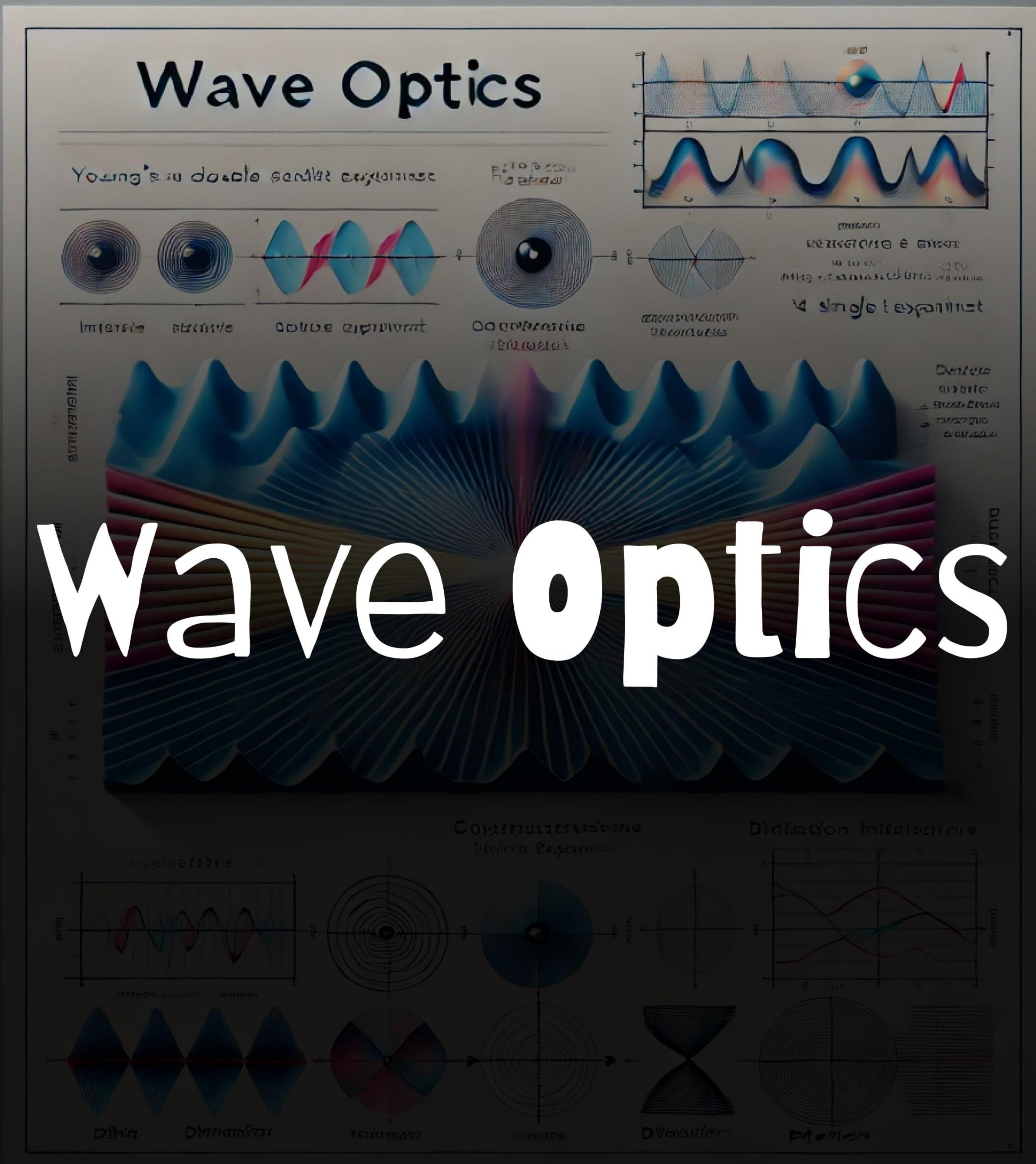
Wave Optics



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Page No.
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WAVE OPTICS

EM wave
↓
Light is non mechanical transverse wave

HUYGEN WAVE THEORY

Assume light as a mechanical and longitudinal wave
Requires medium for propagation
Used the concept of wavelet and wavefront
He explained
- Rectilinear propagation
- Interference (YDSE)
- Reflection
- Refraction
- Diffraction.

But he failed to explain polarisation, photoelectric effect and Compton effect

polarisation ↓ explained by assuming light as transverse wave

photoelectric effect ↓ explained by assuming light as particle nature of light

Q How light travel from sun to earth if there is vacuum between them? (according to Huygen)

→ There is a medium b/w sun and earth called ether medium.
↓
very low density & very high elasticity.

Wave equation.

$\Rightarrow$ $y = A \sin(kx + \omega t + \phi)$

$k = \frac{2\pi}{\lambda}$ $y \rightarrow$ Position of medium particle

$\omega = \frac{2\pi}{T}$ $A \rightarrow$ Amplitude of medium particle

Frequency

No of oscillation per sec
Source dependent
Medium independent
Unit $\rightarrow$ Hz.

Angular frequency.

$\omega = \frac{2\pi}{T} = 2\pi f$

Unit = rad/s

Amplitude

Maximum displacement from mean position on either side
Dependent on source and medium.

Speed of wave.

$v = \lambda \nu = \lambda f$
Medium dependent

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

Wavelength

The distance between two successive crests or trough of the light wave.

Wave equation

$y = A \sin(kx + \omega t + \phi)$

$A \rightarrow$ Amplitude of medium particle

$y \rightarrow$ position after time t

$kx + \omega t + \phi \rightarrow$ Phase (Angle)

$\phi \rightarrow$ initial phase.

Phase difference in λ path length $= 2\pi$

" " " 1 unit length $= \frac{2\pi}{\lambda}$

" " " Δx path length $= \frac{2\pi}{\lambda}\Delta x$

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

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

Intensity of Wave

$I = \frac{E}{At} = \frac{1}{2}\omega^2 A^2 \rho v$

$A \rightarrow$ Area

$A \rightarrow$ Amplitude

$I \propto \omega^2$

$I \propto A^2$

$I \propto \rho \leftarrow$ density of medium

$I \propto v \leftarrow$ velocity of wave.

Point source

Spherical wave front

Intensity $I \propto A^2$ (Amplitude)

$I \propto \frac{1}{r^2} \propto A^2$

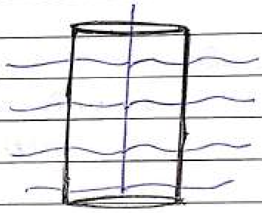
Amplitude $A \propto \frac{1}{r}$ r = distance from point source

Linear source

Cylindrical wavefront

Intensity $I \propto A^2$

$I \propto \frac{1}{r}$



Amplitude $\Rightarrow$ $A \propto \frac{1}{\sqrt{r}}$

Planar source

Planar source / source is at infinity / light is coming from infinity.

Planar wavefront

Intensity $I \propto A^2$

$I \propto r^0$

Amplitude $A \propto r^0$

HUYGEN'S PRINCIPLE

WAVEFRONT

- Wavefront is the locus of all points (wavelet) which oscillate in a same phase
- Wavelet is the point of disturbance due to propagation
- A line perpendicular to wavefront is a ray.
- Wave travel perpendicular to wavefront.
- Electric field = (wave / ray)
- Equipotential = (wavefront)

HUYGEN PRINCIPLE

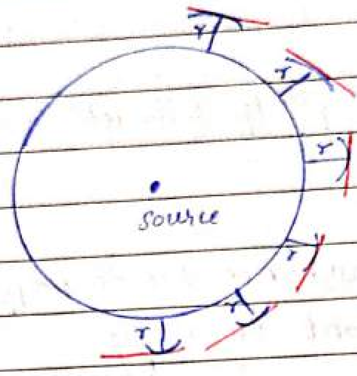
Every point on the wave front becomes a source of secondary disturbance and generates wavelets which spread out in the medium with the same velocity as that of light in the forward direction only.

