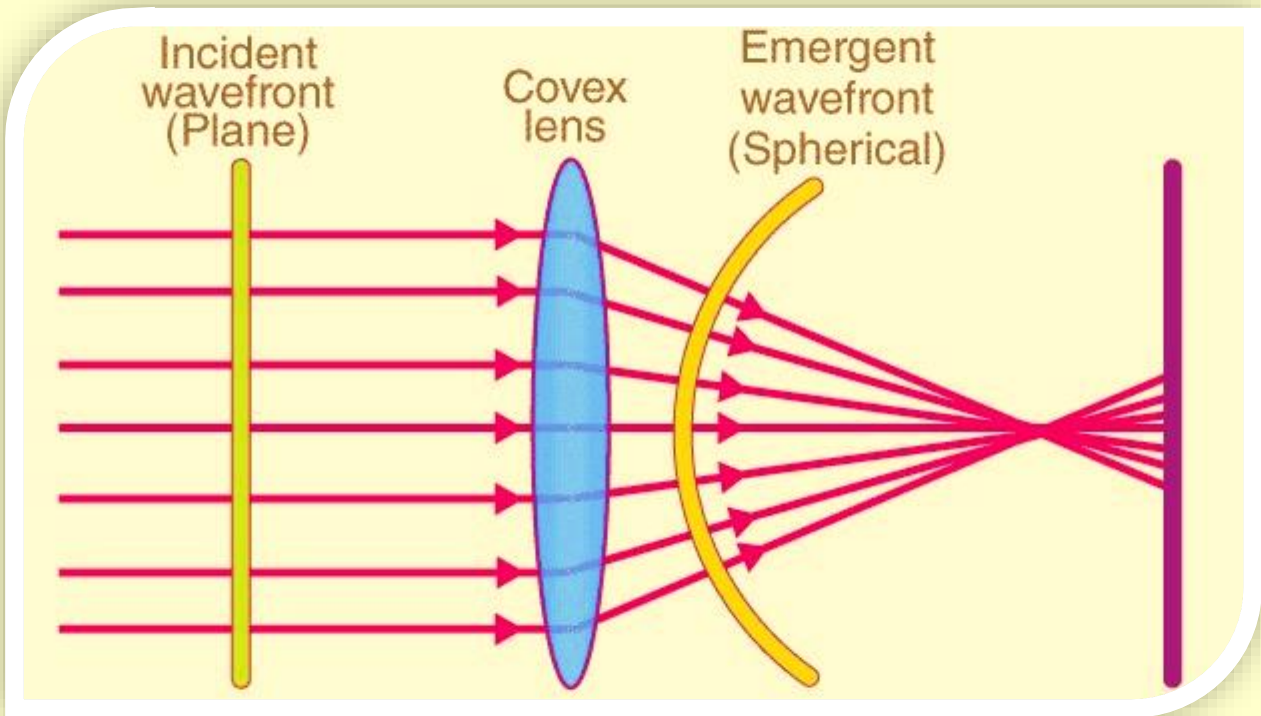
10.WAVE OPTICS



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WAVE OPTICS

Huygen's wave Theory

According to Huygen's principle a body emits light in the form of waves. Each points source of light is a center of disturbance from which waves propagates in all direction.

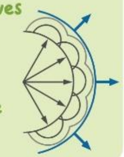
Wave Front

A wavefront is a surface along which the waves phase remains constant.

(i) The energy of wave travels in a direction perpendicular to wavefront.

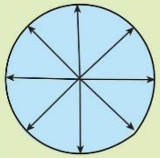
(ii) Rays are perpendicular to wavefront.

(iii) The time taken by light to travel from one wavefront to another is the same along anyray.



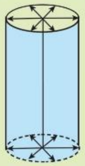
Types of wavefronts

Spherical wavelength



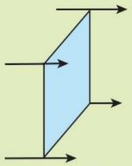
(Due to point source of light).

Cylindrical wavelength



(Due to line source of light).

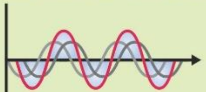
Plane wavelength



(Due to line source of light).

INTERFERENCE

Interference is a phenomenon of superposition of two coherent waves through which they transfer energy and momentum.



MATHEMATICAL INTERPRETATION OF INTERFERENCE OF TWO WAVES

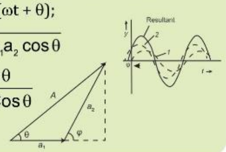
Let a1 and a2 be amplitudes of the waves and φ the phase difference between them.

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

$Y = y_1 + y_2 = A \sin(\omega t + \theta)$;

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

$\tan\theta = \dfrac{a_2 \sin\theta}{a_1 + a_2 \cos\theta}$



YOUNG'S DOUBLE SLIT EXPERIMENT

(i) For Bright Fringes

$S_2P - S_1P = \frac{X_n d}{D} = n\lambda$; d = slit width

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

Distance between central fringe and nth bright fringe : l = wavelength

= Bright fringes are also called maxima's.

(ii) For Dark Fringes $S_2P - S_1P = \frac{X_n d}{D} = \frac{(2n-1)}{2}\lambda$

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

Xn = Distance between central fright and nth dark fringe

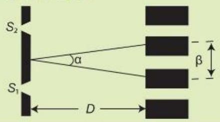
= Dark fringes are also called minima's

Fringe width:-

Fringe width of dark & bright fringes are same and given by $\beta = X_n - X_{n-1} = \frac{\lambda D}{d}$

Angular width of fringe:-

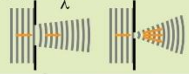
$\propto = \frac{\beta}{d} = \frac{\lambda}{d}$



DIFFRACTION

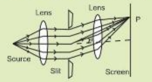
Bending of light waves around the sharp edges of opaque obstacles or aperture and their encroachment in the geometrical shadow of obstacles or aperture.

(i) Necessary Condition:- Size of obstacle (a) must be the order of wavelength (λ). i.e $\frac{a}{\lambda} > 1$

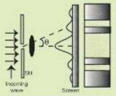


TYPES OF Diffraction

Fresenel Diffraction:- Fresnel Diffraction involves spherical wavefronts. So that source 'S' and point 'P' are at finite distance.



Fraunhofer Diffraction :- It deals with plane wavefronts and an effective viewing distance of infinity.



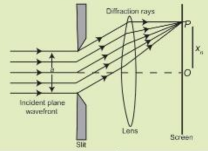
FRAVNHUFER DIFFRACTION FOR SINGLE SLIT

In this diffraction pattern central maxima is bright on the both side of it. maxima & minima occurs symmetrically.

(i) Position of secondary maxima in diffraction $\alpha \sin\theta = (2n-1)\frac{\lambda}{2}$

$\Rightarrow X_n = \frac{(2n-1)D}{2a}\lambda$

(ii) Position of secondary minima in diffraction:- $\alpha \sin\theta = n\lambda \Rightarrow X_n = \frac{n\lambda D}{\alpha}$

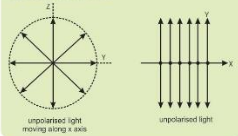


POLARISATION

The process of confining the vibrations of unpolarised light in one single plane using polariser is called polarisation.

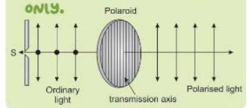
Unpdarised light

An ordinary beam of light consists of a large number of waves emitted by the atoms or molecules of the light source.



Plane Polarised light

Beam of light in which vibration of electric field vector are perpendicular to wave motion and confined to single plane only.

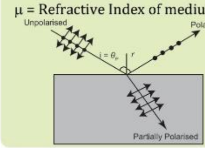


BREWSTER'S LAW

This law state that when light is incident on a transparent sustenance at polarising angle QP. the reflected light is completely plane polarised.

$\mu = \tan\theta_P$; θ_P = Polarising angle.

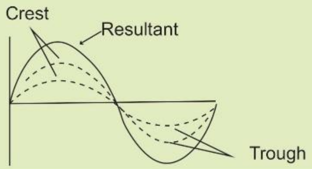
μ = Refractive Index of medium



TYPES OF INTERFRENCE

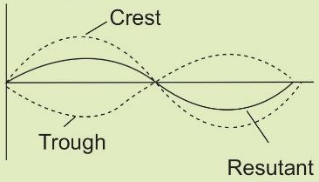
Constructive Interference

- Phase difference → $(\Delta\phi) = 2n\pi$; n = 0,1,2,......
- Path difference → $\Delta X = 2n\left(\frac{\lambda}{2}\right)$
- Time Interval → $\Delta T = 2n\left(\frac{T}{2}\right)$
- Resultant Amplitude → $A = a_1 + a_2$; if $\phi = 0, 2\pi, 4\pi$............$2n\pi$
- Resultant Intersity → $I_{max} = I_1 + I_2 + 2\sqrt{I_1I_2} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$
- $I_{max} = 4I$ where $(I_1 = I_2 = I)$



Destructive Interference

- Phase difference → $(\Delta\phi) = (2n-1)\pi$, Where n = 1,2,3,...
- Path difference → $\Delta x = (2n-1)\frac{\lambda}{2}$
- Time Interval → $\Delta T = (2n-1)\frac{T}{2}$
- Resultant Amplitude → $A = a_1 - a_2$; If $\phi = \pi, 3\pi, 5\pi$ .... $(2n-1)\pi$
- Resultant Intersity → $I_{max} = I_1 + I_2 - 2\sqrt{I_1I_2} = \left(\sqrt{I_1} - \sqrt{I_2}\right)^2$
- $I_{min} = 0$ (When $I_1 = I_2 = I$)



Resolving Power (R.P)

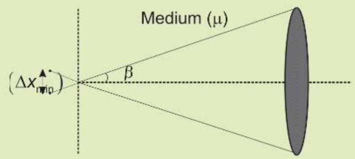
Resolving power an optical instrument is its ability to distinguish two closely placed point.

R.P for Microscope

(i) The minimum distance to form separate images of two objects.

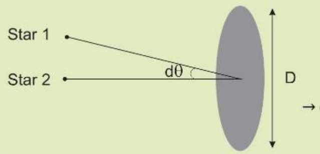
$$\Delta X_{min} = \frac{1.22\lambda}{2\mu \sin\beta}$$

$$R.P = \frac{1}{\Delta X_{min}} = \frac{2\mu \sin\beta}{1.22\lambda}$$



R.P for Telescope

Resolving limit of a telescope is smallest angular separation (dθ) between two distant objects.



$\rightarrow d\theta = \frac{1.22\lambda}{D}$; (i) $R.P = \frac{1}{d\theta} = \frac{D}{1.22\lambda}$; $D = A_{perture}$ of objective Lens.

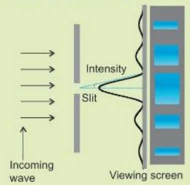
WIDTH OF CENTRAL MAXIMUM

The distance between two secondary minima formed on two sides of central maximum is known as width of central maximum.

$W = \frac{2f\lambda}{\alpha}$

f = focal length of convex lenses

α = Slit width

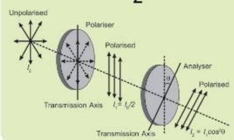


MALUS' LAW

$I_2 = K(A\cos\theta)^2 = KA^2\cos^2\theta$

$I_2 = I_1\cos^2\theta$; I = intensity

(i) $I_{Polarised} = \frac{I_{unpolarised}}{2}$



Wave Optics

Interference

Huygen's Principle and Interference

Physical Optics is a branch of optics that deals with the nature of light. Several theories have been proposed to explain the nature of light. There is no single theory that can completely explain all the observed phenomena with regard to light.

Newton's Corpuscular Theory

According to this theory, light is a stream of tiny particles, called corpuscles, that carry energy and move along straight lines (in a homogeneous medium). Using this theory, the rectilinear propagation of light, the laws of reflection; and to some extent, refraction and total internal reflection can be explained. This theory is not in use because

a. it predicted that light travels faster in a denser medium. Foucalt's rotating mirror experiment (speed of light in different media was determined) disproves this.

b. it cannot explain satisfactorily the phenomenon of simultaneous reflection and refraction, at a refracting surface.

c. it cannot explain the phenomena of interference, diffraction and polarization.

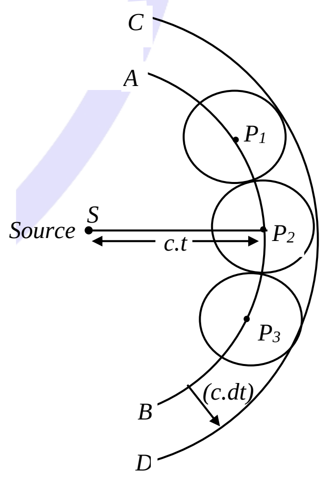
Huygens' Wave Theory

According to this theory, every source of light is a source of waves spreading outwards in all directions. Fresnel modified this theory to explain rectilinear propagation, reflection, refraction, total internal reflection, dispersion, interference, diffraction and polarisation. However, this theory fails to explain the instantaneous emission of photoelectrons in photoelectric effect.

Features of Huygen's Wave theory

1. **Wave Optics** is based on wave theory of light put forward by Huygens. According to wave theory, light is a form of energy which travels through a medium in the form of transverse waves.

2. **A wavefront** is defined as the locus of all particles of a medium, which are vibrating in same phase. When a source of light is a point source, the wavefront is spherical. When a source is linear, the wave front is cylindrical. At very large distances from the source, a portion of spherical or cylindrical wavefront appears to be plane. A wave front travels parallel to itself and perpendicular to the rays.



3. **Huygen's principle** of geometrical construction of a wavefront at any instant says:

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

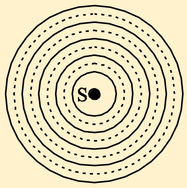
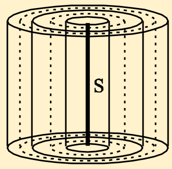
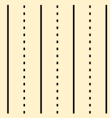
(ii) The secondary wavelets travel in all directions with the speed of light in the medium.

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

Using Huygen's principle, we can prove the laws of reflection, refraction and associated phenomena.

A point source generates a spherical wavefront and a line source generates a cylindrical wavefront. The wavefront due to a source at infinity is considered a plane wavefront.

Huygen's theory assumes that light waves are elastic mechanical longitudinal waves in a medium called ether.

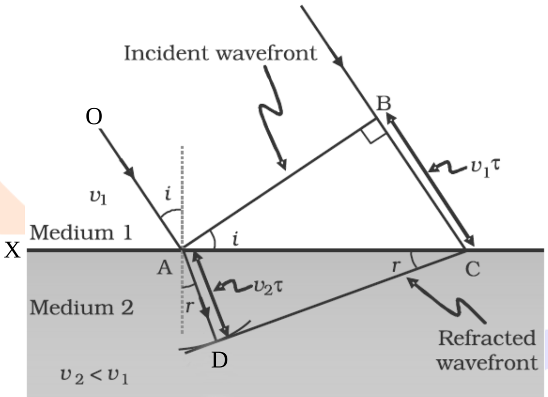
Source	Wavefront	Schematic representation
Point	Spherical	
Linear	Cylindrical	
Source at large distance	Planar	

Reflection of a plane wave by a plane surface and proof of laws of reflection using Huygens' Principle

Let XY represent the surface separating medium 1 and medium 2 as shown in the figure. Let v_1 and v_2 be the speeds of light in medium 1 and medium 2 respectively. Let a plane wavefront AB propagating in the direction OA incident on the interface at an angle 'i' as shown in the figure. If 't' is the time taken by the wavefront to travel the distance BC, then,

$$BC = v_1 t$$

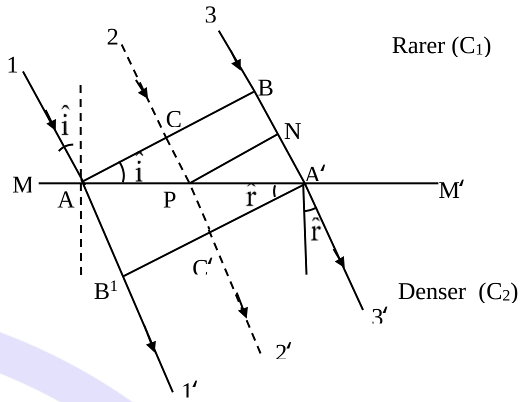
In order to determine the shape of refracted wavefront, we construct a sphere of radius v_2t from point A inside the second medium. Draw the tangent CD to this sphere from C. Then represents the refracted wavefront. Further, AD = v_2t



Refraction on the basis of Huygens theory

MM[1] is a surface separating two media rarer and denser figure. C_1 is the velocity light in rarer medium and C_2 in the denser.

AB is the incident plane wave front A'B' is the refracted wavefront such that BA' = C_1t and AB' = C_2t



Draw PN ⊥ BA^1 so that CP = BN

From ΔABA′ and ΔPNA′, $\frac{AA'}{PA'} = \frac{BA'}{NA'}$ and from Δ AA′B′ and Δ PC′A′

We have $\frac{AA^1}{PA^1} = \frac{AB^1}{PC^1}$ giving

$$\frac{BA'}{NA'} = \frac{C_1 \times t}{NA'} = \frac{AB'}{PC'} = \frac{C_2 \times t}{PC'}$$

Or $\frac{NA'}{C_1} = \frac{PC'}{C_2} \therefore \frac{CP}{C_1} + \frac{PC'}{C_2} = \frac{BN}{C_1} + \frac{NA'}{C_1} = \frac{BA'}{C_1}$

Hence B′C′A′ is the true refracted wavefront

Further $\sin i = \frac{BA'}{AA'} = \frac{C_1 t}{AA'}$ and $\sin r = \frac{AB'}{AA'} = \frac{C_2 t}{AA'}$ giving $\frac{\sin i}{\sin r} = \frac{C_1}{C_2} = {}_1n_2$ which is Snell's law.

Also, incident ray, refracted ray and the normal to the surface at point of incidence all lie in the same plane.

Hence laws of reflection and refraction are established on the basis of wave theory.

Phase difference and path difference

As the concepts of phase and path difference are often used in this chapter, these concepts are briefly discussed below.

Phase, optical path, amplitude and intensity

The argument of sine ratio or cosine ratio in the expressions for wave disturbance is given by

$y = a \sin(\omega t - kx)$ or

$y = a \cos(\omega t - kx)$

i.e., $\phi = (\omega t - kx)$ is called the phase of the wave. Suppose we write $\phi = k\left(\frac{\omega}{k}.t - x\right)$

or $\phi = \frac{2\pi}{\lambda}\ [t.\ \frac{\omega}{k} - x] = \frac{2\pi}{\lambda}\ (tv - x)$ then, $(tv - x) = \Delta$ is called the optical path traversed by the wave in a time t.

So the phase $\phi = \frac{2\pi}{\lambda}\ (\Delta)$ is a function of either t or x or both.

The intensity at any point along the path of a beam is proportional to square of the amplitude of light at that point. i.e., $I \propto a^2$

Consider two light waves of amplitudes A_1 and A_2 and frequencies ν_1 and ν_2 respectively emitted from two different sources and propagated along positive x axis. They are mathematically represented by

$y_1 = a_1 \sin(\omega t - k_1x_1)$ … (7)

$y_2 = a_2 \sin(\omega_2 t - k_2x_2)$ … (8)

The phase difference $\Delta\phi$ between the two waves is given by

$\Delta\phi = \phi_1 - \phi_2 = (\omega_1 t - k_1x_1) - (\omega_2 t - k_2x_2) = (\omega_1 - \omega_2)\ t + (k_2x_2 - k_1x_1)$

$= (\omega_1 - \omega_2)\ t + 2\pi\left(\frac{x_2}{\lambda_2} - \frac{x_1}{\lambda_1}\right)$

If $\omega_1 = \omega_2$ then $\lambda_1 = \lambda_2 = \lambda$ and $\Delta\phi = \frac{2\pi}{\lambda}\ (x_2 - x_1) = \frac{2\pi}{\lambda}\ .\ \Delta x$

Δx is the optical path difference between the two waves in general.

As already discussed propagation of light energy is nothing but propagation of vibrating electric and magnetic vectors. Electric vector represented by $\vec{E}$ and magnetic vector represented by $\vec{H}$ vibrate in phase and remain always mutually perpendicular. The direction of propagation of these vectors i.e., energy propagation direction represented by $\vec{P}$ (the Pointing vector) $\propto (\vec{E} \times \vec{H})$ which is perpendicular to vibration directions of $\vec{E}$ as well as $\vec{H}$. $\vec{E}$ $\vec{H}$ and $\vec{P}$ form an orthogonal triplet. Owing to the fact that some significant effects of light on matter are consequences of electric properties of light, $\vec{E}$ is taken to represent the light wave and not $\vec{H}$.

Hence to be precise y which was referred to as light disturbance in the previous section represents the light wave $\vec{E}$

Interference of light

Interference of light is the phenomenon of modification in the intensity of light due to redistribution of light energy in the region of superposition of two or more light waves.

- Both transverse waves and longitudinal waves exhibit interference.
- An important illustration of interference of longitudinal waves (sound waves) is the phenomenon of beats.

The modification of light intensity can be explained using the **principle of superposition**, which is stated as follows.

When light waves from two or more sources reach a point simultaneously, the electric field of the resultant light wave is the vector sum of the electric fields due to the individual waves.

If $\vec{e}_1$ and $\vec{e}_2$ are the electric fields at a point due to two light waves, then the resultant electric field $\vec{e}$ at that point is given by $\vec{e} = \vec{e}_1 + \vec{e}_2$.

Constructive interference is said to take place at a point if two light waves arrive at that point in phase leading to formation of a bright point.

Destructive interference is said to take place at a point if two light waves arrive at that point out of phase leading to the formation of a dark point.

Conditions for Interference

1. Essential condition for sustained interference

The sources must be coherent. Two sources are said to be coherent, if they emit light waves of same frequency with constant phase difference.

2. Additional conditions for a distinct interference pattern

(a) The waves must have equal or nearly equal amplitudes. This helps in providing good contrast between the bright and dark points (fringes).

(b) The two sources should be close to each other (This ensures that the waves from sources travel in the same direction for good contrast).

(c) The two sources must be narrow. If a source is broad, light waves from different points of the source will have phase difference. This results in many interference patterns which overlap and affect the clarity of the interference pattern.

Two independent sodium vapour lamps are not coherent as light waves from them cannot have a constant phase relationship.

Methods to obtain coherent sources

Coherent sources can be obtained by employing following methods.

(1) Division of wavefront

(a) A wavefront can be divided into two parts using a opaque plank with two small openings.

Example: Young's double slit experiment.

(b) A wavefront can be divided into two parts by reflecting a part of it.

Example: Lloyd's mirror.

(c) A wavefront can be divided into two parts by refracting it.

Example: Fresnel biprism.

(2) Division of amplitude

Two coherent beams of light can be obtained by partial reflection and partial refraction.

Example: Air wedge, Newton's rings.

Theory of interference

Consider two electromagnetic waves of equal angular frequency ω and with a constant phase difference ϕ superposing in a region of space. Let E_1 and E_2 be the amplitudes of these waves and the equations representing them be

$e_1 = E_1 \sin \omega t$ ... (1)

$e_2 = E_2 \sin(\omega t + \phi)$ ... (2)

The resultant is given by $e = E_R \sin(\omega t + \theta)$, where

$$E_R = \sqrt{E_1^2 + 2E_1E_2 \cos\phi + E_2^2}$$

and $$\tan\theta = \frac{E_2 \sin\phi}{E_1 + E_2\cos\phi}$$

Condition for Constructive Interference

The amplitude of the resultant wave $E_R = \sqrt{E_1^2 + 2E_1 E_2 \cos\phi + E_2^2}$ is maximum at those points where for given two waves $\cos\phi = +1$ i.e., phase difference $\phi = 2m\pi$.

The corresponding path difference, $\delta = \frac{\lambda}{2\pi} \times \phi = \frac{\lambda}{2\pi} \times 2m\pi = m\lambda$ where m = 0, 1, 2, 3 . . . At the points, satisfying this condition we have

$$(E_R)_{max} = \sqrt{E_1^2 + 2E_1E_2 + E_2^2} = (E_1 + E_2)$$

Therefore, the intensity is maximum at these points.

Condition for Destructive Interference

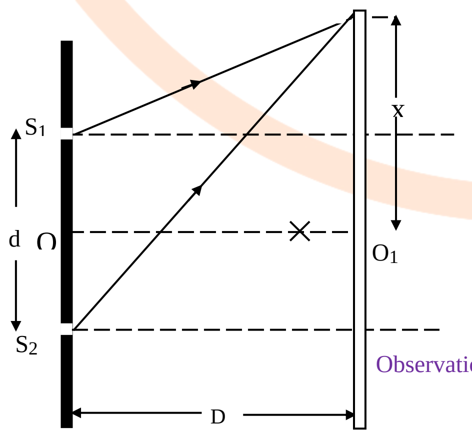
At those points, where the phase difference is such that $\cos\phi = -1$ i.e., phase difference, $\phi = (2m+1)\pi$, the corresponding path difference,

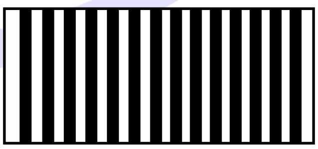
$$\delta = \frac{\lambda}{2\pi} \times \phi = \frac{\lambda}{2\pi} \times (2m+1)\pi = (2m+1)\frac{\lambda}{2},\ m = 0, 1, 2, 3, \ldots$$

The amplitude is minimum at these points and hence, the intensity is also minimum. For waves of equal amplitude, the minimum resultant intensity is zero.

(The path difference for destructive interference can also be written as, $\delta = (2m-1)\frac{\lambda}{2}$, where m = 1, 2, 3, …)

Young's Double Slit experiment





Interference pattern

If λ = wavelength of light used, D = distance between the slits and the strain and d = distance between the slits, then

- Distance of m[th] bright fringe from the central bright fringe, $x_m^{bright} = m\left(\frac{D\lambda}{d}\right)$, **m = 0, 1, 2, …**
- Distance of m[th] dark fringe from the central bright fringe, $x_m^{dark} = \left(\frac{2m-1}{2}\right)\left(\frac{D\lambda}{d}\right)$, **m = 1, 2, 3, …**

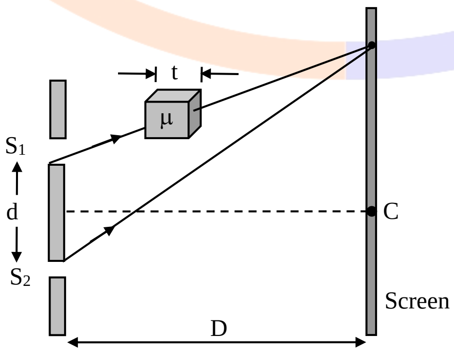
- Fringe width $\beta = \dfrac{\lambda D}{d}$

- If the amplitudes of the interfering waves are E_1 and E_2 then,
  - maximum intensity $I_{max} \propto (E_1 + E_2)^2$
  - minimum intensity $I_{min} \propto (E_1 - E_2)^2$
  - $\dfrac{I_{max}}{I_{min}} = \left(\dfrac{E_1 + E_2}{E_1 - E_2}\right)^2$
  - $E_{R\,(resultant)} = \sqrt{E_1^2 + E_2^2 + 2E_1E_2\cos\varphi}$
  - $I_{res} = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$
- In Young's Double Slit (YDS) experiment,
  - the central fringe is always bright as the waves reaching this portion of the screen are in phase.
  - if one of the slits is narrower than the other, then the dark bands will not be of zero intensity and intensity ratio of the maximum to minimum is $\dfrac{I_{max}}{I_{min}} = \dfrac{(E_1 + E_2)^2}{(E_1 - E_2)^2}$.
  - $I_{RG} = I_1 + I_2 + 2\sqrt{II_2}\cos\phi$
  - if a thin transparent slab of refractive index n is introduced in the path of one of the interfering waves, the entire fringe pattern shifts towards the side on which the slab is introduced. There is no change in the fringe pattern. The number of fringes that shift is given by $s = \dfrac{(n-1)t}{\lambda}$, where t is the thickness of the slab and s is an integer.
- If YDS experiment is conducted in water, the fringes become narrower. This is because wavelength of a given colour is less in water than that in air.
- Characteristics of interference pattern when double slit arrangement is illuminated with white light
  - the central bright fringe appears white.
  - each of the other bright fringes consists of coloured parallel strips.

The colour of the fringe nearest to the central white fringe on either side is red.

Shifting of Fringe Pattern in YDSE

If a transparent thin film of mica or glass is put in the path of one of the waves, then the whole fringe pattern gets shifted towards the slit in front of which glass plate is placed.



(1) Fringe shift $= \dfrac{D}{d}(n-1)\,t = \dfrac{\beta}{\lambda}(n-1)\,t$

(2) Additional path difference = (n –1) t

(3) If shift is equivalent to m fringes then $n = \frac{(m-1)t}{\lambda}$ or $t = \frac{m\lambda}{(n-1)}$

(4) Shift is independent of the order of fringe (i.e., shift of zero order maxima = shift of n^{th} order maxima)

(5) Shift is independent of wavelength.

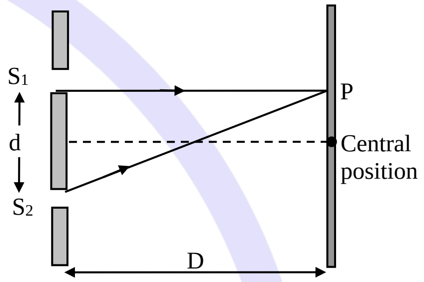
Fringe Visibility (V)

With the help of visibility, knowledge about coherence, fringe contrast an interference pattern is obtained.

$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = 2\frac{\sqrt{I_1 I_2}}{(I_1 + I_2)}$ If $I_{min} = 0$, $V = 1$ (maximum) i.e., fringe visibility will be best.

Also if $I_{max} = 0$, $V = -1$ and If $I_{max} = I_{min}$, $V = 0$

Missing Wavelength in Front of One Slit in YDSE



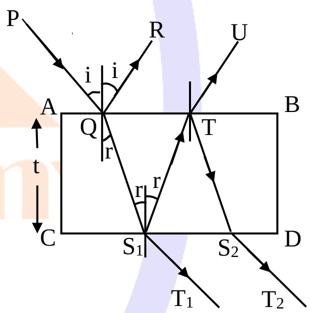
Suppose P is a point of observation infront of slit S_1 as shown.

Missing wavelength at P $\lambda = \frac{d^2}{(2n-1)D}$

By putting n = 1, 2, 3, . . .

Missing wavelengths are $\lambda = \frac{d^2}{D}, \frac{d^2}{3D}, \frac{d^2}{5D}, \ldots$

Interference in Thin Films



A film of a transparent refracting material whose thickness is very small is called a thin film. For example: Oil spreads over the surface of water in the form of a thin film. Consider a beam of ***white light*** incident on a thin transparent film of thickness t and refractive index n.

(i) Interference Due to Reflected Light

If we consider the interference between reflected rays QR and TU, for ***constructive interference***,

$2nt \cos r - \frac{\lambda}{2} = m\lambda$ i.e. $2nt \cos r = m\lambda + \frac{\lambda}{2} = (2m+1)\frac{\lambda}{2}$, where m = 0, 1, 2, 3,….

(The colours corresponding to wavelengths satisfying this condition will be present).

For ***destructive interference***,

$2nt \cos r - \frac{\lambda}{2} = (2m-1)\frac{\lambda}{2}$ i.e. $2nt \cos r = m\lambda$, where m = 1, 2, 3,….

(The colours corresponding to wavelengths satisfying this condition will be absent).

(ii) Interference due to Transmitted Light

If we consider interference between two transmitted rays S_1T_1 and S_2T_2,

For ***constructive interference*** $2nt \cos r = m\lambda$

For ***destructive interference*** $2nt \cos r = (2m-1)\frac{\lambda}{2}$ where m = 1, 2, 3,….

It is seen that, the conditions for a thin film to appear bright in the reflected system is the reverse of those in the transmitted system.

Illustrations

1. A transverse wave has wave velocity and maximum particle velocity respectively as 2.5×10^{10} cm s^{-1} and $\pi \times 10^8$ cm s^{-1}. Given λ = 500 nm. The amplitude A of the wave in meters is

(A) 10^{-7} cm (B) 10^{-9} cm (C) 10^{-6} cm (D) 10^{-5} cm

Ans (A)

$$\frac{A\omega}{\omega/k} = Ak = \frac{\pi\times10^{8}}{2.5\times10^{10}} = 0.4\,\pi10^{-2}$$

But, $k = \frac{2\pi}{\lambda} = \frac{2\pi}{500}\times10^{7}\ \text{cm}^{-1} = 0.4\,\pi\times10^{5}\ \text{cm}^{-1}$

$\therefore\ A = \frac{0.4\pi\times10^{-2}\ \text{cm}^{-1}}{0.4\pi\times10^{5}\ \text{cm}^{-1}} = 10^{-7}$ cm or 10^{-9} m.

2. A transverse wave is represented by $y = 3\text{ (cm)} \cos \pi\,[100\ t(s^{-1}) - x\ (cm^{-1})]$. The wave length, wave velocity, maximum particle velocity and the frequency ν (t and x are in units of s and m) are

(A) 2 cm, 100 cm s^{-1}, 300 π cm s^{-1}, 50 s^{-1}
(B) 1 cm, 50 cm s^{-1}, 300 π cm s^{-1}, 50 s^{-1}
(C) 2 cm, 100 cm s^{-1}, 150 π cm s^{-1}, 100 s^{-1}
(D) 2 cm, 100 cm s^{-1}, 150 π cm s^{-1}, 100 s^{-1}

Ans (A)

$\lambda = \frac{2\pi}{K} = \frac{2\pi}{\pi\,\text{cm}^{-1}} = 2$ cm. $\omega = 100\,\pi\ s^{-1}$

$\therefore\ v$ = wave velocity = $\frac{\omega}{k} = \frac{100\,\pi\,s^{-1}}{\pi\,\text{cm}^{-1}} = 100$ cm s^{-1}

Max particle velocity = $A\omega = 3\times100\,\pi$, cm s^{-1} (As A = 3 cm)

= 300 π cm s^{-1}

Frequency $\nu = \frac{\omega}{2\pi} = \frac{100\,\pi\,s^{-1}}{2\pi} = 50\ s^{-1}$.

3. A transverse wave travelling in a medium of refractive index '2' is given by $y = A \sin\left[2\pi m\times10^{15}\,t - \frac{2\pi}{s}\times10^{5}\,x\right]$ where m and s are constants. If λ = 600 nm and velocity of light in vacuum is 3×10^{10} cm s^{-1} then the numerical value of $m\times s$ is

(A) 3 (B) 0.5 (C) 1.5 (D) 1

Ans (C)

On comparing with $y = a \sin(\omega t - kx)$

$\omega = 2\pi m\times10^{15}$ and $k = \frac{2\pi}{s}\times10^{5}$ we have

wave velocity = $\frac{\omega}{k} = \frac{3\times10^{10}}{2}$ cm s^{-1} $= 1.5\times10^{10}$ cm s^{-1}. Hence, ms = 1.5.

4. Young's double slit is illuminated by coherent beams each of intensity I and of wavelength λ. The intensity of the bright fringe is I_0. The intensity at a point on the screen where the path difference is $\lambda/4$ is given by

(A) zero (B) $\frac{I_0}{2}$ (C) $\frac{I_0}{4}$ (D) $\frac{I_0}{8}$

Ans (B)

$I = I_0 \cos^2\frac{\delta}{2}$. $\delta = \frac{2\pi}{\lambda}\cdot\frac{\lambda}{4} = \frac{\pi}{4}$ $\quad\therefore\ \cos^2\frac{\delta}{2} = \frac{1}{2}$ $\quad\therefore\ I = \frac{I_0}{2}$.