The envelope of these secondary waves at any instant of time gives the position of the new wave front at that instant

The wave front in a medium is always perpendicular to the direction of wave propagation.

HUYGEN CONSTRUCTION

A common tangent enveloping secondary wavelet in forward direction gives new wavefront

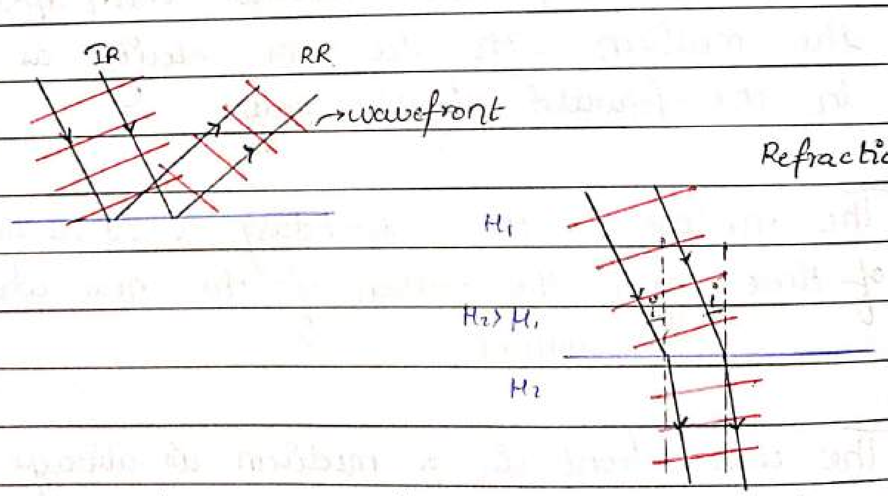


Behaviour of plane Waveform

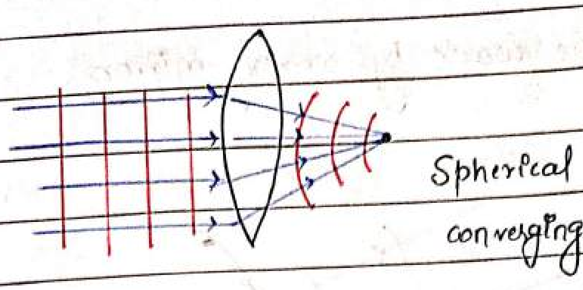
Behaviour of plane waveform on reflection & refraction.

1) Plane wave reflected from plane mirror.

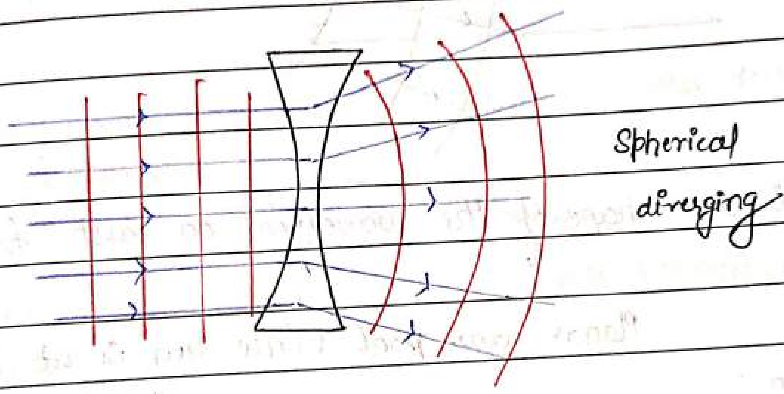
Reflection



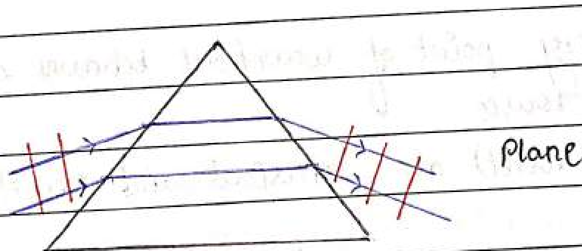
2) Refraction of a plane wave front by a convex lens



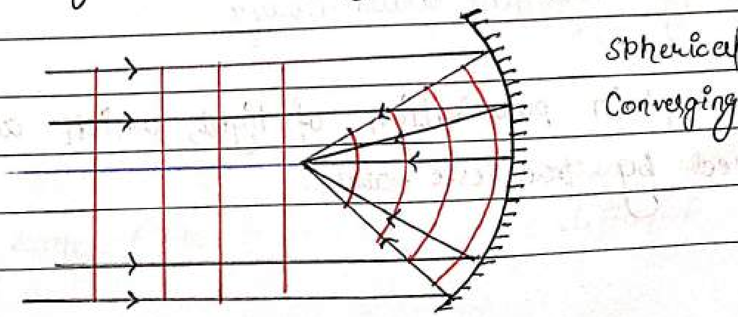
3) Refraction of a plane waveform by concave lens.



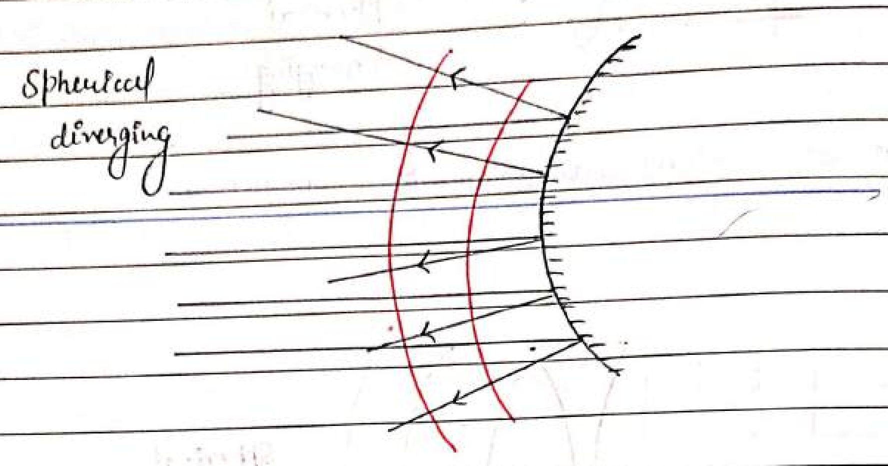
4) Refraction of plane wave from prism.



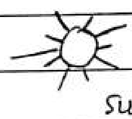
5) Reflection of plane wave by concave mirror.



6) Reflection of plane wave by convex mirror.



Q What is the shape of the wavefront on earth for sun



Planar wave front (since sun is at infinity)

Secondary Wavelets (source) / Huygens construction

1) Each and every point of wavefront behaves as a secondary source
2) Those point (wavelet) are spherical and travel with speed of light
3) The secondary wavelets spread in all direction but in backward direction intensity is zero

Demerits of Huygens wave theory.