5. Young's double slit set up is illuminated by white light

(A) Central fringe is a dark fringe. Other fringes are coloured
(B) Central fringe is a bright fringe other fringes are coloured
(C) Central fringe is a dark fringe other fringes are not coloured
(D) Central fringe is a bright fringe other fringes are not coloured

Ans (B)

For the central fringe the path difference is zero irrespective of wavelength. So it is a bright fringe and other fringes are coloured as bright fringes of same order for different colours (wave lengths) are located at different positions.

6. In a Young's double slit set up the slit widths are in the ratio 2:3. On assuming that the amplitudes of the light coming out of the slits are proportional to the slit widths, the ratio of I_{max} to I_{min} is

(A) 81:16 (B) 25:1 (C) 169:25 (D) 9:4

Ans (B)

The amplitudes of interfering beams are in the ratio 2:3. $\therefore$ The ratio of I_{max} to I_{min}

i.e., $\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \frac{5^2}{1} = 25.$

7. There are two double slit set up, similar to YDS. In the first one, two slits send out coherent beams of same amplitude and same frequency whereas in the second they send out incoherent beams of same amplitude and same frequency as earlier. The ratio of intensity at the centre of the screen in the first case to that in the second is

(A) 4:1 (B) 2:1 (C) 1:2 (D) 1:1

Ans (B)

In the I set up the intensity at the centre of the screen is proportional to 4I where I is the intensity of each of the interfering beam. In the second set up the intensity at that point is I + I = 2I beams being incoherent.

8. The intensities of two light sources are 5 units and 7 units respectively. If the phase difference between the two waves is $\frac{\pi}{2}$, the resultant intensity at the point of superposition is

(A) 5 units (B) 7 unit (C) 12 units (D) 35 units

Ans (C)

Let R = resultant amplitude, we have $R^2 = a_1^2 + a_2^2 + 2a_1a_2\cos\theta$. But $\theta = \frac{\pi}{2}$.

Therefore, $R^2 = a_1^2 + a_2^2$. But $I \propto R^2$

$\therefore I = I_1 + I_2 \quad \Rightarrow I = 5 + 7 = 12$ units.

9. The ratio of maximum to minimum intensities in a interference pattern is 36 : 1. The ratio of the amplitudes of the two waves is

(A) 3 : 2 (B) 2 : 3 (C) 5 : 1 (D) 1 : 5.

Ans (C)

$\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2} = \frac{25}{1} \Rightarrow \frac{a_1+a_2}{a_1-a_2} = \frac{5}{1} \Rightarrow 5a_1 - 5a_2 = a_1 + a_2 \Rightarrow 4a_1 = 6a_2 \;\therefore\; \frac{a_1}{a_2} = \frac{6}{4} = \frac{3}{2}$

10. In a Young's double slit experiment, fringe width is found to be 0.6 mm. If the whole apparatus is immersed in water of refractive index $\frac{4}{3}$ without disturbing the geometrical arrangement, the new fringe width will be

(A) 0.30 mm (B) 0.40 mm (C) 0.45 mm (D) 0.8 mm

Ans (C)

$\beta = \frac{\lambda D}{d}$ and $\beta' = \frac{\lambda' D}{d}$ or $\frac{\beta}{\beta'} = \frac{\lambda}{\lambda'}$ or $\frac{\beta'}{\beta} = \frac{\lambda'}{\lambda} = \frac{1}{n}$. $\therefore \beta' = \frac{\beta}{n} = \frac{0.6}{\frac{4}{3}} = 0.45$ mm

11. In Young's double slit experiment, the slits are of equal width. The maximum intensity at a point in the interference pattern obtained on the screen is 100 units. Now the intensity of light from one of the slits is reduced to 36 % by reducing the slit width. The intensity of light at the same point is

(A) 64 units (B) 60 units (C) 34 units (D) 74 units

Ans (A)

Intensity $\propto$ slit width. I_1, I_2 be the intensities of light emerging out of the slits.

$$\frac{I_1}{I_2} = \frac{W_1}{W_2} = \frac{W_1}{0.36W_1} = \frac{100}{36} = \frac{25}{9}$$

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

$= 25 + 9 + 2\sqrt{25 \times 9} \Rightarrow I = 64$ units.

12. *Light of wavelength 5600 Å is used to illuminate the slits in Young's double slit experiment. The separation between the slits is 0.8 mm. The angular fringe width of a dark fringe on a screen kept at 160 cm from the slits is

(A) 4.8×10^{-4} rad (B) 7×10^{-4} rad (C) 9×10^{-4} rad (D) 6×10^{-4} rad

Ans (B)

Angular fringe width, $\theta = \frac{\beta}{D}$; Fringe width, $\beta = \frac{\lambda D}{d}$

$$\theta = \frac{\left(\frac{\lambda D}{d}\right)}{D} = \frac{\lambda}{d} = \frac{5600 \times 10^{-10}}{0.8 \times 10^{-3}} \Rightarrow \theta = 7 \times 10^{-4} \text{ rad.}$$

13. *In a Young's double slit experiment, the 12th maximum in an interference pattern obtained with wavelength λ_1 is at a distance x_1 from the central maximum. The 9th maximum obtained with wavelength λ_2 is at a distance x_2. Then $\frac{x_1}{x_2}$ is given by

(A) $\frac{4\lambda_2}{3\lambda_1}$ (B) $\frac{3\lambda_1}{4\lambda_2}$ (C) $\frac{3\lambda_2}{4\lambda_1}$ (D) $\frac{4\lambda_1}{3\lambda_2}$

Ans (D)

$$x_m^{bright} = \frac{m\lambda D}{d}, \ m = 0, 1, 2, 3, \ldots$$

$$x_1 = 12 \times \frac{D}{d}\lambda_1, \quad x_2 = 9 \times \frac{D}{d} \times \lambda_2 \quad \therefore \frac{x_1}{x_2} = \frac{12\lambda_1}{9\lambda_2} = \frac{4}{3}\frac{\lambda_1}{\lambda_2}$$

14. In a given region of a thin film, 10 fringes are observed in the reflected beam if the wavelength of the incident light is 4800 Å. If the wavelength of incident light is changed to 6000 Å, then number of fringes observed in the same region will be

(A) 5 (B) 6 (C) 7 (D) 8

Ans (D)

Path difference is same for both the waves $\therefore m_1\lambda_1 = m_2\lambda_2$

$$\text{or } m_2 = m_1 \times \frac{\lambda_1}{\lambda_2} = \frac{10 \times 4800 \times 10^{-10}}{6000 \times 10^{-10}} = 8$$

15. In a Young's double slit experiment $I_{max} : I_{min} = 32 : 18$, the ratio of the amplitudes of light from two interfering source is

(A) 4 : 3 (B) 3 : 4 (C) 7 : 1 (D) 4 : 7

Ans (C)

$$\frac{I_{max}}{I_{min}} = \left(\frac{a_1 + a_2}{a_1 - a_2}\right)^2 = \left(\frac{a+1}{a-1}\right)^2 = \frac{16}{9} \left(\text{where } a = \frac{a_1}{a_2}\right) \quad \therefore \frac{(a+1)}{(a-1)} = \frac{4}{3} \text{ or } a = 7.$$

16. A thin glass plate of refractive index 1.5 is placed in air. White light is incident normally on the plate. 600 nm and 500 nm are the two wavelengths that are missing in the reflected light. The minimum thickness of the film is

(A) 500 nm (B) 1000 nm (C) 750 nm (D) 250 nm

Ans (B)

$2\mu t = n_1 \times 500 \text{ nm} = n_2 \times 600 \text{ nm}$

Smallest integral values satisfying this are $n_1 = 6$ and $n_2 = 5$

$\therefore$ $2\mu t = 3000$ nm $\qquad \therefore$ $t = \frac{3000}{2\times 1.5}$ nm = 1000 nm.

17. A photocell is illuminated by a small bright source placed 1 m away. When the same source of light placed 1/2 m away, the number of electrons emitted by photocathode would

(A) decrease by a factor of 2
(B) increase by a factor of 2
(C) decrease by a factor of 4
(D) increase by a factor of 4.

Ans (D)

We know that $I \propto \frac{1}{r^2}$

When the same source of light is placed $\frac{1}{2}$m away, the intensity will become

$I' \propto \frac{1}{\left(\frac{1}{2}\right)^2} \Rightarrow I' \propto 4$. Therefore, number-of photons will become four times.

18. A Young's double slit set up is illuminated by a micro wave of λ = 0.5 mm with d = 1.5 mm. If D = 1.5 m, the separation between two minima nearest to 0^{th} order bright fringe is

(A) $\frac{1}{\sqrt{35}}$ m
(B) $\sqrt{35}$ m
(C) $\frac{2}{\sqrt{35}}$ m
(D) $\frac{3}{\sqrt{35}}$ m

Ans (D)

The two minima are at equal distances from the centre of the screen on either sides of it.

For I minima d sin $\theta = \frac{\lambda}{2}$ or sin $\theta = \frac{\lambda}{2d} = \frac{1}{6}$

As tan $\theta = \frac{y}{D}$ $\quad y = 1.5 \times \tan\theta = \frac{1\cdot 5(1/6)}{\sqrt{35/36}} = \frac{1.5}{\sqrt{35}}$

$\therefore$ The separation between two first minimum is $= \frac{1.5}{\sqrt{35}} + \frac{1.5}{\sqrt{35}} = \frac{3}{\sqrt{35}}$.

19. Two identical light sources s_1 and s_2 emit light of same wavelength λ. These light rays will exhibit interference if

(A) their phase differences remain constant
(B) their phases are distributed randomly
(C) their light intensities remain constant
(D) their light intensities change randomly

Ans (A)

Hint: For interference, it is necessary that there should be constant phase difference between two light rays.

20. Which of the following is not an essential condition for interference?

(A) The two interfering waves must propagate in almost the same direction
(B) The waves must have the same period and wavelength
(C) The amplitudes of the two waves must be equal
(D) The two interfering beams of light must originate from the same source

Ans (C)

Hint : For 2 waves to interfere, amplitudes between them should be slightly different.

21. In Young's double slit experiment, for light of which colour the fringe width is maximum

(A) violet
(B) blue
(3) red
(D) yellow

Ans (C)

Hint: $\beta = \frac{D\lambda}{d} \Rightarrow \beta \propto \lambda$

22. In Young's double slit experiment, the ratio of intensities of bright and dark fringes is 9. This means

(A) intensities of individual sources are 5 and 4 units respectively
(B) the intensities of individual sources are 4 and 1 units respectively

(C) the ratio of their amplitudes is 3

(D) the ratio of their amplitudes is 2

Ans (B)

Hint: $\frac{I_{bright}}{I_{dark}} = \frac{I_{max}}{I_{min}} = 9 \Rightarrow \left(\frac{a_1 + a_2}{a_1 - a_2}\right)^2 = 9$

$\frac{a_1 + a_2}{a_1 - a_2} = 3 \Rightarrow \frac{a_1}{a_2} = 2$ and $\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{4}{1}$

23. When a thin transparent plate of thickness t and RI μ is placed in the path of one of the beams in Young's double slit experiment, the path difference between two waves is

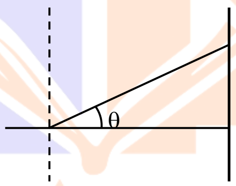
(A) $(\mu + 1)t$ (B) $(\mu - 1)t$ (C) $\frac{\mu+1}{t}$ (D) μt

Ans (B)

24. In the Young's double slit experiment a point P on the central bright fringe is such that intensity of point P is 1/4 times the maximum intensity, distance between the slits is d and wavelength λ. Then angular separation of point P is

(A) $\sin^{-1}\left(\frac{\lambda}{d}\right)$ (B) $\sin^{-1}\left(\frac{\lambda}{2d}\right)$ (C) $\sin^{-1}\left(\frac{\lambda}{3d}\right)$ (D) $\sin^{-1}\left(\frac{\lambda}{4d}\right)$

Ans (C)



The resultant intensity is given by

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

Now, according to the given condition

$\frac{I}{4} = \frac{I}{4} + \frac{I}{4} + 2\frac{I}{4}\cos\phi$

$\Rightarrow \cos\phi = -\frac{1}{2} \Rightarrow \phi = \frac{2\pi}{3}$

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

$\therefore \Delta x = \frac{\phi}{2\pi}\lambda = \frac{2\pi}{3 \times 2\pi}\lambda = \frac{\lambda}{3}$

$\therefore$ d sin θ = $\frac{\lambda}{3} \Rightarrow \theta = \sin^{-1}\frac{\lambda}{3d}$

Diffraction

Bending of light waves around the edges of an obstacle or an aperture (slit) whose dimensions are comparable with the wavelength of light, is called diffraction. This phenomenon results in producing uneven illuminations near the geometric shadow regions of the obstacle and aperture.

Two types or classes of diffraction pattern are possible.

1. **Fresnel's type:** Here, the diffraction is due to a spherical or cylindrical wavefront due to a source at finite distances form wavefront.

2. **Fraunhofer's type:** Here, the diffraction is due to a plane wavefront. In this case, the screen and the source are (in effect) at infinite distances from the slit (obstacle). Usually, a convex lens is used for making incident wavefront a plane wavefront (parallel rays), and another convex lens is used for focusing the diffraction pattern.

Validity of Ray Optics : Fresnel's Distance

A parallel beam of light on passing through a slit of width 'a' gets diffracted into a beam of an angle θ given by

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

where λ is the wavelength of light and θ is assumed to be small.

In traversing a distance $D =$ distance between the slit and the screen, this beam spreads over a linear width x given by $x = \theta D = \frac{\lambda D}{a} z$

A parameter, known as Fresnel's distance, is defined to decide the distance up to which the concepts of ray optics (rectilinear propagation of light) are valid and beyond which the spreading is large. **Fresnel's distance is defined as the distance of the screen from the slit at which the spreading of light due to diffraction becomes equal to the size of the slit.** It is denoted by Z_f. (Also denoted by D_f).

Thus, when $x = a$ and $D = Z_f$ we get

$$a = \frac{\lambda}{a} Z_f \quad \Rightarrow Z_f = \frac{a^2}{\lambda}$$

When $D < Z_f$, the broadening by diffraction is not much and light travels almost along a straight path. Thus, the concepts of ray optics are valid whenever $D < Z_f$.

Therefore, If $D < Z_f$, then $D < \frac{a^2}{\lambda} \Rightarrow a > \sqrt{\lambda D}$

The quantity $\sqrt{\lambda D}$ is called the Fresnel's zone and is denoted by a_f.

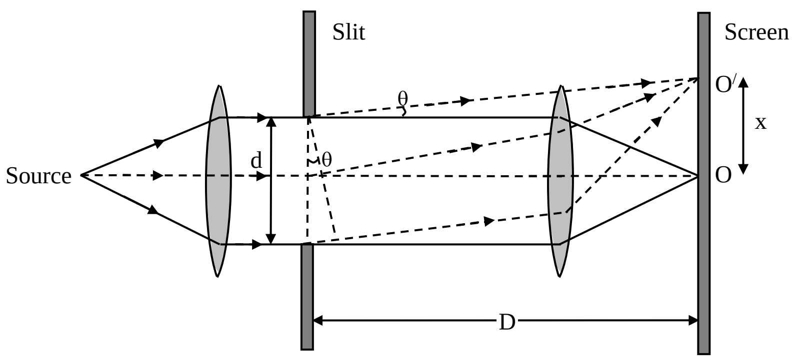
$$a_f = \sqrt{\lambda D}$$

Thus, if $a > a_f$, the concepts of ray optics can be used without any significant error.

When $D > Z_f$, the broadening by diffraction is appreciable and light does not travel along a straight path. Thus, the concepts of ray optics are not valid whenever $D > Z_f$.

If $D > Z_f$, then we get $D > \frac{a^2}{\lambda}$ and the ray optics fails. This expression also shows that the ray optics is valid only when the wavelength has a limiting value of zero. ($\lambda \to 0$).

Fraunhofer's diffraction at a single slit



Diffraction at a single slit, illuminated by monochromatic light, has the following characteristics;

(a) A central maximum (of maximum width and intensity) is on the right bisector (equidistant from the two edges of the slit). The width of the central bright band, $\beta = \frac{2D\lambda}{a}$, where a is the width of the slit and D is the distance between the slit and the screen.

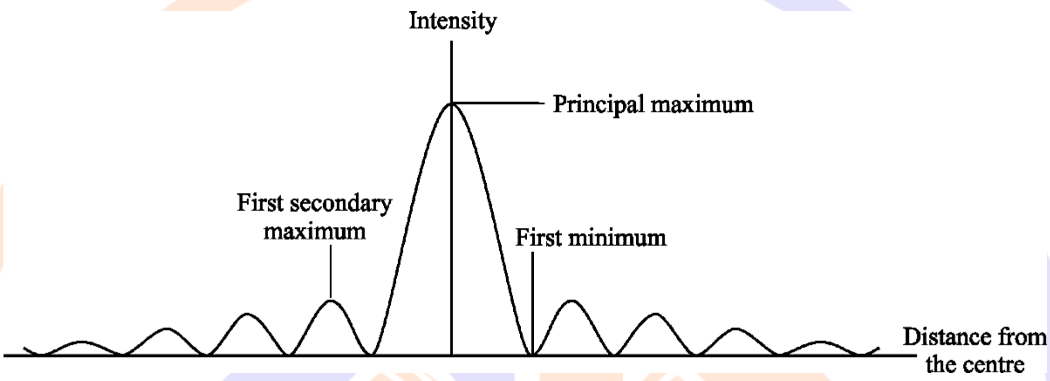
(b) For the m^{th} secondary minima, path difference, $a \sin \theta = m\lambda$, $m = 1, 2, 3, \ldots$

for I, II, III . . . dark fringe

m^{th} secondary maxima, path difference, $a \sin \theta = (2m + 1)\lambda / 2$, m = 1, 2, 3, ...

for I, II, III . . . bright fringe.

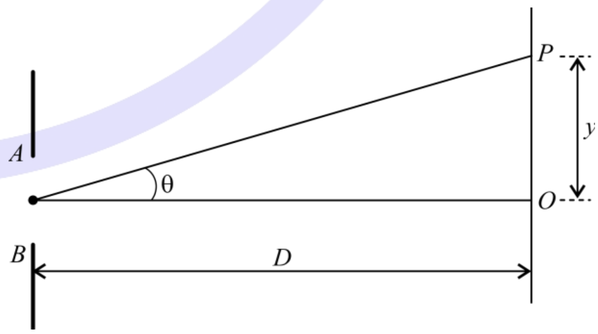
Characteristics of Fraunhofer diffraction pattern



Intensity distribution and diffraction bonds in a Fraunhofer single slit diffraction.

1. The diffraction pattern consists of alternating bright and dark bands of varying intensity and varying width.
2. The bright band at the centre has maximum intensity and maximum width. It is called the principal maximum or central maximum.
3. The dark bands surrounding the bright bands are called minima. The first dark bands surrounding the principal maxima on either sides are called first minima.
4. The other bright bands have decreasing intensity and decreasing width away from principal maximum. These are called secondary maxima.
5. Bright bands become less bright and dark banks become less dark. After a few bands, the bright and dark banks cannot be differentiated.

Width of central maximum



From the diagram, $\sin \theta = \frac{y}{D}$.

For small values of θ, $\theta = \frac{y}{D}$

(If θ is small then, $\sin \theta \simeq \theta$).

Let P be n^{th} minimum.

The condition for minima is

$a \sin \theta = n\lambda$

Hence, $a.\theta = n\lambda \Rightarrow a.\frac{y}{D} = n\lambda$

or $y = \frac{n\lambda D}{a}$ where n = 1, 2, 3, …….

This gives the distance of n^{th} minima from central maximum.

For first minimum, n = 1. Hence, first minimum is at a distance of $y_1 = \frac{\lambda D}{a}$ from the central maximum

Thus, the width of the central maximum, which is the distance between the two first minima on either sides, is

$$\beta = 2y_1 \Rightarrow \beta = \frac{2\lambda D}{a}$$

This shows that width of first minima varies

(i) directly as the wavelength, (λ)

(ii) directly as the distance between the slit and the screen (D)

(iii) inversely as the width of the single slit (a)

If the lens is held very close to the slit or screen is far away from the lens then we can approximate

$D \simeq f$ and hence, $y_n = \frac{n\lambda f}{a}$ and $\beta = \frac{2\lambda f}{a}$

Difference between interference pattern and diffraction pattern

Interference pattern (in YDSE)	Diffraction pattern (in Fraunhofer diffraction)
1. Produced by two sources which are coherent	1. Produced by a single wavefront
2. Waves from both the sources interfere to produce the pattern	2. Secondary waves from the same wavefront interfere to produce the pattern
3. Bright fringes are of equal intensity.	3. The intensity of a bright fringe decreases with increase in order

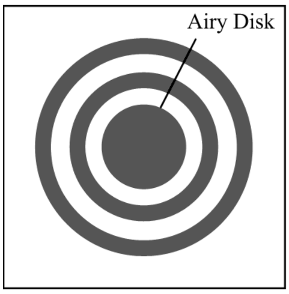
Resolving power

The resolving power of an optical instrument is its ability to show two close lying points on an object as separate points on the image. This property is different from magnifying power.

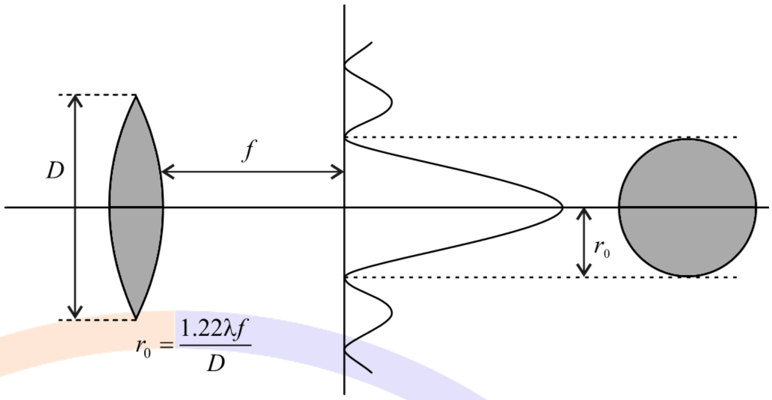
The ability of an optical instrument to show two close lying point objects distinctly is called its resolving power. Consider a parallel beam of light incident on a convex lens. The laws of geometrical optics predict that the beam gets focused to a point and a point image is formed. But observations show that the beam, instead of getting focused to a point, would get focused to a spot of finite area. Diffraction effects become pronounced at an aperture of any shape. The diffraction pattern formed by a circular aperture is of special interest because of its role in limiting how well an optical instrument can resolve fine details. The diffraction pattern formed at the focal plane of the lens consists of a central bright spot surrounded by a series of alternating bright and dark rings. The central bright spot is called the **Airy disk** (in honor of Sir George Airy).

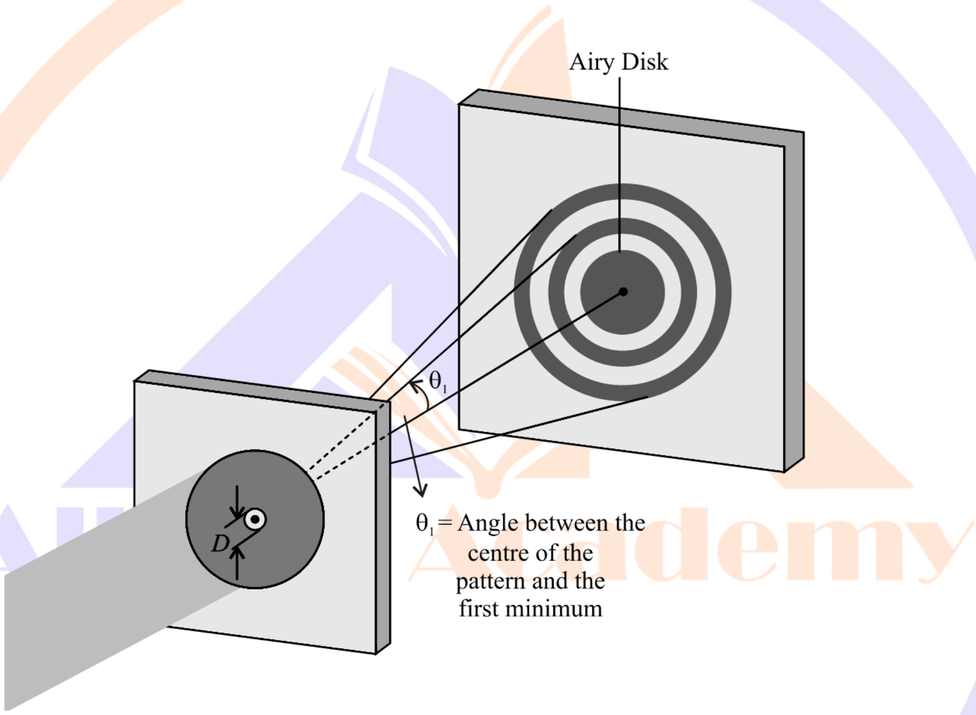
If the aperture diameter is D and the wavelength is λ, the angular radius θ_1 of the first dark ring is given by

$$\sin\theta_1 = 1.22\frac{\lambda}{D}$$



Diffraction pattern formed by circular aperture





Diffraction pattern formed at convex lens and circular aperture.

If the case of convex lens of aperture D, the angular radius θ_1 of Airy disk is given by

$\sin\theta_1 = 1.22\frac{\lambda}{D}$ and the radius is $r_0 = \frac{1.22\lambda f}{D}$.

The angular radii of next two dark rings are given by

$\sin\theta_2 = 2.23\frac{\lambda}{D}$, $\sin\theta_3 = 3.23\frac{\lambda}{D}$

Between these are bright rings with angular radii given by

$\sin\theta = 1.63\frac{\lambda}{D}$, $2.68\frac{\lambda}{D}$, $3.70\frac{\lambda}{D}$ and so on.

Though the size of the spot and subsequent rings are very small, they play a significant role in determining the resolving powers of optical instruments like a telescope or a microscope.

If we have two point objects, their images are not two points but two diffraction patterns. When the objects are close together, their diffraction patterns overlap. A widely used criterion for resolution of two point objects is called the Rayleigh's criterion.

Rayleigh's Criteria for Resolution

The Rayleigh's criterion for resolution is that the principal maximum of the intensity distribution curve for one point on an object should fall on the first minimum corresponding to another point.

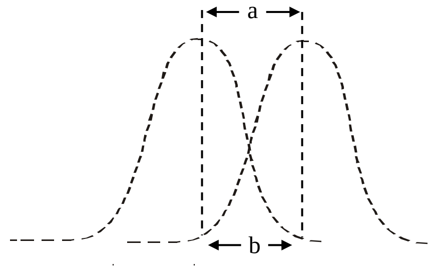


Figure shows intensity distribution curves due to close lying point sources.

In the figure,

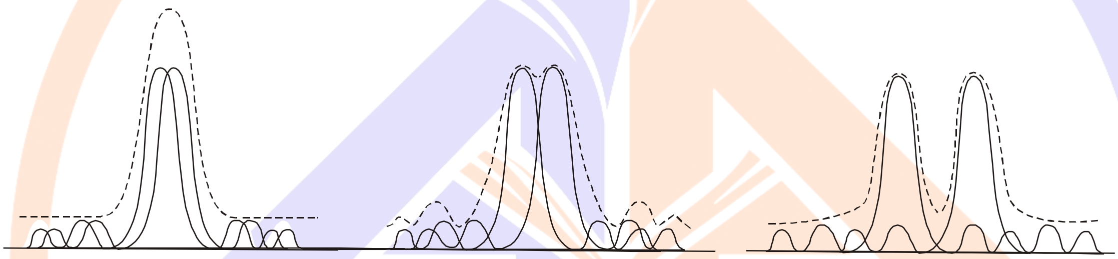
a $\rightarrow$ distance between the two principal maxima

b $\rightarrow$ distance between the first secondary minima of the two intensity distribution curves.

(i) if a > b, the two points are said to be well resolved.

(ii) if a = b, the two points are said to be just resolved.

(iii) of a < b, the two points are said to be unresolved.



(a) Unresolved diffraction pattern (b) Just resolved diffraction pattern (c) Well resolved diffraction pattern

Rayleigh's criterion

Limit of resolution (LR)

1. For a **microscope**, it is defined as the minimum distance between two points on an object, so as to be just seen as separate points in the image. $LR = \Delta x = \dfrac{\lambda}{2n \sin\theta}$, (LR $\rightarrow$ limit of resolution) where λ is the wavelength, n is the refractive index of the medium between the objective and the object, sand θ is the semi vertical angle of the cone of light rays reaching the objective lens from a point object.

2. For a **telescope**, it is defined as the smallest angle that should be subtended at the centre of the objective by two points on an object, so as to be just seen as separate points, $LR = \theta = \dfrac{1.22\lambda}{D}$

   $\lambda \rightarrow$ wave length, D $\rightarrow$ diameter of the objective

Resolving power (RP)

In both the cases, the resolving power is given by $1/LR$. Resolving power has no dimensions.

1. Resolving power of a microscope = $\dfrac{2n \sin\theta}{\lambda}$

The resolving power of microscope can be increased by

(a) **Increasing n**. This is done by taking cedar wood oil (higher n) between the object and the objective. Such microscopes are called oil immersion objective type.

(b) **Decreasing λ**. This is achieved in ultramicroscopes wherein ultraviolet radiation is used to illuminate the object. The image is photographed in such microscopes.

2. Resolving power of a telescope = $\frac{D}{1.22\ \lambda}$

It is seen that a telescope with an objective of larger aperture has higher resolving power.

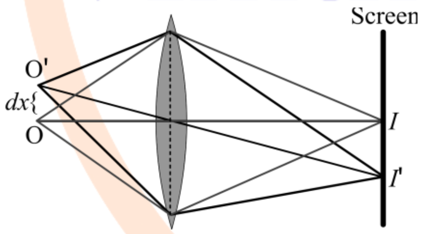
Differences between Interference and Diffraction

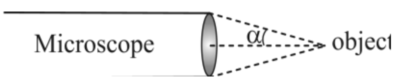
	Interference	Diffraction
1.	Interference is the modification in the intensity of light due to superposition of two or more coherent waves.	Diffraction is bending of light around the edges of obstacles with dimensions comparable to wavelength of light
2.	Interference occurs due to the superposition of two or more waves from different coherent sources	Diffraction occurs due to the superposition of secondary waves from different parts of the same wavefront
3.	Fringe width of all bright and dark fringes are equal	Fringe width is not a constant. It decreases away from the central bright fringe.
4.	Intensity of all bright fringes is the same.	Intensity of central maximum is highest. Intensity of secondary maxima decreases away from the central maximum
5.	Contrast between bright and dark fringes is good	Contrast between bright and dark fringes is poor

Limit of resolution and Resolving power of a microscope

The limit of resolution of a microscope is defined as the minimum separation between two point objects so that they are seen as just separated in the image.

The limit of resolution of a microscope is given by $dx = \frac{1.22\lambda}{2n\sin\alpha}$





Limit of resolution of a microscope

where dx = separation between two point objects that are just resolved in the image.

λ = wavelength of light used.

α = semi-vertical angle subtended by the objective at the object.

n = refractive index of the medium between the object and the objective.

Smaller the limit of resolution of a microscope, higher is its ability to show closely lying points as well separated.

$$\text{Resolving power} = \frac{1}{\text{limit of resolution}} = \frac{2n\sin\alpha}{1.22\lambda}$$

$$\text{Resolving power} = \frac{2n\sin\alpha}{1.22\lambda}$$

Resolving power of a microscope can be increased using ultraviolet light which has a smaller wavelength compared to visible light. Such a microscope is called an ultra microscope.

Some times, the space between the objective of a microscope and the object is filled with a suitable transparent oil. Such a microscope has a higher resolving power than a microscope with air separating the object and the objective. The microscope is said to be oil immersion type.

Limit of resolution and resolving power of a telescope

Limit of resolution of a telescope is defined as the smallest angle that has to be subtended by two point objects at the objective so that they are seen as just separated in the image.

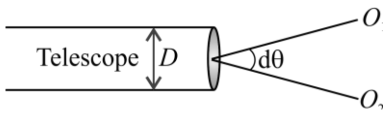
Limit of resolution of a telescope is given by, $d\theta = \frac{1.22\lambda}{D}$

where, $\lambda =$ wavelength of light used.

D = diameter of the objective of the telescope.

$$\text{Resolving power} = \frac{1}{\text{limit of resolution}} = \frac{D}{1.22\lambda}$$

$$\text{Resolving power} = \frac{D}{1.22\lambda}$$



Limit of Resolution of a telescope

It is seen that a telescope with an objective of larger aperture has higher resolving power.

The resolving power of a telescope can be increased by increasing the aperture of the lens.

Since it is difficult to construct large lenses, world's large telescopes are of reflecting type rather than refracting type.

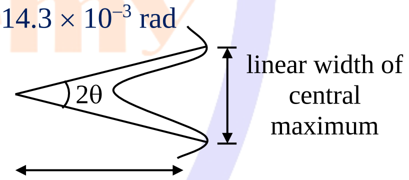
Resolving power	Magnifying power
1. It is the ability of an instrument to show two close lying points on an object as well separated points in the image.	1. It is the ability of an instrument to show a small object as a big one in the image.
2. It increases with decrease in the wavelength of light used to illuminate the object.	2. It is independent of wavelength of light used to illuminate the object.

Illustrations

1. Light of wavelength 6328 Å is incident on a single slit of width 0.2 mm. The angular width of the central maximum on a screen kept at a distance 9 m from the slit is

(A) 1.5×10^{-3} rad (B) 3.142×10^{-3} rad (C) 6.328×10^{-3} rad (D) 14.3×10^{-3} rad

Ans (C)



For I minima, $\sin\theta = \frac{\lambda}{a}$, When θ is small, $\theta \approx \frac{\lambda}{a}$

$\therefore$ Angular width of central maximum is $2\theta = \frac{2\lambda}{a} = \frac{2 \times 6328 \times 10^{-7}}{0.2 \times 10^{-3}} = 6.328 \times 10^{-3}$ rad

2. The direction of the second order diffraction minima in the Fraunhoffer diffraction pattern at a single slit is ('a' is the slit width)

(A) $\sin\theta = \frac{\lambda}{2a}$ (B) $\sin\theta = \frac{2\lambda}{a}$ (C) $\sin\theta = 2\lambda a$ (D) $\sin\theta = \frac{a}{2\lambda}$

Ans (B)

For the formation of diffraction minima, the path difference = $a \sin\theta = n\lambda$

For the second order minima, n = 2

$a \sin\theta = 2\lambda$ or $\sin\theta = \frac{2\lambda}{a}$

3. Light is incident normally on a diffraction grating through which the first order diffraction is seen at 32°. The second order diffraction will be seen at

(A) 48° (B) 64°

(C) 80° (D) there is no second order diffraction in this case

Ans (D)

We know $C \sin\theta = n\lambda$, where C is grating constant

$\therefore \frac{C\sin\theta_1}{C\sin\theta_2} = \frac{1\times\lambda}{2\times\lambda} \Rightarrow \frac{\sin\theta_1}{\sin\theta_2} = \frac{1}{2} \Rightarrow \sin\theta_2 = 2\sin\theta_1 \Rightarrow \theta_2 = \sin^{-1}(2\sin\theta_1)$

As $\sin(\theta_2)$ cannot be greater than one, second order diffraction is not possible in this case.