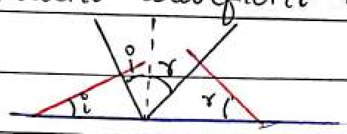
Unable to explain polarisation of light, which can only be explained by transverse nature.

He can't explain electromagnetic nature of light

He can't explain why secondary wavelets are formed in forward direction only.

MR* Point

The angle between incident wavefront and surface is angle of incident.



The angle between surface and refracted wavefront is angle of reflection (r).

Time between two same type of wavefront is always same

Coherent Source

Two wave of zero phase difference is coherent source → wrong

Two wave have constant phase difference is called coherent source

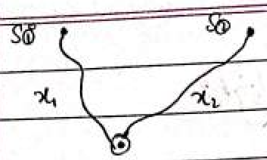
Two independent light source must not be coherent.

If $f_1 = f_2$ → two waves are coherent $\Delta\phi$ = constant

If $f_1 \neq f_2$ → Incoherent wave $\Delta\phi$ = depends on time

Coherent source

The source which emits a light wave with same frequency and same phase or constant phase different.



$\Delta\phi \Rightarrow$ depends on time

$\because$ these source are incoherent.

$Y_1 = A_1 \sin(\omega_1 t + Kx_1 + \phi_1)$

$Y_2 = A_2 \sin(\omega_2 t + Kx_2 + \phi_2)$

Phase difference

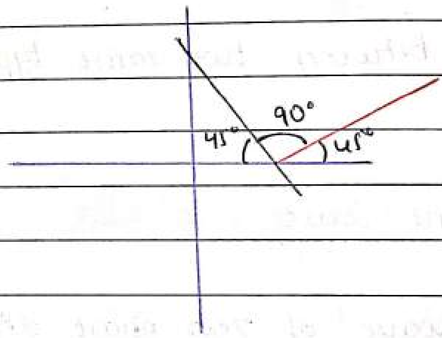
$\Delta\phi = (\omega_1 - \omega_2)t + (x_1 - x_2)K + \phi_1 - \phi_2$

Q A wavefront is parallel to line $Y = -x + 4$ then direction of propagation of wave with $+x$ axis is.

a) $120°$
b) $45°$
c) $145°$
(d) $120°$

Ans $Y = mx + c$

$m = 45°$ anti clockwise.



Q Wavefront is a locus of all the point vibrate with same.

a) amplitude
b) Phase
c) Period
d) Frequency.

Q A wavefront of a wave has direction with wave motion.

a) parallel
b) Perpendicular
c) At 45°
d) Opposite.

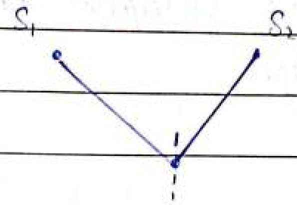
INTERFERENCE

Superposition of two coherent wave of same wavelength and frequency.

$\downarrow$ K.

$y_1 = A_1 \sin(kx_1 + \omega t)$

$y_2 = A_2 \sin(kx_2 + \omega t)$



Superimpose

$$y = y_1 + y_2 = A_1 \sin(kx_1 + \omega t) + A_2 \sin(kx_2 + \omega t) = A \sin(kx + \omega t)$$

$$\Delta\phi = k(x_1 - x_2)$$

Constructive Interference

$\Delta\phi = 0, 2\pi, 4\pi, 6\pi \ldots$

$\Delta\phi = n(2\pi) \quad n = 0, 1, 2, 3, 4 \ldots$

$= 2\pi n$

$\Delta x = \lambda n \quad n = 0, 1, 2, 3, 4 \ldots$

$A_{net} = \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos\phi}$

$\Rightarrow \sqrt{A_1^2 + A_2^2 + 2A_1A_2\cos 0^\circ}$

$\Rightarrow \sqrt{A_1^2 + A_2^2 + 2A_1A_2}$

$\Rightarrow \sqrt{(A_1 + A_2)^2}$

$A_{net} = A_1 + A_2$

$I_{net} = A_{net}^2 = (A_1 + A_2)^2 = (\sqrt{I_1} + \sqrt{I_2})^2$

$\Rightarrow I_{max} = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}$

If amplitude $\Rightarrow A_1 = A_2$

$A_{max} = 2A$

$I_{max} = 4I$

Distructive Interference

$\Delta\phi = \pi, 3\pi, 5\pi, 7\pi \ldots$

$\Delta\phi = (2n+1)\pi$

$\Delta x = \left(n + \frac{1}{2}\right)\lambda$

$A_{net} = A_1 - A_2$

$I_{min} = (A_1 - A_2)^2 = (\sqrt{I_1} - \sqrt{I_2})^2$

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

If amplitude $A_1 = A_2$

$A_{min} = A_1 - A_2 = 0$

$I_{min} = 0$

$$\frac{I_{max}}{I_{min}} = \left(\frac{A_1+A_2}{A_1-A_2}\right)^2 = \left(\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}\right)^2$$

Q. Light from two sources, each of same frequency and travelling in same direction, but with intensity in the ratio 4:1 interfere. Find ratio of maximum to minimum intensity.

Ans. ω = same

$$\frac{I_1}{I_2} = \frac{4}{1}$$

$$\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}\right)^2 = \left(\frac{2+1}{2-1}\right)^2 = 3\times 3 = 9 \text{ Ans}$$

Q. Two periodic waves of intensities I_1 and I_2 pass through a region at the same time direction. The sum of the maximum and minimum intensities is.

(A) $I_1 + I_2$
(B) $(\sqrt{I_1}+\sqrt{I_2})$
(C) $(\sqrt{I_1}-\sqrt{I_2})^2$
(D) $2(I_1+I_2)$

Ans. $I_{max} + I_{min} = I_1 + I_2 + \cancel{2\sqrt{I_1}\sqrt{I_2}} + I_1 + I_2 - \cancel{2\sqrt{I_1}\sqrt{I_2}}$
$= 2(I_1+I_2)$

Doubt

Q. The path difference between two waves.
$y_1 = A_1 \sin \omega t$ and $y_2 = A_2 \cos(\omega t + \phi)$ will be

(A) $(\lambda/2\pi)\phi$
(B) $(\lambda/2\pi)(\phi+\pi/2)$
(C) $(2\pi\lambda)(\phi-\pi/2)$
(D) $(2\pi\lambda)\phi$

Ans
$y_1 = A_1\cos(\omega t+\pi/2)$
$y_2 = A_2\cos(\omega t+\phi)$
$\Delta\phi = \pi/2 - \phi$
$\Delta x = \frac{\Delta\phi}{2\pi}\lambda$
$\Delta x = \left(\frac{\pi}{2}-\phi\right)\frac{1}{2\pi}\lambda$
$= \frac{\lambda}{4}$

$y_1 = A_1\sin(\omega t)$
$y_2 = A_2\sin\left(\frac{\pi}{2}+(\omega t+\phi)\right)$
$\Delta\phi = \omega t - \frac{\pi}{2} + \omega t + \phi$
$= 2\omega t + \phi - \frac{\pi}{2}$
$\Delta x = \frac{\Delta\phi}{2\pi}\lambda$
$= 2\omega t$

$\Delta\phi = \cancel{\omega t} - \frac{\pi}{2} - \cancel{\omega t} - \phi$
$\Delta x = \frac{\Delta\phi}{2\pi}\lambda$
$= -\left(\frac{\pi}{2}+\phi\right)\frac{\lambda}{2\pi}$

Q The resultant amplitude in interference with two coherent source depends upon.

a) Intensity
b) Only phase difference
c) On both of the above
d) None of the above

Q The displacements of two interfering light waves are $Y_1 = 4A\sin(\omega t)$ and $y_2 = 3\cos(\omega t)$. The amplitude of the resultant wave is (Y_1 and Y_2 are in CGS system)

a) 5 cm
b) 7 cm
c) 1 cm
(d) zero

$A_{net}^2 = A_1^2 + A_2^2 + 2A_1A_2\cos\phi$

If $A_1 = A_2$

$A_{net}^2 = 2A^2 + 2A^2\cos\phi$

$A_{net}^2 = 2A^2(1+\cos\phi)$

$A_{net}^2 = 2A^2(2\cos^2\phi/2)$

$A_{net}^2 = 4A^2\cos^2\phi/2 \longrightarrow A_{net} = 2A\cos\phi/2$

$I_{net} = 4I\cos^2\phi/2$

Condition for Interference

* The two sources of light should emit continuous waves of same wavelength and same time period i.e the sources should have phase coherence. same ω

same

* The two sources of light should be very close to each other.
* The waves emitted by two sources should either have zero phase difference or constant phase difference.