4. Fraunhoffer diffraction experiment, L is the distance between the obstacle, b is the size of obstacle and λ is wavelength of incident light. The general condition for the applicability of Fraunhoffer diffraction is

(A) $\frac{b^2}{L\lambda} >> 1$ (B) $\frac{b^2}{L\lambda} = 1$ (C) $\frac{b^2}{L\lambda} << 1$ (D) $\frac{b^2}{L\lambda} \neq 1$

Ans (C)

The general condition for Fraunhoffer diffraction is $\frac{b^2}{L\lambda} << 1$

5. A parallel beam of fast moving electrons is incident normally on a narrow slit. A screen is placed at a large distance from the slit. If the speed of the electrons is increased. Which of the following statement is correct?

(A) Diffraction pattern is not observed on the screen in the case of electrons
(B) The angular width of the central maximum of the diffraction pattern will increase
(C) The angular width of the central maximum will decrease
(D) The angular width of the central maximum will remains the same

Ans (C)

6. A window is fitted with a wire mesh. The spacing between the wires is 2 mm. For the wires in the mesh to be just resolved when observed through a telescope from a distance of 200 m, the diameter of the aperture of the lens must be (wavelength of light used is 5000 Å

(A) 3.6 cm (B) 4.6 cm (C) 5.9 cm (D) 6.1 cm

Ans (D)

Separation between the wires, $x = y \times \frac{1.22\lambda}{a}$ (x, y, a as in solution (35))

$x = \frac{1.22 \times 5 \times 10^{-7} \times 200}{2 \times 10^{-3}} = 6.1 \times 10^{-2}$ m = 6.1 cm

Polarization

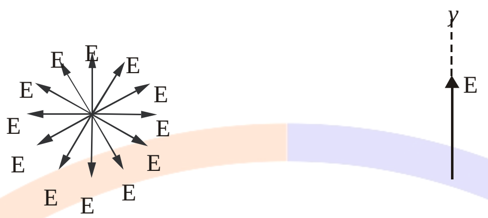
According to Maxwell's electromagnetic theory, light (in general, all electro magnetic radiations) consists of oscillating electric and magnetic field vectors perpendicular to each other and also to the direction of propagation. Hence, the light waves can be regarded as transverse electromagnetic waves.

The lack of symmetry or the asymmetry about the direction of propagation of light is called polarization.

- Longitudinal waves have symmetry about the direction of propagation and, hence, the question of polarization does not arise.
- Longitudinal waves exhibit the phenomena of interference and diffraction similar to transverse waves; only the transverse waves exhibit polarization.

Plane of polarization: It is a plane containing the electric vector and the line of propagation.

Unpolarized light: A light wave in which the electric vectors are randomly oriented at right angles to the direction of propagation. Thus, unpolarised light **does not show any lack of symmetry** about the **direction of propagation**. The ordinary light is **unpolarized light.**



(a) Unpolarized light

(b) Lineraly polarized light along y-direction

Symbolic representation of unpolarized and polarized light

Types of polarized light

Polarized light can be of three types: (a) linearly polarized (b) circularly polarized and (c) elliptically polarized. Unpolarized and linearly polarized light are symbolically represented as shown in Fig. (a) and (b) respectively.

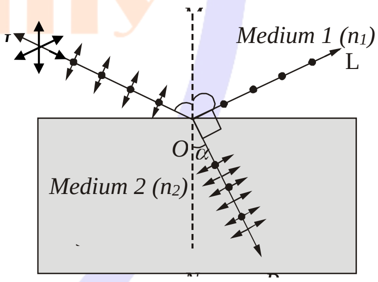
In **linearly polarized light** (often called plane polarized light) the electric field vectors E oscillate in a fixed plane. The projection of the tip of electric field vector on a plane perpendicular to the line of propagation is a straight line.

In **circularly polarized light**, at any point, the electric field vector E is constant in magnitude. The projection of the tip of electric field vector on a plane perpendicular to the line of propagation is a circle.

In **elliptically polarized light**, at any point, the electric field vector E is not constant in magnitude. The projection of the tip of electric field vector on a plane perpendicular to the line of propagation is an ellipse.

Methods of Polarization

1. **By reflection :** It is found that the light reflected from a refracting surface is completely plane polarized when the light is incident such that the reflected ray and the refracted ray are perpendicular to each other. This particular angle of incidence is called the **polarizing angle** or **Brewster's angle** (θ_p). It can be shown that, **tan θ_p = n,** where n is the refractive index of the medium.

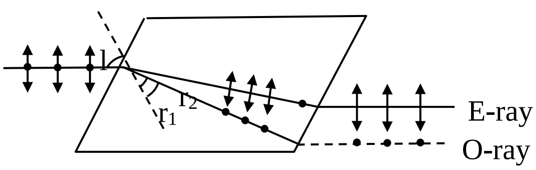


Brewster's law : When light is incident on a refracting surface at the polarizing angle (θ_p), the reflected ray and the refracted ray are at right angles to each other; i.e., $\theta_p + r + 90° = 180°$, where r is the angle of refraction.

Even when $i = \theta_p$, the reflected ray is completely polarized, but the refracted ray is partially polarized.

2. **Polarization by double refraction:** The phenomenon exhibited by an anisotropic crystal, due to which there are two refracted rays for each incident ray, is called **double refraction**. The incident ray splits into two rays inside such a crystal. The ray which has the same speed in all directions in the crystal is called the **ordinary ray**. The ray which has different speeds in different directions, is called the **extraordinary ray**.

Double Refraction (Birefringence)



Bertholinus discovered double refraction

i. When a light ray is refracted through a calcite crystal, two refracted rays are observed one is ordinary-ray (O-ray) and the other one is extra-ordinary ray (E-ray). This phenomenon is known as double refraction.

ii. Both O-ray and E-ray are plane polarised in perpendicular planes.

iii. If' i′ is the angle of incidence and r_1, r_2 be the angles of refractions of O-ray and E-ray respectively.

$$\mu_0 = \frac{\sin i}{\sin r_1} \quad \text{and} \quad \mu_e = \frac{\sin i}{\sin r_2}$$

Where μ_0 = refractive index of O - ray

μ_e = refractive index of E-ray

iv. Differences between O - ray and E - ray

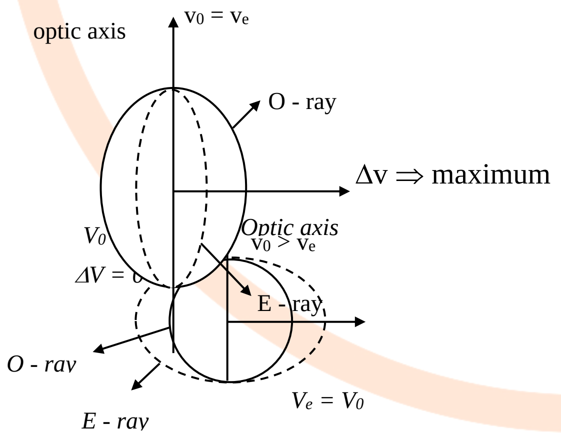
O - ray	**E - ray**
1. Obeys laws of refraction	1. Does not obey laws of refraction
2. μ_0 is independent on angle of incidence	2. μ_e depends on angle of incidence
3. Velocity of O- ray is same in all direction inside the crystal	3. Velocity of E-ray is different in different direction inside the crystal
4. Wave front of O- ray is spherical	4. Wave front of E - ray is ellipsoidal.
5. O - ray contains dot components only	5. E - ray contains arrow components only
6. Image due to O - ray is stationary When the crystal is rotated	6. Image due to E -ray rotates about the image due to O - ray when the crystal is rotated

v. The velocities of E-ray and O-ray are same along the optic axis; $V_e = V_0$ i.e., double refraction does not takes place along optic axis.

vi. In the direction perpendicular to the optic axis, the difference between V_0 and V_c is maximum.

vii. In a direction other than optic axis (a) $V_0 > V_c$ for positive crystals. $\mu_0 < \mu_e$.

Ex: Quartz, Ice, rutile



(b) $v_0 < v_e$ for negative crystals $\mu_0 > \mu_e$

Ex : Tourmaline and calcite

- The ordinary ray obeys the laws of refraction whereas the extraordinary ray does not.
- Both the ordinary ray and the extraordinary ray are 100% plane polarized, and the planes of polarization are perpendicular to each other. Hence, they do not interfere.
- The refractive index of the birefringent crystal for the ordinary ray is a constant (n_o). n_o is independent of the angle of incidence. The refractive index n_e of the crystal with respect to the extraordinary ray depends on the angle incidence.
- A direction in a doubly refracting crystal, along which the ordinary ray and the extraordinary ray travel with the same speed, is called the **optic axis**. The optic axis is not a line, but only a direction.
- For a positive crystal (Quartz): $n_e > n_0$; for a negative crystal (calcite) $n_e < n_0$.

3. Polarization by selective absorption (dichroism) :

When unpolarized light is passed through some crystals, (example: tourmaline), only light having E-vectors in a particular plane are transmitted and the rest are absorbed. This phenomenon is called selective absorption or dichriosm.

4. Polarization by polaroid

Polarization can be done by passing the unpolarized light through polaroids, which also exhibit the property of allowing only those waves whose plane of polarization is in a particular orientation.

A polaroid sheet is made of a large number of tiny dichroic crystals (Example: Quinine iodosulphate) such that all the crystals have their optic axes parallel to one another.

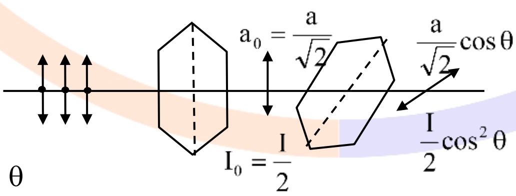
H and K polaroids : H-polaroid is prepared by stretching a film of polyvinyl alcohol subjecting it to a large stress. The stretching orients the molecules with their longer axes in the direction of stress and the film becomes doubly refracting. When it is stained with iodine, the film becomes dichroic.

K-polaroid is prepared by heating a stretched film of polyvinyl alcohol with a dehydrating agent. In this process, the film becomes dichroic. K-polaroids are used in the headlights of automobiles to reduce glare.

Malus Law

It gives the intensity of light emitting from the analyser if the angle between polarizer and analyser is known.

Let a_0 and I_0 be the amplitude and intensity of the light emerging from the polariser and let θ be the angle between the transmission axis of polariser and analyser. Then amplitude of light emitting from analyser is



$a = a_0 \cos\theta \Rightarrow a \propto \cos\theta$

The intensity of light emitting from the analyser is

$I \propto a^2 = a_0^2 \cos^2\theta$

$I = I_0 \cos^2\theta$

the above equation is known as Malus law

(iii) If the transmission axis of polariser and analyzer are parallel ($\theta = 0°$) then intensity of the light from the analyser is maximum then polariser and analyser are said to be in parallel position, $I_{max} = I_0\ \theta = 0°$

If the transmission axis of polariser and analyser are perpendicular ($\theta = 90°, 270°$) then intensity of light from analyser is zero

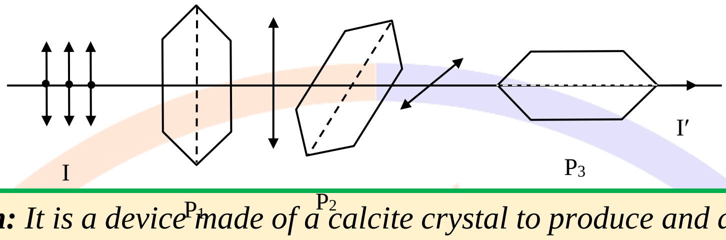
$I = I_0 \cos^2\theta \Rightarrow I = 0 \qquad \because \theta = 90°$

Then the polariser and analyser are said to be in crossed position

(iv) 'n' polarisers are arranged so that the first and the last ones are crossed, θ is the angle between any two successive polarisers, I is the intensity of incident light then intensity of emerging light is $I' = \frac{I}{2}\cos^x \theta$ where x = 2 (n – 1)

(v) P_1, P_2 and P_3 are three polarisers, angle between P_1, and P_2 is θ_1, and the angle between P_2 and P_3 is θ_2, and I is the intensity of incident light then the intensity of emerging light

$$I' = \frac{I}{2}\cos^2\theta_1 \cos^2\theta_2$$



- ***Nicol prism:*** *It is a device made of a calcite crystal to produce and analyse plane polarized light. It is obtained by the following method. A calcite crystal, whose length is three times the breadth is cut into two identical halves through a plane passing through its blunt corners. The two pieces are cemented together using Canada balsam. The end faces are polished to obtain the angles of 112° and 68° in the principal section. In a nicol prism, the ordinary ray gets eliminated by total internal reflection at the interface of calcite crystal and Canada balsam. The transmitted extraordinary ray is plane polarized.*
- *If* ***unpolarized*** *light of intensity I_0 is incident on a polarizer, the intensity of the transmitted light is equal to $\frac{I_0}{2}$.*

Illustrations

1. The critical angle for a medium is 45°. The polarizing angle for the given medium is approximately

(A) 50° (B) 54° (C) 28° (D) 36°

Ans (B)

From Brewster's law, $\theta_p = \tan^{-1}(n)$; $\sin c = \sin 45° = \frac{1}{\sqrt{2}}$

$n = \frac{1}{\sin C}$ $n = \frac{1}{\left(\frac{1}{\sqrt{2}}\right)} = \sqrt{2}$ $\Rightarrow \theta_p = \tan^{-1}(1.414) \simeq 54°$

2. A ray of light incident on a glass plate at the polarizing angle gets deviated by 26° on entering the glass. The polarizing angle is

(A) 40° (B) 58° (C) 64° (D) 68°

Ans (B)

When light is incident at polarizing angle, the reflected and the refracted rays are perpendicular to each other. Therefore, $\theta_p + r = 90°$. The deviation $d = \theta_p - r = 26°$

From the two equations, we get, $\theta_p = 58°$.

3. *When light is incident at an angle of 60° on a transparent liquid, the angle of refraction is 45°. The polarizing angle for the liquid is

(A) 58° (B) 50°46′ (C) 62° (D) 64°26′.

Ans (B)

$\tan i_P = n$ (from Brewster's law)

But $n = \frac{\sin i}{\sin r}$ $\Rightarrow \tan i_P = \frac{\sin i}{\sin r} = \frac{\sin 60°}{\sin 45°}$

$\Rightarrow \tan i_P = 1.2247$ or $i_P = 50°\,46'$

4. A polarizer and an analyser are kept such that maximum amount of light I_0 is transmitted. When the analyser is rotated through an angle of 60°, the fraction of the maximum intensity of light transmitted is

(A) $\frac{2}{3} I_0$ (B) $\frac{I_0}{2}$ (C) $\frac{I_0}{4}$ (D) $\frac{3}{4} I_0$

Ans (C)

From Malu's law, the intensity of light transmitted through an analyser is given by

$I = I_0 \cos^2 \theta$

$\frac{I}{I_0} = \cos^2 60° \Rightarrow I = \frac{I_0}{4}$

5. An unpolarised beam of intensity I_0 is incident on a pair of nicols making an angle of 60° with each other. The intensity of light emerging from the pair is

(A) I_0 (B) $I_0/2$ (C) $I_0/4$ (D) $I_0/8$.

Ans (C)

According to Malus law

NCERT LINE BY LINE QUESTIONS

1. The phenomenon of diffraction takes place for [NCERT Pg. 367]
(1) Sound waves only (2) Light waves only
(3) Matter waves only (4) All type of waves

2. If Young's double slit experiment uses a monochromatic light, the shape of fringes formed on the screen is [NCERT Pg. 364]
(1) Parabola (2) Straight line (3) Circle (4) Hyperbola

3. A diffraction pattern is obtained by using beam of red light. What will happen, if red light is replaced by the blue light? [NCERT Pg. 369]
(1) Bands disappear
(2) Bands become broader and farther apart
(3) Diffraction bands becomes narrow and crowded
(4) No change takes place

4. Which of the following is correct for light diverging from a point source? [NCERT Pg. 360]
(1) The intensity changes in proportion to the distance squared
(2) The wavefront is parabolic
(3) The intensity changes inversely proportional to distance squared
(4) The intensity changes inversely proportional to distance

5. In Young's double slit experiment, the slits are separated by 0.28 mm and the screen is placed 1.4 m away. The width of bright fringe is measured to be 1.2 cm. The wavelength of light used in the experiment is [NCERT Pg. 364]
(1) 2.4×10^{-6}m (2) 3×10^{-7}m
(3) 1.5×10^{-7}m (4) 5×10^{-7}m

6. The angle between the axis of two polaroids is 30°. The ratio of intensities of the emergent and unpolarised incident light will be [NCERT Pg. 378]
(1) 1 : 4 (2) 1 : 3 (3) 3 : 4 (4) 3 : 8

7. In Young's double slit experiment, the phase difference between two waves reaching at a point is $\pi/3$. The intensity of this point expressed as a fraction of maximum intensity I_o is [NCERT Pg. 364]
(1) $\frac{3}{2}I_0$ (2) $\frac{I_0}{2}$ (3) $\frac{4}{3}I_0$ (4) $\frac{3}{4}I_0$

8. When a low flying aircraft passes overhead, we sometimes notice a slight shaking of the picture in our TV, screen. This is because of .... between the direct signal and reflected signal [NCERT Pg. 364]
(1) Interference (2) Diffraction (3) Polarisation (4) Refraction

9. The idea of secondary wave wavelets for the propagation of the light wave was first given by [NCERT Pg. 354]
(1) Fresnel (2) Newton

(3) Maxwell (4) Htygen

10. The ratio of the amplitude of the two sources producing interference is 3 : 5, the ratio of intensities at maxima and minima is [NCERT Pg. 360]