Interference of 'n' coherent wave of same intensity I_0 in constructive interference

$I_{net} = (\sqrt{I_1} + \sqrt{I_2} + \sqrt{I_3} \ldots\ldots + \sqrt{I_n})^2$

$I_{net} = (n\sqrt{I_1})^2$

$I_{net} = n^2 I$

$I_{max} = n^2 I$

for constructive interference.

Date / /
Page No.

If there are n incoherent wave each of intensity I_0, then the ~~resulty~~ resultant intensity is.

For two wave interference

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

$\langle I_{net}\rangle = \langle I_1\rangle + \langle I_2\rangle + 2\sqrt{I_1}\sqrt{I_2}\langle\cos\phi\rangle$

$\Rightarrow \langle I_{net}\rangle = I_1 + I_2 + 0$

$I_{net} = nI$

for interference

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

Ans $I_{net} = 4I\cos^2\frac{\phi}{2}$

$\Rightarrow 4\times I_0\cos^2\frac{2\pi}{3\times 2}$

$4I_0\times\frac{1}{4} = I_0$ Ans

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

Ans Constructive interference $\Rightarrow I_{max} = (\sqrt{I_1}+\sqrt{I_2})^2 = (\sqrt{I_0}+2\sqrt{I_0})^2 = 3^2 I_0 = 9I_0$

Destructive interference $\Rightarrow I_{min} = (\sqrt{I_1}-\sqrt{I_2})^2 = (\sqrt{I_0}-2\sqrt{I_0})^2 = I_0$

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

Ans For incoherent wave

$$I_{net} = I_1 + I_2$$
$$= I_0 + 3I_0 = 4I_0 \text{ Ans}$$

Q. Light from two sources, each of same frequency and travelling in same direction, but with intensity in the ratio 4:1.

Q Two sources of intensity 2I and 8I are used in an interference experiment. The intensity at a point where the waves from two sources superimpose with phase difference of (a) zero (b) $\pi/2$ and (c) π is.

(a) 18 I, 10 I, 2 I

(c) 5I, 4I, I

c) 2I, I, I/2

(d) 2I, 10I, 18I

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

$$= (\sqrt{2I} + \sqrt{8I})^2$$
$$\Rightarrow (\sqrt{2I} + 2\sqrt{2I})^2$$
$$\Rightarrow (3\sqrt{2I})^2$$
$$= 18I$$

$I_{min} = (\sqrt{I_1} - \sqrt{I_2})^2$

$$= 2I$$

For $\Delta\phi = \pi/2$

$$I_{net} = 2I + 8I + 2\sqrt{2I}\sqrt{8I}\cos\frac{\pi}{2}$$
$$I_{net} = 10I$$

Q The intensity of interference waves in an interference pattern is same as I_0. The resultant intensity at the point of observation will be.

a) $I = 2I_0[1 + \cos\phi]$
b) $I = I_0[1 + \cos\phi]$
c) $I = \frac{[1 + \cos\phi]}{I_0}$
D) $I = \frac{[1 + \cos\phi]}{2I_0}$

FRING VISIBILITY

It is the measure of intensity contrast between dark to bright band.

$$\boxed{V = \eta = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}}$$

η will be one if

$I_1 = I_2 = I$

$I_{max} = 4I$

$I_{min} = 0$

Q The necessary condition for phenomenon of interference to occur is.

a) There should be two coherent sources
b) The frequency and amplitude of both the waves should be same
c) The propagation of waves should be simultaneously and in same direction.
d) All of the above.

Q The equation for two waves obtained by two light sources are as given below.
$Y_1 = A_1 \sin 3\omega t$, $Y_2 = A_2 \cos(3\omega t + \pi/6)$. What will be the value of phase difference at the time t.

a) $3\pi/2$
b) $2\pi/3$ ANS $\cancel{3\omega t} + \frac{\pi}{6} + \frac{\pi}{2} - \cancel{3\omega t}$
c) π
d) $\pi/2$ $= 2\pi/3$

Q Two coherent sources have intensity ratio of 100:1 and are used for obtaining the phenomenon of interference. Then the ratio of maximum and minimum intensity will be.

a) 100:1
b) 121:81
c) 1:1
(d) 5:1

Ans $\frac{I_{max}}{I_{min}} = \frac{(\sqrt{I_1}+\sqrt{I_2})^2}{(\sqrt{I_1}-\sqrt{I_2})^2} = \left(\frac{10+1}{10-9}\right)^2 = \frac{121}{81}$

Q $Y_1 = 5\sin(kx + \omega t - 30)$, $Y_2 = 5\cos(kx + \omega t)$
find $Y_1 + Y_2$

ANS $Y = Y_1 + Y_2 = 5\sin(kx + \omega t + 30°)$

Q Two independent monochromatic sodium lamps cannot

Date / /
Page No.

produce interference because.

a) The frequencies of two sources are different
b) The phase difference between two sources changes with respect to time
c) The two sources become coherent
d) The amplitudes of two sources are different

Q $Y_1 = 4\sin(kx + \omega t + 30°)$, $Y_2 = 4\cos(kx + \omega t)$
find $Y = Y_1 + Y_2$

Ans $Y = 4\sqrt{3}\sin(kx + \omega t + 60°)$

Q Two wave of equation $Y_1 = 4\sin(kx + \omega t + 30°)$ and $Y_2 = 3\sin(kx + \omega t + 120°)$
find ______ wave equation.

Ans $Y_1 + Y_2 = 5\sin(kx + \omega t + 67°)$

Q Two wave of equation $Y_1 = 3\sin(\omega t + kx)$
$Y_2 = 3\cos(\omega t + kx + 30°)$

Ans $Y_1 + Y_2 = 3\sin(\omega t + kx + 60°)$

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

a) $5I$ and I
b) $5I$ and $3I$
c) $9I$ and I
d) $9I$ and $3I$

Ans $\frac{I_{max}}{I_{min}}^m = ?$

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

$= 9I$

$I_{min} = I$

Q If two waves represented by $y_1 = 4 \sin \omega t$ and $y_2 = 3 \sin(\omega t + \pi/3)$ interfere at a point, the amplitude of the resulting will be about.

a) 7

~~b)~~ 6

c) 5

d) 3.5

Ans $A_{net}^2 = A_1^2 + A_2^2 + 2A_1A_2 \sin \cos\phi$

$\Rightarrow 16 + 9 + 2 \times 4 \times 3 \cos \pi/3$

$\Rightarrow 25 + 12 = 37$

$A_{net} = \sqrt{37} \approx 6$

Q If an interference pattern has maximum and minimum intensities in 36:1 ratio then what will be the ratio of amplitudes?

a) 5:7

b) 7:4

c) 4:7

~~d)~~ 7:5

Date / /
Page No.