(1) 25:6 (2) 5 : 3 (3) 16: 1 (4) 25 : 9

11. Colours of the soap bubble is due to [NCERT Pg. 360]

(1) Interference (2) Heat radiation

(3) Polarisation (4) Absorption

12. Intensity of a bright fringe in a single slit diffraction pattern on a screen [NCERT Pg. 369]

(1) Is same for all bright fringes

(2) Increases and decreases alternatively as we move away from central fringe

(3) Decreases as we move away from central bright fringe

(4) Increases as we move away from central bright fringe

13. Wavefronts associated with point source of wave is [NCERT Pg. 353]

(1) Spherical (2) Planar (3) Cylindrical (4) Ellipsoid

14. Light of wavelength 600 nm is incident on an aperture of size 2mm. The distance upto which light can travel such that its spread is less than the size of aperture is [NCERT Pg. 379]

(1) 12.13 m (2) 6.67 m (3) 3.33 m (4) 2.19 m

15. The slits in Young's double slit experiment are illuminated by light of wavelength 6000 A. If the path difference at the central bright fringe is zero, then the path difference at fourth bright fringe is [NCERT Pg. 364]

(1) 2.4×10^{-6}m (2) 1.2×10^{-6}m (3) 10^{-6}m (4) 0.5×10^{-6}m

16. The refractive index of a medium is $\sqrt{3}$. If the unpolarised light is incident on it from air at the polarizing angle of the medium, the angle of refraction is [NCERT Pg. 379]

(1) 60° (2) 45° (3) 30° (4) 0°

17. When interference of light waves takes place [NCERT Pg. 361]

(1) Energy is created in the region of maximum intensity

(2) Energy is destroyed in the region of minimum intensity

(3) Conservation of energy hold good and energy is redistributed

(4) Conservation of energy does not hold good

18. Two faints separated by a distance of 0.1 mm can just be inspected in a microscope when light of wave length 6000 Å is used. If the light of wavelength of 8000 Å is used, then the limit of resolution will be [NCERT Pg. 373]

(1) 0.8 mm (2) 1.2 mm (3) 0.1 mm (4) 0.13 mm

19. Transverse nature of light was confirmed by the phenomena of [NCERT Pg. 376]

(1) Reflection of light (2) Diffraction of light

(3) Interference of light (4) Polarisation of light

20. A light of wavelength 550 nm coming from a distant Star. The limit of resolution of a telescope whose objective has a diameter of 2 m is [NCERT Pg. 373]

(1) 3.38×10^{-7}rad (2) 3.35×10^{-5}rad

(3) 3.35×10^{-6} rad (4) 2.15×10^{-7} rad

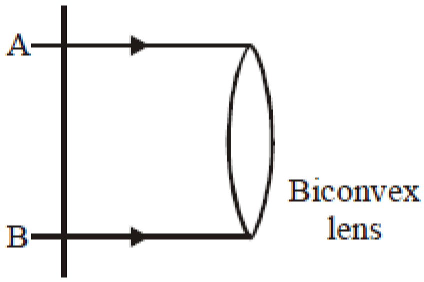
NCERT BASED PRACTICE QUESTIONS

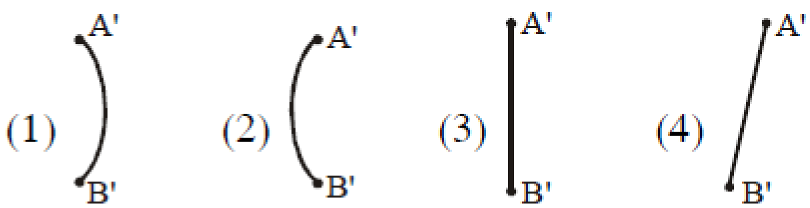
1. Wave theory of light is not initially accepted because:-
(1) It does not explain reflection and refraction processes
(2) It does not explain photoelectric effect
(3) It does not explain doppler's effect
(4) It does not explain propagation of light through vacuum

2. According to Maxwell light waves are associated with:-
(1) a constant magnitude electric field
(2) a magnetic field of constant magnitude
(3) changing electric and magnetic fields
(4) electric and magnetic fields of constant magnitude

3. A wavefront is a :-
(1) a surface imagined parallel and coplaner with light rays
(2) a surface around a source such that each point of it is at a constant distance from the source
(3) a surface which contains the plane of oscillations of electric field of light
(4) a surface which is created by medium particles oscillating in same phase

4. If AB is incident wavefront. Then refracted wavefront (just after transmission) is :-





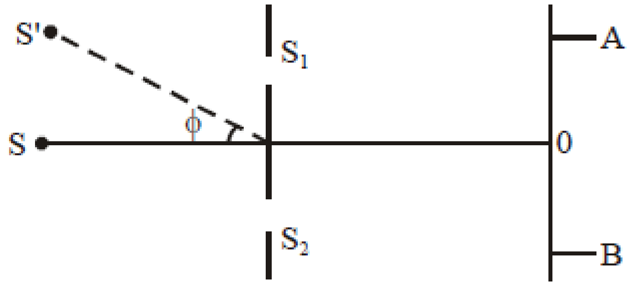
5. Two source are said to be coherent when :-
(1) Phase difference between waves produced by them is a function of time
(2) Phase difference between waves produced by them is $\pi/2$
(3) Phase difference between waves produced by them is 0
(4) Phase difference between them remains constant with time

6. In the phenomenon of interference, energy is :-
(1) Destroyed at destructive interference
(2) Created at constructive interference
(3) Conserved but it is redistributed
(4) Same at all points

7. The shape of the fringe obtained on the screen in case of YDSE is :-
(1) a straight line (2) a parabola

(3) a hyperbola (4) a circle

8. In young's double slit experiment, if source S is shifted by an angle ϕ as shown. Then central bright fringe will be shifted by angle ϕ towards:-



(1) end A of screen (2) end B of screen
(3) does not shift at all
(4) either end A or B depending on extra phase difference caused by shifting of source

9. In young's double-slit experiment the central bright fringe can be identified.
(1) as it has greater intensity than the other bright fringe
(2) as it is wider than the other bright fringes
(3) as it is narrower than the other bright fringe
(4) by using white light instead of monochromatic light

10. Diffraction is a general characteristic exhibited by:-
(1) Sound waves (2) Light waves
(3) Water waves (4) All of the above

11. For better resolution, a telescope must have a :-
(1) Large diameter objective (2) Small diameter objective
(3) May be large (4) Neither large nor small

12. The resolving power of a microscope is basically determined by the :-
(1) Speed of the light used (2) Wavelength of the light used
(3) Both (1) and (2) (4) Neither (1) nor (2)

13. Which of the given statement is/are correct for phenomenon of diffraction ?
(i) For diffraction through a single-slit the wavelength of wave must be comparable to the size of the slit
(ii) The diffraction is very common in sound wave but not so common in light waves
(iii)Diffraction is only observed in electromagnetic waves
(1) Only i (2) ii and iii (3) i and ii (4) i, ii, and iii

14. The phenomenon of polarisation of light indicates that :-
(1) light is a longitudinal wave
(2) light is a transverse electromagnetic wave
(3) light is a transverse wave only
(4) either (2) or (3)

15. Which factor could possibly influence the speed of light in vacuum :-
(1) Motion of the source or observer
(2) Frequency of light/wave length of light
(3) Intensity of light wave
(4) None of the above

16. Which factor could possibly influence the speed of light in isotrophic medium :-
(1) Direction of propogation

(2) Nature of source
(3) Motion of source relative to the medium
(4) Motion of the observer relative to the medium

17. When scattering of light is taking place and observer is abserving at 90^o scattered light will be :-
(1) Unpolarized
(2) Partially polarised
(3) Circularly polarised
(4) Perfectly plane polarised

18. When plane polarized light having plane of incident as plane of vibration is incident at Brewster's angle :-
(1) reflected light will be polarised
(2) There will be no reflection
(3) there will be no refraction
(4) none of the above

19. When scattering sunlight is being caused by air molecule in sky it rediate energy :-
(1) Equally in all direction
(2) Maximum energy in the direction of oscillations
(3) No energy in the direction of oscillations
(4) Does not radiate energy at all

20. Beyond Fresnel distance :-
(1) Diffraction becomes insignificant
(2) Diffraction are smaller compared to the size of beam
(3) Spreading of light due to diffraction dominates over ray optics
(4) Ray optics is valid

21. Mark incorrect option :-
(1) A telescope produces images of far object near to air eye
(2) A telescope produces images of far object magnified
(3) A microscope produces images of near object magnified
(4) A microscope produces image of near object far from eye

22. Presence of oil in oil immerged microscope is to:-
(1) to increase magnification of microscope
(2) increase aperture of microscope
(3) increase numerical aperture of microscope
(4) to make numerical aperture less than one in microscope

23. Interference and diffraction effect are :-
(1) Inconsistent with energy conservation
(2) Consistent with energy conservation
(3) Destruction in region of darkness
(4) Creation of energy in the region of brightness

24. How we can increase number of interference fringes inside the central maxima of diffraction patter of double slit :-
(1) by increasing distance of the screen
(2) by increasing size of slits
(3) by decreasing seperation between slits
(4) by decreasing size of slits

25. What is the effect on the interference fringes in YDSE when source slit moved closer to the double slit plane :-

(1) b increases (2) b decrease
(3) Fringes become less sharp (4) fringes become more sharp

26. What is the effect on interference fringes in YDSE when width of the source slit increased.
(1) b increases (2) b decreases
(3) Fringes become less sharp (4) Fringes become more sharp

27. For two light source to be coherent :-
(1) there amplitude must be same
(2) phase of wave should not change
(3) phase difference of wave must remain constant
(4) wave must be transverse

28. The principle of superposition of waves applies whenever two or more sources of light :-
(1) are coherent (2) are of same frequency
(3) obtained from same source (4) illuminate the same point

29. The equation of a light wave is written as
$y = A\sin(kx - \omega t)$. Hare y represents :-
(1) displacement of ether particles (2) Pressure in the medium
(3) density of medium (4) Electric field

30. Light waves emitted from an ordinary source change in time of order of :-
(1) 10^{-2} sec (2) 10^{-8} sec (3) 10^{-4} sec (4) 1 sec

31. A plane wavefront is incident on concave mirror then spherical wavefront will converge at :-
(1) focus (2) centre of curvature (3) infinity (4) $\frac{f}{2}$ point

32. What happens when two separate light source illuminate a wall :-
(1) Uniform illumination (2) Interference fringes
(3) Dark appear (4) Four times intensity of each source

TOPIC WISE PRACTICE QUESTIONS

Topic 1: Wave nature, Wavefront, Reflection and Refraction

1. Wave front is the locus of all points, where the particles of the medium vibrate with the same
(1) phase (2) amplitude (3) frequency (4) period

2. Light waves travel in vacuum along the y-axis. Which of the following may represent the wave-front?
(1) x = constant (2) y = constant (3) z = constant (4) x + y + z = constant

3. Find the minimum thickness of a film which will strongly reflect the light of wavelength 598 nm. The refractive index of the material of the film is 1.25.
(1) 118 nm (2) 120 nm (3) 218 m (4) 225 mm

4. Spherical wave fronts, emanating from a point source, strike a plane reflecting surface. What will happen to these wave fronts, immediately after reflection?
(1) They will remain spherical with the same curvature, both in magnitude and sign.
(2) They will become plane wave fronts.
(3) They will remain spherical, with the same curvature, but sign of curvature reversed.
(4) They will remain spherical, but with different curvature, both in magnitude and sign.

5. Huygens concept of wavelets is useful in
(1) explaining polarisation (2) determining focal length of the lenses

(3) determining chromatic aberration (4) geometrical reconstruction of a wave front

6. According to Huygen's construction, tangential envelope which touches all the secondary spheres is the position of

(1) original wave front (2) secondary wave front

(3) geometrical wave front (4) extended wave front

7. Huygens concept of secondary wave

(1) allows us to find the focal length of a thick lens

(2) is a geometrical method to find a wave front

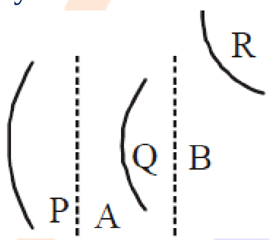
(3) is used to determine the velocity of light

(4) is used to explain polarisation

8. The wave fronts of a light wave travelling in vacuum are given by x + y + z = c. The angle made by the direction of propagation of light with the X-axis is

(1) 0º (2) 45º (3) 90º (4) $\cos^{-1}\left(1/\sqrt{3}\right)$

9. Figure shows wave front P passing through two systems A and B and emerging as Q and then as R. The system A and B could, respectively, be



(1) a prism and a convergent lens (2) a convergent lens and a prism

(3) a divergent lens and a prism (4) a convergent lens and a divergent lens

Topic 2: Interference of Light, Coherent and Incoherent Sources

10. The max. Intensity produced by two coherent sources of intensity I_1 *and* I_2 will be

(1) $I_1 + I_2$ (2) $I_1^2 + I_2^2$

(3) $I_1 + I_2 + 2\sqrt{I_1 I_2}$ (4) zero

11. Two sources of light are said to be coherent, when they give light waves of same

(1) amplitude and phase (2) wavelength and constant phase difference

(3) intensity and wavelength (4) phase and speed

12. To demonstrate the phenomenon of interference, we require two sources which emit radiation of

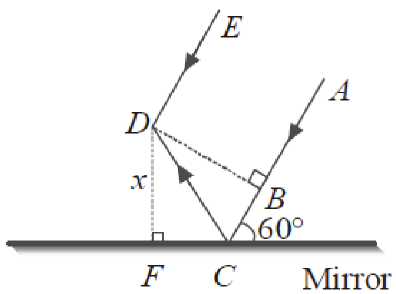
(1) nearly the same frequency

(2) the same frequency

(3) different wavelengths

(4) the same frequency and having a definite phase relationship

13. For the two parallel rays *AB* and *DE* shown here, *BD* is the wave front. For what value of wavelength of rays destructive interference takes place between ray *DE* and reflected ray *CD*?



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

14. The ratio of intensities of two waves is 9 : 1. They are producing interference. The ratio of maximum and minimum intensities will be

(1) 10 : 8 (2) 9 : 1 (3) 4 : 1 (4) 2 : 1

15. Interference was observed in interference chamber where air was present, now the chamber is evacuated, and if the same light is used, a careful observer will see

(1) No interference (2) interference with brighter bands
(3) Interference with dark bands (4) interference fringe with larger width

16. White light falls normally on a film of soapy water whose thickness is 5×10^{-5} cm and refractive index is 1.40. The wavelengths in the visible region that are reflected the most strongly are:

(1) 5000 Å and 4000 Å (2) 5400 Å and 4000 Å
(3) 6000 Å and 5000 Å (4) 4500 Å only

17. Ratio of intensities of two waves are given by 4:1. Then the ratio of the amplitudes of the two waves is

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

18. Which one of the following statements is correct?

(1) Monochromatic light is never coherent.
(2) Monochromatic light is always coherent.
(3) Two independent monochromatic sources are coherent.
(4) Coherent light is always monochromatic.

19. The interfering fringes formed by a thin oil film on water are seen in yellow light of sodium lamp. We find the fringes

(1) Coloured (2) black and white (3) yellow and black (4) coloured without yellow

20. Two coherent monochromatic light beams of intensities I *and* $4I$ are superposed. The maximum and minimum possible intensities in the resulting beam are

(1) $5I$ *and* I (2) $5I$ *and* $3I$ (3) $9I$ *and* I (4) $9I$ *and* $3I$

21. The path difference between two interfering waves at a point on screen is 171.5 times the wavelength. If the path difference is 0.01029 cm. Find the wavelength

(1) $6000\times10^{-10}cm$ (2) 6000 Å (3) $6000\times10^{-8}mm$ (4) None of these

22. 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) $\frac{(\mu-1)}{t}$

23. For observing interference in thin films with a light of wave length λ the thickness of the film:

(1) may be of any magnitude (2) should be much smaller than λ
(3) should be of the order of λ (4) should be a few thousand times of λ

24. In which of the following is the interference due to the division of wave front?

(1) Young's double slit experiment (2) Fresnel's biprism experiment
(3) Lloyd's mirror experiment (4) Demonstration colours of thin film

25. Light from two coherent sources of the same amplitude A and wavelength λ illuminates the screen. The intensity of the central maximum is I_0. If the sources were incoherent, the intensity at the same point will be

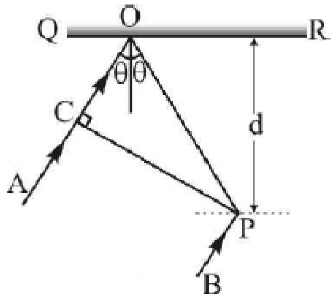
(1) $4I_0$ (2) $2I_0$ (3) I_0 (4) $I_0/2$

26. A point p is situated 90.50 and 90.58 cm away from two coherent sources. The nature of illumination of the point 'p' if the wavelength of light is 4000 Å, is

(1) bright (2) dark

(3) neither bright nor dark (4) none of these

27. In the adjacent diagram, CP represents a wave front and AO & BP, the corresponding two rays. Find the condition on θ for constructive interference at P between the ray BP and reflected ray OP



(1) $\cos\theta = 3\lambda/2d$ (2) $\cos\theta = \lambda/4d$

(3) $\sec\theta - \cos\theta = \lambda/d$ (4) $\sec\theta - \cos\theta = 4\lambda/d$

28. Sodium light ($\lambda = 6\times10^{-7} m$) is used to produce interference pattern. The observed fringe width is 0.12 mm. The angle between two interfering wave trains, is

(1) $1\times10^{-3}\,rad$ (2) $1\times10^{-2}\,rad$ (3) $5\times10^{-3}\,rad$ (4) $5\times10^{-2}\,rad$

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

(1) $2I$ (2) $4I$ (3) $5I$ (4) $7I$

Topic 3: Young's Double Slit Experiment

30. Which of the following is not essential for two sources of light in Young's double slit experiment to produce a sustained interference?

(1) Equal wavelength (2) Equal intensity

(3) Constant phase relationship (4) Equal frequency

31. The fringe width in a Young's double slit experiment can be increased if we decrease

(1) width of slits (2) separation of slits

(3) wavelength of light used (4) distance between slits and screen

32. Instead of using two slits, if we use two separate identical sodium lamps in Young's experiment, which of the following will occur?

(1) General illumination (2) Widely separate interference

(3) Very bright maxima (4) Very dark minima

33. The maximum intensity of fringes in Young's experiment is *I*. If one of the slit is closed, then the intensity at that place becomes I_0. Which of the following relation is true ?

(1) $I = I_0$ (2) $I = 2I_0$

(3) $I = 4I_0$ (4) there is no relation between I and I_0

34. When we close one slit in the Young's double slit experiment, then

(1) the bandwidth is increased (2) the bandwidth is decreased

(3) the bandwidth remains unchanged (4) the diffraction pattern is observed

35. S is the size of the slit, d is the separation between the slits and D is the distance where Young's double slit interference pattern is being observed. If l be the wavelength of light, then for sharp fringes, the essential condition is:

(1) $\frac{S}{D} < \frac{\lambda}{d}$ (2) $\frac{D}{S} < \frac{\lambda}{d}$ (3) $S\lambda < dD$ (4) $SD > \lambda d$

36. In a YDSE bi-chromatic light of wavelengths 400 nm and 560 nm are used. The distance between the slits is 0.1 mm and the distance between the plane of the slits and the screen is 1m. The minimum distance between two successive regions of complete darkness is

(1) 4 mm (2) 5.6 mm (3) 14 mm (4) 28 mm

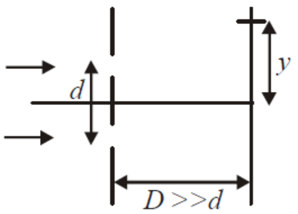
37. In a Young's double slit experiment, the separation of the two slits is doubled. To keep the same spacing of fringes, the distance D of the screen from the slits should be made

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

38. In YDSE, how many maxima's can be obtained on a screen including central maxima in both sides of the central fringe if $\lambda = 3000\,\mathring{A}, d = 5000\,\mathring{A}$

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

39. Consider the YDSE arrangement shown in figure. If $d = 10\lambda$ then position of 8^{th} maxima is



(1) $y = \frac{D}{10}$ (2) $y = \frac{D}{3}$ (3) $y = \frac{4}{5}D$ (4) $y = \frac{4D}{3}$

40. In a Young's double-slit experiment the fringe width is 0.2 mm. If the wavelength of light used is increased by 10% and the separation between the slits is also increased by 10%, the fringe width will be

(1) 0.20 mm (2) 0.401 mm (3) 0.242 mm (4) 0.165 mm

41. In Young's double slit expt. the distance between two sources is 0.1 mm. The distance of the screen from the source is 20 cm. Wavelength of light used is 5460 Å. The angular position of the first dark fringe is

(1) 0.08° (2) 0.16° (3) 0.20° (4) 0.32°

42. In Young's double slit experiment, λ = 500nm, d = 1mm, D = 1m. Minimum distance from the central maximum for which intensity is half of the maximum intensity is

(1) $2.5\times10^{-4} m$ (2) $1.25\times10^{-4} m$ (3) $0.625\times10^{-4} m$ (4) $0.3125\times10^{-4} m$

43. If the intensities of the two interfering beams in Young's double-slit experiment are I1 and I2, then the contrast between the maximum and minimum intensities is good when

(1) $|I_1 \text{ and } I_2|$ is large (2) $|I_1 \text{ and } I_2|$ is small

(3) $either\ I_1\ or\ I_2\ is\ zero$ (4) $I_1 = I_2$

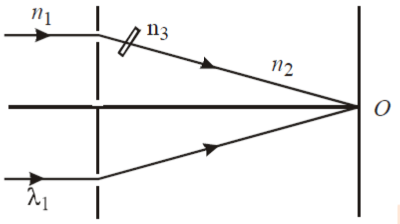
44. A Young's double slit experiment uses a monochromatic source. The shape of the interference fringes formed on a screen is

(1) circle (2) hyperbola (3) parabola (4) straight line

45. In Young's experiment, two coherent sources are placed 0.90 mm apart and fringe are observed one metre away. If it produces second dark fringe at a distance of 1 mm from central fringe, the wavelength of monochromatic light used would be

(1) $60\times10^{-4} cm$ (2) $10\times10^{-4} cm$ (3) $10\times10^{-5} cm$ (4) $6\times10^{-5} cm$

46. In the figure shown in a *YDSE*, a parallel beam of light is incident on the slits from a medium of refractive index n_1. The wavelength of light in this medium is λ_1. A transparent slab of thickness t and refractive index is put in front of one slit. The medium between the screen and the plane of the slits is n_2. The phase difference between the light waves reaching point O (symmetrical, relative to the slit) is



(1) $\frac{2\pi}{n_1\lambda_1}(n_3-n_2)t$ (2) $\frac{2\pi}{\lambda_1}(n_3-n_2)t$ (3) $\frac{2\pi n_1}{n_2\lambda_1}\left(\frac{n_3}{n_2}-1\right)t$ (4) $\frac{2\pi n_1}{\lambda_1}(n_3-n_2)t$

47. Distance between screen and source is decreased by 25%. Then the percentage change in fringe width is
(1) 20% (2) 31% (3) 75% (4) 25%

48. In Young¢s double slit experiment intensity at a point is (1/4) of the maximum intensity. Angular position of this point is (separation between slits is d)
(1) $\sin^{-1}(\lambda/d)$ (2) $\sin^{-1}(\lambda/2d)$ (3) $\sin^{-1}(\lambda/3d)$ (4) $\sin^{-1}(\lambda/4d)$

49. In Young's double slit experiment, the slits are 3 mm apart. The wavelength of light used is 5000 Å and the distance between the slits and the screen is 90 cm. The fringe width in mm is
(1) 1.5 (2) 0.015 (3) 2.0 (4) 0.15

50. In Young's experiment intensity at a point on the screen is 75% of the maximum value. Minimum phase difference between the waves arriving at this point from the two slits will be
(1) 30° (2) 45° (3) 60° (4) 135°

Topic 4: Diffraction and Polarization of Light

51. If the width of the slit in single slit diffraction experiment is doubled, then the central maximum of diffraction pattern becomes
(1) broader and brighter (2) sharper and brighter
(3) sharper and fainter (4) broader adn fainter.

52. When monochromatic light is replaced by white light in Fresnel's biprism arrangement, the central fringe is
(1) coloured (2) white (3) dark (4) None of these

53. The first diffraction minima due to a single slit diffraction at $\theta = 30^0$ for a light of wavelength 5000Å. The width of the slit is
(1) $5\times10^{-5} cm$ (2) $10\times10^{-5} cm$ (3) $2.5\times10^{-5} cm$ (4) $1.25\times10^{5} cm$

54. A beam of light is incident on a glass slab $(\mu = 1.54)$ in a direction as shown in the figure. The reflected light is analysed by a polaroid prism. On rotating the polaroid, (tan 57° = 1.54)
(1) the intensity remains unchanged
(2) the intensity is reduced to zero and remains at zero
(3) the intensity gradually reduces to zero and then again increase
(4) the intensity increases continuously

55. Unpolarised light of intensity 32 W m–2 passes through three polarizers such that the transmission axis of the last polarizer is crossed with that of the first. The intensity of final emerging light is 3 W m–2. The intensity of light transmitted by first polarizer will be
(1) $32Wm^{-2}$ (2) $16Wm^{-2}$ (3) $8Wm^{-2}$ (4) $4Wm^{-2}$

56. Optically active substances are those substances which
(1) produces polarised light
(2) produces double refraction
(3) rotate the plane of polarisation of polarised light
(4) converts a plane polarised light into circularly polarised light.

57. When an unpolarised light of intensity I_0 is incident on a polarizing sheet, the intensity of the light which does not get transmitted is
(1) $\frac{1}{4}I_0$ (2) $\frac{1}{2}I_0$ (3) I_0 (4) *Zero*

58. A beam of light of $\lambda = 600nm$ from a distant source falls on a single slit 1 mm wide and the resulting diffraction pattern is observed on a screen 2 m away. The distance between first dark fringe on either side of the central bright fringe is:
(1) 1.2 cm (2) 1.2 mm (3) 2.4 cm (4) 2.4 mm

59. Abeam 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) $I_0/8$

60. Unpolarised light is incident on a dielectric of refractive index $\sqrt{3}$. What is the angle of incidence if the reflected beam is completely polarised?
(1) 30° (2) 45° (3) 60° (4) 75°

61. A parallel beam of light of wavelength λ is incident normally on a narrow slit. A diffraction pattern is formed on a screen placed perpendicular to the direction of the incident beam. At the second minimum of the diffraction pattern, the phase difference between the rays coming from the two edges of slit is
(1) $\lambda\pi$ (2) 2π (3) 3π (4) 4π

62. A single slit Fraunhoffer diffraction pattern is formed with white light. For what wavelength of light the third secondary maximum in the diffraction pattern coincides with the second secondary maximum in the pattern for red light of wavelength 6500 Å?
(1) 4400 Å (2) 4100 Å (3) 4642.8 Å (4) 9100 Å

63. Two polaroid's are placed in the path of unpolarised beam of intensity I_0 such that no light is emitted from the second polaroid. If a third polaroid whose polarization axis makes an angle θ with the polarization axis of first polaroid, is placed between these polaroid's then the intensity of light emerging from the last polaroid will be
(1) $\left(\frac{I_0}{8}\right)\sin^2 2\theta$ (2) $\left(\frac{I_0}{4}\right)\sin^2 2\theta$ (3) $\left(\frac{I_0}{2}\right)\cos^4\theta$ (4) $I_0\cos^4\theta$

64. The Fraunhoffer 'diffraction' pattern of a single slit is formed in the focal plane of a lens of focal length 1 m. The width of slit is 0.3 mm. If third minimum is formed at a distance of 5 mm from central maximum, then wavelength of light will be
(1) 5000 Å (2) 2500 Å (3) 7500 Å (4) 8500 Å

65. Unpolarised light is incident on a plane sheet on water surface. The angle of incidence for which the reflected and refracted rays are perpendicular to each other is $\left(\mu \text{ of water} = \frac{4}{3}\right)$
(1) $\sin^{-1}\left(\frac{4}{3}\right)$ (2) $\tan^{-1}\left(\frac{3}{4}\right)$ (3) $\tan^{-1}\left(\frac{4}{3}\right)$ (4) $\sin^{-1}\left(\frac{1}{3}\right)$

NEET PREVIOUS YEARS QUESTIONS

1. Unpolarised light is incident from air on a plane surface of a material of refractive index 'm'. 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? **[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) $i = \tan^{-1}\left(\frac{1}{\mu}\right)$ (4) $i = \sin^{-1}\left(\frac{1}{\mu}\right)$

2. 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 is100 cm. It is found that the angular width of the fringes is 0.20°. To increase the fringe angular width to 0.21° (with same λ and D) the separation between the slits needs to be changed to **[2018]**

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

3. The ratio of resolving powers of an optical microscope for two wavelengths $\lambda_1 = 4000A^0$ and $\lambda_1 = 6000A^0$ is **[2017]**

(1) 9 : 4 (2) 3 : 2 (3) 16 : 81 (4) 8 : 27

4. Two Polaroids P1 and P2 are placed with their axis perpendicular to each other. Unpolarised light I0 is incident on P1. A third polaroid P3 is kept in between P1 and P2 such that its axis makes an angle 45° with that of P1 . The intensity of transmitted light through P2 is **[2017]**

(1) $\frac{I_0}{4}$ (2) $\frac{I_0}{8}$ (3) $\frac{I_0}{16}$ (4) $\frac{I_0}{2}$

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

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

6. 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 fir1st secondary maximum is observed at an angle of : **[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) $\sin^{-1}\left(\frac{3}{4}\right)$

7. 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 a distance D = 10 d? **[2016]**

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

8. In a double slit experiment, the two slits are 1 mm apart and the screen is placed 1 m away. A monochromatic light 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? **[2015]**

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

9. For a parallel beam of monochromatic light of wavelength 'l', diffraction is produced by a single slit whose width 'a' is 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: **[2015]**

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

10. 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: **[2014]**

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

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

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

12. 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 1m 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 (μ_{water} = 4/3) **[NEET – 2019]**

(1) 0.266° (2) 0.15° (3) 0.05° (4) 0.1°

13. 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 (ODISSA)]

(1) $5\frac{\lambda}{2}$ (2) $10\frac{\lambda}{2}$ (3) $9\frac{\lambda}{2}$ (4) $11\frac{\lambda}{2}$

14. Angular width of the central maxima in the Fraunhofer diffraction for λ = 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 (ODISSA)]**

(1) 1800 Å (2) 4200 Å (3) 6000 Å (4) 420 Å

15. 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 (Covid-19)]**

(1) zero (2) π (3) $3\pi/2$ (4) $\pi/2$

16. In 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

17. Assume that light of wavelength 600nm is coming from a star. The limit of resolution of telescope whose objective has a diameter of 2m 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

18. The Brewster's angle i_b for an interface should be: **[NEET – 2020]**

1) $i_b = 90^0$ 2) $0^0 < i_b < 30^0$ 3) $30^0 < i_b < 45^0$ 4) $45^0 < i_b < 90^0$

19. 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, then 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

NCERT LINE BY LINE QUESTIONS – ANSWERS

1) d 2) d 3) c 4) c 5) a 6) d 7) d 8) a 9) d 10) c
11) a 12) c 13) a 14) b 15) a 16) c 17) c 18) d 19) d 20) a

NCERT BASED PRACTICE QUESTIONS – ANSWERS

1) 4	2) 3	3) 4	4) 2	5) 4	6) 3	7) 3	8) 2
9) 4	10) 4	11) 1	12) 2	13) 3	14) 2	15) 4	16) 4
17) 4	18) 2	19) 3	20) 3	21) 2	22) 3	23) 2	24) 4
25) 3	26) 3	27) 3	28) 4	29) 4	30) 2	31) 1	32) 1

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1)	1	2)	2	3)	1	4)	3	5)	4	6)	2	7)	2	8)	4	9)	2	10)	3
11)	2	12)	4	13)	1	14)	3	15)	4	16)	1	17)	1	18)	4	19)	1	20)	3

21)	2	22)	2	23)	2	24)	2	25)	4	26)	1	27)	2	28)	3	29)	2	30)	2
31)	2	32)	1	33)	3	34)	4	35)	4	36)	4	37)	3	38)	3	39)	4	40)	1
41)	2	42)	2	43)	4	44)	4	45)	4	46)	4	47)	4	48)	3	49)	4	50)	3
51)	2	52)	2	53)	2	54)	3	55)	2	56)	3	57)	2	58)	4	59)	3	60)	3
61)	4	62)	3	63)	1	64)	1	65)	3										

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1)	2	2)	2	3)	2	4)	2	5)	3	6)	4	7)	4	8)	4	9)	4
10)	3	11)	4	12)	2	13)	3	14)	2	15)	1	16)	4	17)	2	18)	4
19)	4																

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. **(1)** Wavefront is the locus of all points, where the particles of the medium vibrate with the same phase.

2. **(2)** If a plane wave of light travelling along the y-direction electric field may be along any direction in x-z plane
(i.e. y = c), hence wavefront may be represented by y = c.

3. **(1)** For strong reflection, the least optical path difference introduced by the film should by $\lambda/2$. The optical path difference between the waves reflected from the two surfaces of the film is $2\mu d$.

Thus, for strong reflection, $2\mu d = \lambda/2$.

$$d = \frac{\lambda}{4\mu} = \frac{589}{4\times1.25} = 118\,\text{nm}$$

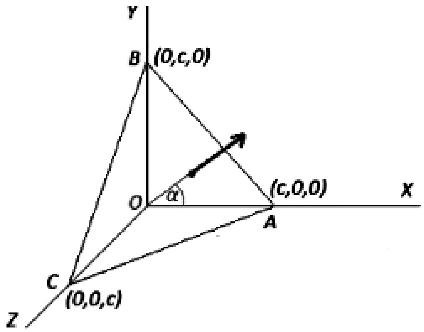
4. **(3)** They will remain spherical, with the same curvature, but sign of curvature reversed

5. **(4)** geometrical reconstruction of a wavefront

6. **(2)** secondary wavefront

7. **(2)** Huygens principle gives us a geometrical method of tracing a wavefront.

8. **(4)** The given equation of the wavefronts represent a plane that intersects each of the axes at a distance c from the origin. Let these points be named A, B and C. ABC is an equilateral triangle of side c.



The direction of propagation of light will be normal to the plane. In this case, the normal makes equal angles with each of the axes say α. Since the sum of the squares of the direction cosines equals one, here for the normal $\cos^2\alpha+\cos^2\alpha+\cos^2\alpha = 1$

$\rightarrow 3\cos^2\alpha = 1$

$\rightarrow \cos^2\alpha = 1/3$

$\rightarrow \cos\alpha = 1/\sqrt{3}$

$\rightarrow \alpha = \cos^{-1}(1/\sqrt{3})$

9. **(2)** P to Q: convergence increasing; Q to R : direction changing.

10. **(3)** As $R^2 = a^2 + b^2 + 2ab\cos\phi$

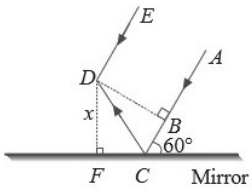
$$\therefore I_{max} = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos 0^0$$

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

11. **(2)** For coherent sources λ is same and phase is also same or phase diff. is constant.

12. **(4)** the same frequency and having a definite phase relationship

13. **(1)** Path difference,



14. **(3)** $\frac{I_1}{I} = \frac{a_1^2}{a_2^2} = \frac{9}{1}$ or $\frac{a_1}{a_2} = \frac{3}{1}$ $\quad \therefore \frac{I_{max}}{I_{min}} = \frac{(3+1)^2}{(3-1)^2} = \frac{16}{4} = \frac{4}{1}$

15. **(4)** As the chamber is evacuated the wavelength of the light increases slightly. Thus as the fringe width is directly proportional to wavelength the fringe width increases.