Ans $\frac{I_{max}}{I_{min}} = \frac{36}{1} = \frac{(\sqrt{I_1}+\sqrt{I_2})^2}{(\sqrt{I_1}-\sqrt{I_2})^2}$

$\Rightarrow \frac{6}{1} = \frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}$;

$6\sqrt{I_1} - 6\sqrt{I_2} = \sqrt{I_1} + \sqrt{I_2}$

$5\sqrt{I_1} = 7\sqrt{I_2}$

$\frac{7}{5} = \frac{\sqrt{I_1}}{\sqrt{I_2}} = \frac{A_1}{A_2}$

Q In Young's double slit interference experiment, using two coherent waves of different amplitudes, the intensities ratio between bright and dark fringes is 3. Then, the value of the ratio of the amplitudes of the wave that arrive there is.

(a) $\left(\frac{\sqrt{3}+1}{\sqrt{3}-1}\right)$

B) $\left(\frac{\sqrt{3}-1}{\sqrt{3}+1}\right)$

c) $\sqrt{3}:1$

d) $1:\sqrt{3}$

Ans $\frac{I_{max}}{I_{min}} = \frac{(A_1+A_2)^2}{(A_1-A_2)^2} = 3$

$\frac{A_1+A_2}{A_1-A_2} = \sqrt{3}$

$A_1 + A_2 = \sqrt{3}A_1 - \sqrt{3}A_2$

$A_1(\sqrt{3}-1) = (\sqrt{3}+1)A_2$

$$\frac{A_1}{A_2} = \left(\frac{\sqrt{3}+1}{\sqrt{3}-1}\right)$$

Q Two coherent source of intensity ratio α interfere. The value of $\frac{I_{max} - I_{min}}{I_{max} + I_{min}}$ is.

(A) $2\sqrt{\frac{\alpha}{1+\alpha}}$

(B) $\frac{2\sqrt{\alpha}}{1+\alpha}$

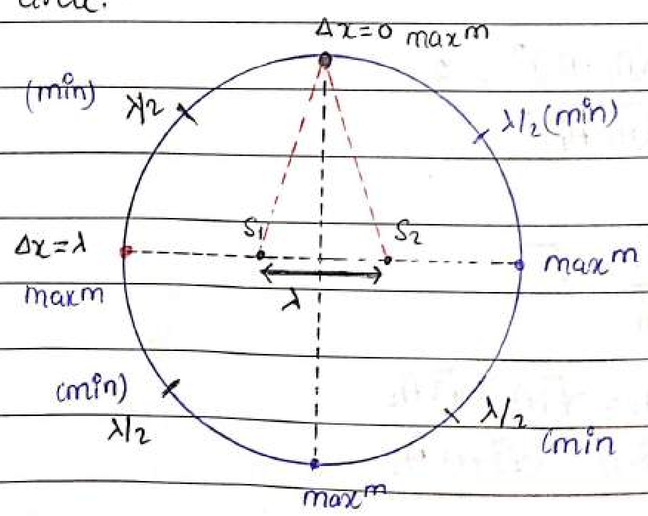
(C) $\frac{1+\alpha}{2\sqrt{\alpha}}$

(D) $\frac{1-\alpha}{1+\alpha}$

Ans $$\frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{2\cancel{4}\sqrt{I_1}\sqrt{I_2}}{\cancel{2}(I_1+I_2)} = \frac{2\sqrt{I_2\alpha}\sqrt{I_2}}{I_2\alpha + I_2} = \frac{2\sqrt{\alpha}\,\cancel{I_2}}{\cancel{I_2}(\alpha+1)}$$

$$= \frac{2\sqrt{\alpha}}{\alpha+1}$$

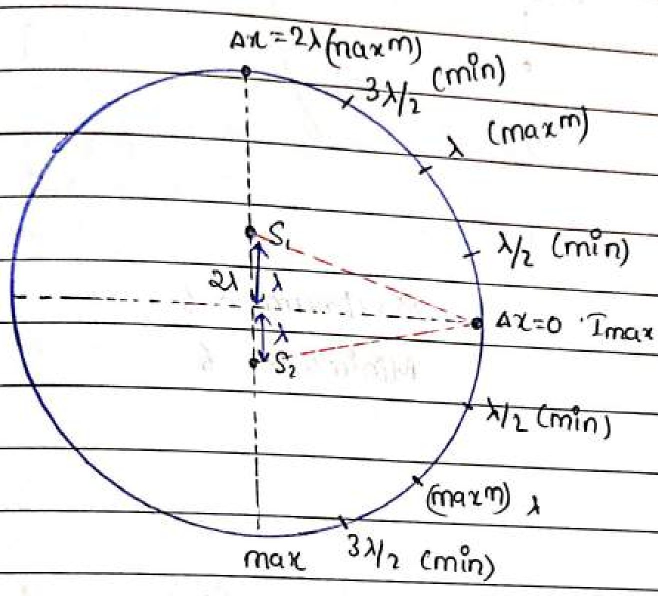
* λ is the wavelength of light, find total no. of maxima & minima on circle.



Date / /
Page No.
Shivalal

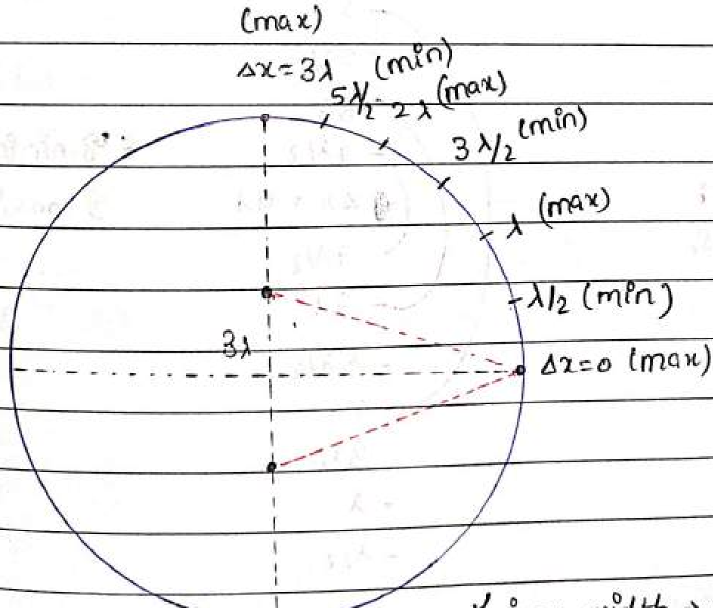
4 → maxima
4 → minima } → On circle

fringe width → large



8 → maxima
8 → minima } → On circle

Q

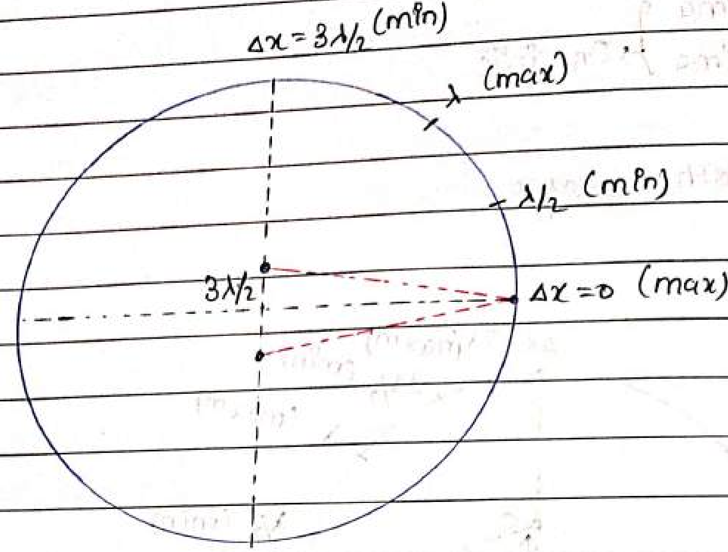


fringe width → small

12 → Maxima
12 → Minima

Page No.

Q

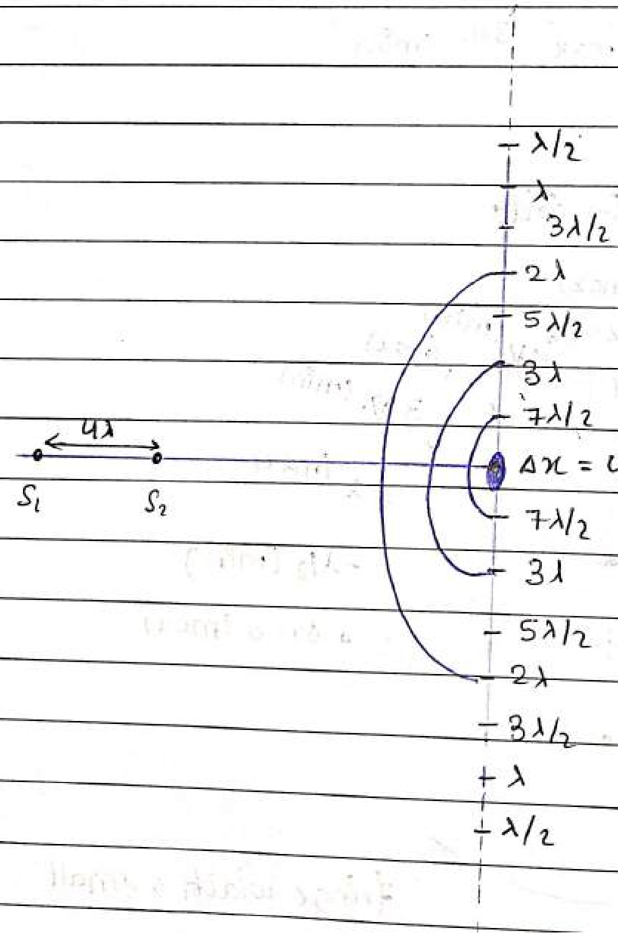


Maximum → 6

Minima → 6

Q

Find no. of maxima & minima on screen



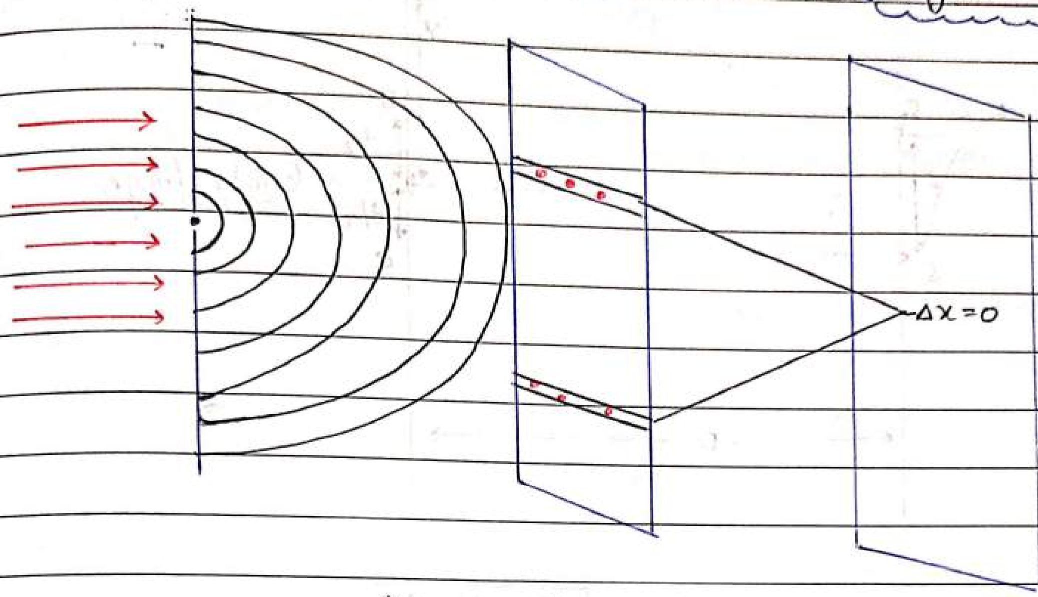
4 minima

4 maxima

Date / /
Page No.

YOUNG'S DOUBLE SLIT EXPERIMENT

Intensity of light $\propto$ slit width



slit width $\approx \lambda_{light}$ $\approx \mu m$
↓
so that light behave as a wave

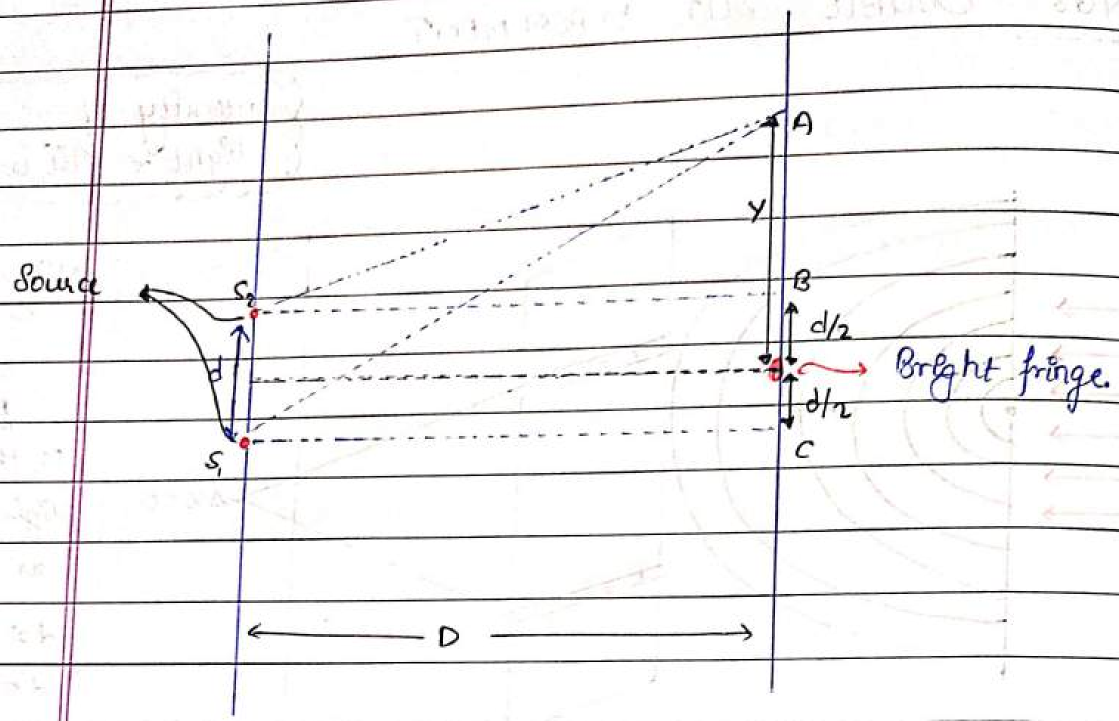
$d >>> \lambda$

$d \approx cm$

Light behaves as a ray when light interacts with object having dimension very much greater than wavelength of light. (No interference)

Light behave as a wave when light interacts with object having dimension of order of wavelength of light.