16. **(1)** For normal incidence,

$$2\mu t \cos 0^0 = (2n-1)\frac{\lambda}{2}$$

or $\lambda = \frac{4\mu t}{(2n-1)} = \frac{4\times1.5\times5\times10^{-5}}{(2n-1)}$

For n = 3, 4, λ = 5000 Å and 4000 Å

17. **(1)** $\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{4}{1}$ $\quad \therefore \frac{a_1}{a_2} = \frac{2}{1}$

18. **(4)** Coherent light is always monochromatic.

19. **(1)** Bright fringes are yellow and dark fringes are black.

20. **(3)** $I_{max} = I + 4I + 2\sqrt{I\times4I} = 9I$,

and $I_{min} = I + 4I - 2\sqrt{I\times4I} = I$

21. **(2)** Path difference = $171.5\lambda = \frac{343}{2}\lambda$

= odd multiple of half wavelength.

It means dark fringe is observed.

According to question, $0.01029 = \frac{343}{2}\lambda$

$$\Rightarrow \lambda = \frac{0.01029\times2}{343} = 6\times10^{-5}\text{cm} \Rightarrow \lambda = 6000\overset{0}{\text{A}}$$

22. **(2)** Thickness of air film = t

Optical Path = μt

Path Difference = $\mu t - t = (\mu-1)t$

23. **(2)** should be much smaller than λ

24. **(2)** Fresnel's experiment deals with two coherent sources of equal amplitude. Lloyd's mirror experiment deals with reflection of light from a monochromatic slit source, and intends to prove wave nature of light. While in a thin film, the white light on both upper and lower surfaces split into various colors and interfere with each other. Young's Double slit experiment, deals with interference patterns caused due to division of wave fronts of two monochromatic lights

25. **(4)** For two coherent sources, $I_1 = I_2$

This is given as I_0 for maximum and zero for minimum. If there are two noncoherent sources, there will be no maximum and minimum intensities. Instead of all the intensity I_0 at maximum and zero for minimum, it will be just $I_0/2$.

26. **(1)** Bright

27. **(2)** PO = $d\sec\theta$ and CO = PO cos 2θ = $d\sec\theta\cos2\theta$

Path difference,

Δx = CO + PO = ($d\sec\theta + d\sec\theta\cos2\theta$)

Effective path difference

$$\Delta x_{eff} = d(\sec\theta + \sec\theta.\cos 2\theta) + \frac{\lambda}{2}$$

For constructive interference, $\Delta x_{eff} = \lambda$

or $d(\sec\theta + \sec\theta\cos 2\theta) + \frac{\lambda}{2} = \lambda$ or $\cos\theta = \frac{\lambda}{4d}$

28. **(3)** The fringe width is given by, $\beta = \frac{\lambda D}{d}$

The angular width of fringe is given by

$$\frac{d}{D} = \frac{\lambda}{\beta} = \frac{6\times10^{-7}}{0.12\times10^{-3}} = 5\times10^{-3}\,\text{rad}$$

29. **(2)** $I_A = I + 4I + 2\sqrt{I+4I}\cos\pi/2 = 5I$

and $I_B = I + 4I + 2\sqrt{I\times4I}\cos\pi = I$

So, $I_A - I_B = 5I - I = 4I$

30. **(2)** Wavelength/frequency must be same and phase difference must be constant for producing sustained interference.

31. **(2)** $\beta = \frac{\lambda D}{d}$

$\therefore \beta$ increases on decreasing d, separation of slits.

32. **(1)** There will be general illumination as super imposing waves do not have constant phase difference.

33. **(3)** If a is the amplitude of wave, then

34. **(4)** Young's double slit experiment no longer remains it becomes fraunhoffer's Diffraction from single slit.

35. **(4)** $SD > \lambda d$

36. **(4)** For dark fringes of both waves at same place

or $(n+1)\times 400 = n\times 560$

or $n = 2.5$, and $n + 1 = 3.5$

There integer value is 5 and 7.

The distance between two regions of complete dark,

$$\Delta x = 7\frac{D\lambda}{d} = \frac{7\times1\times400\times10^{-9}}{0.1\times10^{-3}} = 28\,\text{mm}$$

37. **(3)** $\beta = \beta^{|}$ or $\frac{D\lambda}{d} = \frac{D^{|}\lambda}{(2d)}$ $\therefore D^{|} = 2D$

38. **(3)** $\Delta x_{max} = d = 5000\,\overset{0}{A}$. Given $\lambda = 5000\,\overset{0}{A}$.

As $\lambda < d < 2\lambda$, $\therefore n = 3$

39. **(4)** For maxima $d\sin\theta = n\lambda$

$$\sin\theta = \frac{n\lambda}{d} = \frac{8\lambda}{10\lambda} \Rightarrow \sin\theta = \frac{4}{5} \Rightarrow \tan\theta = \frac{4}{3}$$

Also $\tan\theta = \frac{y}{D}$ $\therefore y = \frac{4D}{3}$

40. **(1)** $\beta = \frac{D\lambda}{d}$ and $\beta^{|} = \frac{D\times1.1\lambda}{1.1d} = \frac{D\lambda}{d} = \beta = 0.2\,\text{mm}$

41. **(2)** The position of nth dark fringe. So position of first dark fringe in $x_1 = \lambda D/2d$

$d = 20$ cm, $D = 0.1$mm, $\lambda = 5460$ Å, $x_1 = 0.16°$

42. **(2)** Let x be the minimum distance and I_0 be the intensity of central maximum then,

$$\frac{I_0}{2} = I_0\cos^2\left(\frac{\pi x}{\beta}\right)$$

$$\frac{\pi x}{\beta} = \frac{\pi}{4} \to x = \frac{\lambda D}{4d} = \frac{5\times10^{-7}\times1}{4\times10^{-3}} = 1.25\times10^{-4}\,\text{m}$$

43. **(4)** Order of the fringe can be counted on either side of the central maximum. For example, no. 3 is first order bright fringe.

44. (4) Young's double slit experiment proved beyond a shadow of a doubt that light is a wave. The superposition of light from two slits produces an interference pattern.

45. **(4)** The shape of interference fringes formed on a screen in case of a monochromatic source is a straight line. Remember for double hole experiment a hyperbola is generated.

46. **(4)** Optical path difference

$\Delta x = (\mu_1 - \mu_2)t$

47. **(4)** $x \propto D$

$\therefore$ If d becomes thrice, then X becomes $\frac{1}{3}$ times.

48. **(3)**

49. **(4)** $\beta = \frac{\lambda D}{d} = \frac{5000 \times 10^{-10} \times 0.9}{3 \times 10^{-3}} m = 1.5 \times 10^{-4} m = 0.15 mm$

50. **(3)** $\frac{3}{4} I_0 = I_0 \cos^2 \frac{\theta}{2} \Rightarrow \cos \frac{\theta}{2} = \frac{\sqrt{3}}{2}$

$\frac{\theta}{2} = 30^0 \Rightarrow \theta = 60^0$

51. **(2)** Width of central maximum in diffraction pattern due to single slit $= \frac{2\lambda D}{d}$

where λ is the wavelength, *D* is the distance between screen and slit and *a* is the slit width.
As the slit width *a* increases, width of central maximum becomes sharper or narrower. As same energy is distributed over a smaller area. Therefore central maximum becomes brighter.

52. **(2)** At the centre, all colours meet in phase, hence central fringe is white.

53. **(2)** d sin 30° = 1 × 5 × 10^{-7}m

d = 10^{-6}m = 10^{-4}cm = 10 × 10^{-5} cm.

54. **(3)** Here Angle of incidence, i = 57

tan 57° = 1.54

u_{glass} = tan i

It means, Here Breswster's law is followed and the reflected ray is completely polarised.
Now, when reflected ray is analysed through a polaroid then intensity of light is given by malus law.
i.e. $I = I_0 \cos^2\theta$, on rotating polaroid 'θ' changes.
Due to which intensity first decreases and then increases.

55. **(2)** Intensity of polarised light transmitted from 1st polariser,

$I_1 = I_0 \cos^2\theta$

but $(\cos^2\theta)_{av} = \frac{1}{2}$ So, $I_1 = \frac{1}{2} I_0 = \frac{32}{2} = 16\, Wm^{-2}$

56. **(3)** Such substances rotate the plane of polarised light.

57. **(2)** $I = I_0 \cos^2\theta$

Intensity of polarized light $= \frac{I_0}{2}$

$\Rightarrow$ Intensity of untransmitted light $= I_0 - \frac{I_0}{2} = \frac{I_0}{2}$

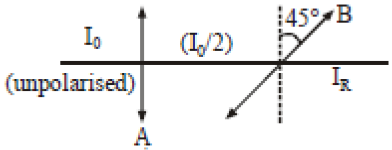
58. **(4)** Given: D = 2m; d = 1 mm = 1 × 10^{-3} m

λ = 600 nm = 600 × 10^{-6} m

Width of central bright fringe (= 2β)

$= \frac{2\lambda D}{d} = \frac{2 \times 600 \times 10^{-6} \times 2}{1 \times 10^{-3}} m = 2.4 mm$

59. **(3)**



Relation between intensities

$$I_R = \left(\frac{I_0}{2}\right)\cos^2(45^0) = \frac{I_0}{2}\times\frac{1}{2} = \frac{I_0}{4}$$

60. **(3)** $\mu = \tan i \Rightarrow i = \tan^{-1}(\mu) = \tan^{-1}(\sqrt{3}) = 60^0$

61. **(4)** Conditions for diffraction minima are

Path diff. $\Delta x = n\lambda$ and Phase diff. $\delta\phi = 2n\pi$

Path diff. $= n\lambda = 2\lambda$

Phase diff. $= 2n\pi = 4\pi \ (\because n = 2)$

62. **(3)** $x = \dfrac{(2n+1)\lambda D}{2a}$

For red light, $x = \dfrac{(4+1)D}{2a}\times 6500\,\overset{0}{A}$

For other light, $x = \dfrac{(6+1)D}{2a}\times\lambda\,\overset{0}{A}$

x is same for each

$\therefore 5\times 6500 = 7\times\lambda \Rightarrow \lambda = \frac{5}{7}\times 6500 = 4642.8\,\overset{0}{A}$

63. **(1)** $I = \left[\left(\frac{I_0}{2}\right)\cos^2\theta\right]\cos^2(90^0-\theta)$

$= \dfrac{I_0}{2}\cos^2\theta\sin^2\theta = \dfrac{I_0}{8}\sin^2 2\theta$

64. **(1)** $a\sin\theta = n\lambda \Rightarrow \dfrac{ax}{f} = 3\lambda$

(since θ is very small so $\sin\theta \approx \tan\theta \approx \theta = x/f$)

$\lambda = \dfrac{ax}{3f} = \dfrac{0.3\times10^{-3}\times5\times10^{-3}}{3\times1}$

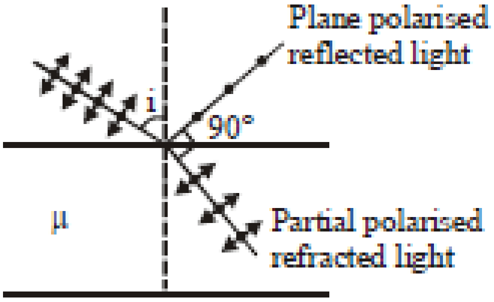
$= 5\times10^{-7}\,m = 5000\,\overset{0}{A}$

65. **(3)** Given, refractive index, $\mu = \dfrac{4}{3}$

According to Brewster's law when unpolarised light strikes at polarising angle i_p on an interface then reflected and refracted rays are normal to each other and is given by : $i_p = \mu \quad \therefore i_p = \tan^{-1}\left(\frac{4}{3}\right)$

NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. **(2)** When reflected light rays and refracted rays are perpendicular, reflected light is polarised with electric field vector perpendicular to the plane of incidence.



Also, $\tan i = \mu$ (i = Brewester angle)

2. **(2)** Angular width $= \frac{\lambda}{d}$

So, $0.20^0 = \frac{\lambda}{2mm} \Rightarrow \lambda = 0.20^0 \times 2$

Again, $0.21° = \frac{\lambda}{d}$

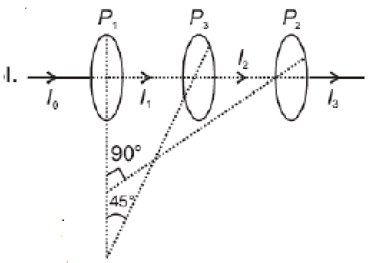
Now putting the value of λ

$d = \frac{0.20^0 \times 2mm}{0.21^0}$; $\therefore d = 1.9\,nm$

3. **(2)** Resolving power of a microscope $= \frac{2\mu \sin\theta}{\lambda}$

i.e., $R \propto \frac{1}{\lambda}$ or $\frac{R_1}{R_2} = \frac{\lambda_2}{\lambda_1}$ $\quad \therefore \frac{R_1}{R_2} = \frac{6000\,\overset{0}{A}}{4000\,\overset{0}{A}} = \frac{3}{2}$

4. **(2)** According to malus law, $I = I_0 \cos^2\theta$



$I_1 = \frac{I_0}{2}, I_2 = \frac{I_0}{2}\cos^2 45^0; = \frac{I_0}{2} \times \frac{1}{2} = \frac{I_0}{4}$

$I_3 = \frac{I_0}{4}\cos^2 45^0 \Rightarrow I_3 = \frac{I_0}{8}$

5. **(3)** According to question

8th bright fringe in medium = 5th dark firing in air

$Y_{8th\,bright} = 8\frac{\lambda D}{\mu d}$

$Y_{5th\,dark} = (2\times5-1)\frac{\lambda D}{2d} = \frac{9}{2}\frac{\lambda D}{d}$

$\Rightarrow \frac{9}{2}\frac{\lambda D}{d} = 8\frac{\lambda D}{\mu d}$ or, refractive index $\mu = \frac{16}{9} = 1.78$

6. **(4)** For the first minima,

$\theta = \frac{n\lambda}{a} \Rightarrow \sin 30^0 = \frac{\lambda}{a} = \frac{1}{2}$

First secondary maxima will be at

$$\sin\theta = \frac{3\lambda}{2a} = \frac{3}{2}\left(\frac{1}{2}\right) \Rightarrow \theta = \sin^{-1}\left(\frac{3}{4}\right)$$

7. **(4)**

8. **(4)** Here, distance between two slits, $d = 1mm = 10^{-3}m$
distance of screen from slits, $D = 1$ m
wavelength of monochromatic light used, $\lambda = 500nm = 500 \times 10^{-9}m$
width of each slit a =?

Width of central maxima in single slit pattern $= \frac{2\lambda D}{a}$

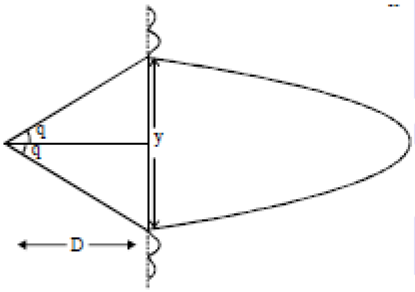
Fringe width in double slit experiment $\beta = \frac{\lambda D}{d}$

So, required condition $\frac{10\lambda D}{d} = \frac{2\lambda D}{a}$

$$\Rightarrow a = \frac{d}{5D} = \frac{1}{5} \times 10^{-3} m = 0.2\,mm$$

9. **(4)** Linear width of central maxima y

$$= D(2q) = 2Dq = \frac{2D\lambda}{a} \quad \therefore q = \frac{\lambda}{a}$$



10. **(3)** For path difference λ, phase difference $= 2\pi$ rad.

For path difference $\frac{\lambda}{4}$, phase difference $= \frac{\pi}{2}$ rad.

As $K = 4I_0$ so intensity at given point where path difference is $\frac{\lambda}{4}$

$$K' = 4I_0 \cos^2\left(\frac{\pi}{4}\right)\left(\cos\frac{\pi}{4} = \cos 45^0\right) = 2I_0 = \frac{K}{2}$$

11. **(4)** Given: $D = 2m$; $d = 1$ mm $= 1 \times 10^{-3}$ m
$\lambda = 600$ nm $= 600 \times 10^{-6}$ m
Width of central bright fringe $(= 2\beta)$

$$= \frac{2\lambda\beta}{d} = \frac{2 \times 600 \times 10^{-6} \times 2}{1 \times 10^{-3}} m$$

$= 2.4 \times 10^{-3}$ m $= 2.4$ mm

12.

$\theta' = \theta/\mu$

$$\therefore \quad \theta' = \frac{0.2^\circ}{4/3} = 0.15^\circ$$

13. Path difference for nth minima $= (2n-1)\frac{\lambda}{2}$

For fifth minima $(n = 5) = \frac{9\lambda}{2}$

14. Angular width $\propto \frac{\lambda}{d}$

$$\Rightarrow \frac{\theta_0}{0.7\theta_0} = \frac{\frac{6000\,\overset{0}{A}}{d}}{\frac{\lambda}{d}} \Rightarrow \lambda = 4200\,\overset{0}{A}$$

15. For central maximum, the phase difference between the two waves will be zero.

16. $\beta = \frac{\lambda D}{d}$; $\beta' = \frac{\lambda 2D}{\frac{d}{2}}$

$\beta' = 4\beta$

Fringe with becomes 4 times

17. $\Delta\theta = \frac{1.22\lambda}{d} = \frac{1.22 \times 6 \times 10^{-7}}{2} = 3.66 \times 10^{-7}\,rad$

18. $\tan i_p = \frac{\mu_D}{\mu_R}$

$\mu_D > \mu_R \Rightarrow \frac{\mu_D}{\mu_R} > 1 \Rightarrow \tan i_P > 1 \Rightarrow i_P > 45^0$

$\therefore 45^0 < i_P < 90^0$

19. $n_1\lambda_1 = n_2\lambda_2$

$8(600) = n_2(400)$

$n_2 = 12$