Light behaves as a particle when it interacts with relativistic particle (like $e^{\ominus}$, p, n, α particle) light behave as photon



$$S_2A = y^2 + \sqrt{D^2 + \left(y - \frac{d}{2}\right)^2}$$

$$S_1A = \sqrt{\left(y + \frac{d}{2}\right)^2 + D^2}$$

Δx = path difference = $S_1A - S_2A$

$$\Delta x = \sqrt{\left(y + \frac{d}{2}\right)^2 + D^2} - \sqrt{\left(y - \frac{d}{2}\right)^2 + D^2}$$

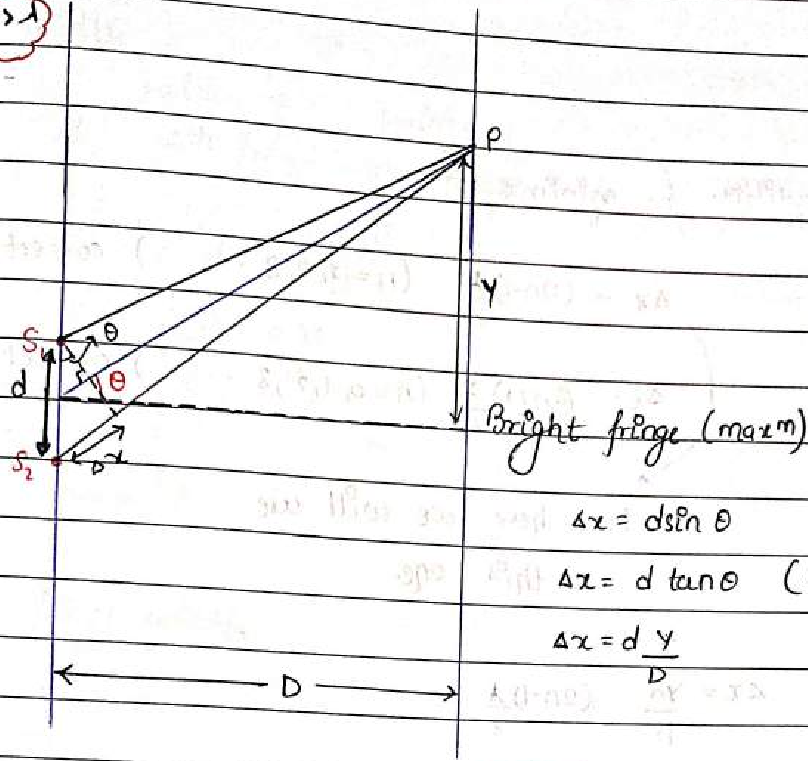
for constructive interference

$$\Delta x = \lambda n$$

Date / /
Page No.

YDSE

$D >>> d >>> \lambda$



$\Delta x = d \sin\theta$

$\Delta x = d \tan\theta$ ($\theta \Rightarrow$ very small)

$\Delta x = d \dfrac{y}{D}$

Condition for maxima. (Constructive interference)

$\Delta x = 0, \lambda, 2\lambda, 3\lambda, 4\lambda, 5\lambda \ldots = n\lambda \qquad n = 0, 1, 2, 3, 4, \ldots$

$\Delta\phi = 2\pi n$

$y \propto \dfrac{1}{d}$ → distance b/w slit

$\Delta x = \dfrac{yd}{D} = n\lambda$

$y \propto D$ → distance b/w screen & slit.

$y = \dfrac{n\lambda D}{d}$ $n = 0$ central maxm $y = 0$

↑ position of n^{th} bright fringe

$n = 1$ 1^{st} maxm $y = \dfrac{\lambda D}{d}$

$n = 2$ 2^{nd} maxm $y = \dfrac{2\lambda D}{d}$

Condition for minima.

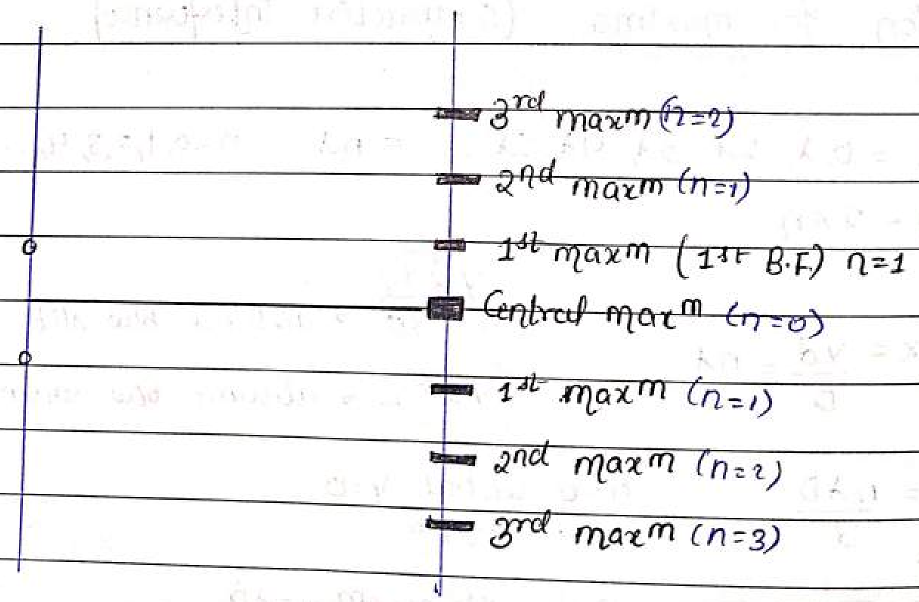
$\Delta x = (2n-1)\frac{\lambda}{2}$ $(n = 1, 2, 3, \ldots\ldots)$ correct

$\Delta x = (2n+1)\frac{\lambda}{2}$ $(n = 0, 1, 2, 3 \ldots\ldots)$ correct

but here we will use this one.

$$\Delta x = \frac{yd}{D} = (2n-1)\frac{\lambda}{2}$$

Position of nth Dark fringe $\leftarrow$ $y = \frac{(2n-1)\lambda D}{2d}$



Date / /
Page No.

Fringe width

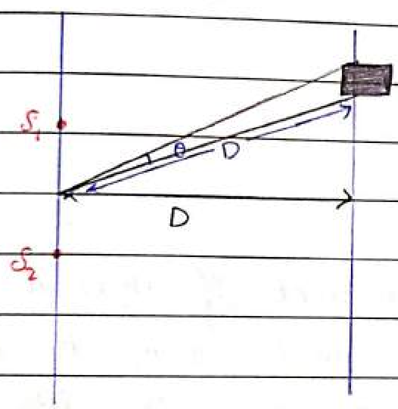
$$\beta = \text{position of } (n^{th} \text{ fringe}) - \text{position } (n-1) \text{ fringe}$$

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

$$\beta = \cancel{\frac{n\lambda D}{d}} - \cancel{\frac{n\lambda D}{d}} + \frac{\lambda D}{d}$$

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

Angular fringe width



Using concept of Arc length

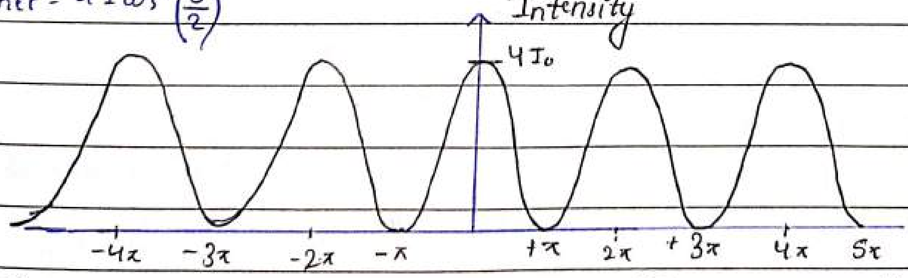
Arc $= R\theta$

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

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

$Y_{n^{th}}$ Bright $= \frac{n\lambda D}{d}$ $\quad \beta = \frac{\lambda D}{d}$ $\quad \theta = \frac{\lambda}{d}$

$I_{net} = 4I\cos^2\left(\frac{\theta}{2}\right)$



Q 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.

a) half

b) four times

c) one fourth

d) double

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

a) x (blue) = x (green)

b) x (blue) > x (green)

c) x (blue) < x (green)

d) $\frac{x \text{ (blue)}}{x \text{ (green)}} = \frac{5460 \text{ Å}}{4360 \text{ Å}}$

Ans $Y = \frac{n\lambda D}{d}$ $\quad y \propto \lambda$

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

a) $11\frac{\lambda}{2}$

b) $\frac{5\lambda}{2}$

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

d) $\frac{9\lambda}{2}$

Ans $\Delta x = (2n-1)\frac{\lambda}{2} = \frac{9\lambda}{2}$

Q In a double slit experiment when light of wavelength 400 nm was used, angular width of the first width minima formed on a screen placed 1 m away, was found to be 0.2°. What will be the angular width of the ~~fourth~~ first minima, if the entire experimental apparatus is immersed in water? ($\mu_{water} = 4/3$)

a) 0.1°
b) 0.266°
c) 0.15°
d) 0.05°

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

$\frac{\theta_1}{\theta_2} = \frac{\lambda n}{\lambda}$

$\Rightarrow \frac{\theta_1}{\theta_2} = n$

$\theta_2 = \frac{\theta_1}{n} = \frac{0.2 \times 3}{4} = 0.15°$ Ans

YDSE in air	YDSE in medium
1) fringe width in air $\beta = \frac{\lambda D}{d}$	Fringe width in liquid $\beta' = \frac{\lambda D}{\mu d} = \frac{\beta}{\mu}$ i.e. decreases by a factor of μ
2) Angular fringe width $\theta = \frac{\lambda}{d}$	Angular fringe width in liquid $= \frac{\lambda}{d\mu}$ it also decreases by a factor of μ
3) Position of fringes on screen Maximum $y = \frac{n\lambda D}{d}$ Minimum $y = (2n-1)\frac{\lambda D}{2d}$	Position of fringes on screen. Maximum $\Rightarrow \frac{n\lambda D}{d\mu}$ Minimum $= (2n-1)\frac{\lambda D}{2\mu d}$

Q In Young's double slit experiment the separation d between the slits is 2mm, the wavelength λ of the light used is 5896 Å and distance D between the screen and slits is 100cm. 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 need to be changed to.

a) 1.8 mm

b) 1.9 mm

c) 2.1 mm

d) 1.7 mm

Ans

$$\theta = \frac{\lambda}{d} = 0.20^\circ$$

$$\lambda = \theta d$$

$$\theta_1 d_1 = \theta_2 d_2$$

$$0.20 \times 2 = 0.21\ d$$

$$d = \frac{20}{21} \times 2 = \frac{40}{21} = 1.7 \text{ mm}$$ Ans

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

a) 60×10^{-4} cm

b) 10×10^{-4} cm

c) 10×10^{-5} cm

d) 6×10^{-5} cm.

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Date / /
Page No.

ANS $d = 0.90mm$

$D = 1m$

$Y = 1mm$

$n = 2$

$Y = \frac{(2n-1)\lambda}{2}\frac{D}{d}$

$1mm = \frac{\cancel{3}\lambda}{2} \times \frac{1}{10^{-3} \times \cancel{0.9}\, 0.3}$

$0.6 \times 10^{-6}\ m$

$\Rightarrow 6 \times 10^{-5}\ cm$ Ans

Q In Young's double slit experiment carried out with light of wavelength $(\lambda) = 5000\ \mathring{A}$, the distance between the slits is 0.2 mm and the screen is at 200 cm from the slits. The central maximum is at $x=0$. The third maximum (taking the central maximum as zeroth maximum) will be at x equal to.

a) 1.67 cm

b) 1.5cm

c) 0.5cm

d) 5.0cm

Ans $d = 0.2mm$

$D = 200cm$

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

$Y = \frac{3 \times 5000\ \mathring{A} \times 200 \times 10^{-2}}{0.2 \times 10^{-3}} \Rightarrow 15 \frac{\times 10^{-3} \times \cancel{2}}{\cancel{2}} = 1.5cm$

Q Two slits in Young's modulus experiment have width in the ratio 1:25. The ratio of intensity at the maxima and minima in the interference pattern $\frac{I_{max}}{I_{min}}$ is.

a) $\frac{121}{49}$

b) $\frac{49}{121}$

c) $\frac{4}{9}$

~~d)~~ $9/4$

Ans $\frac{\omega_1}{\omega_2} = \frac{I_1}{I_2} = \frac{1}{25}$

$$\frac{I_{max}}{I_{min}} = \frac{(\sqrt{I_1}+\sqrt{I_2})^2}{(\sqrt{I_1}-\sqrt{I_2})^2} = \frac{(6)^2}{(4)^2} = \frac{36}{16} = 9/4 \text{ Ans}$$

Q In an interference pattern, the slit widths are in the ratio 1:9. Then find out the ratio of minimum and maximum intensity.

a) 1:2

b) 1:6

c) 1:3

~~d)~~ 1:4

Ans $\frac{I_1}{I_2} = \frac{1}{9}$

$$\frac{I_{min}}{I_{max}} = \frac{(\sqrt{I_1}-\sqrt{I_2})^2}{(\sqrt{I_1}+\sqrt{I_2})^2} = \frac{4}{16} \Rightarrow \frac{1}{4}$$

Date / /
Page No.

If ω_1 and ω_2 are the widths of two slits from which intensities of light I_1 and I_2 then.

$$\frac{\omega_1}{\omega_2} = \frac{I_1}{I_2}$$

I_{max} (Bright fringe) $= (\sqrt{I_1} + \sqrt{I_2})^2$
I_{min} (Dark fringe) $= (\sqrt{I_1} - \sqrt{I_2})^2$

If width is same $(I_1 = I_2)$
$I_{max} = 4I$
$I_{min} = 0$

Q 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.

(a) no interference
(b) interference with brighter band
(c) interference with dark bands
(d) Interference fringe with larger width.

Ans $\theta' = \frac{\theta}{\mu}$

$\mu_{air} = 1.01$

$\mu_{vacuum} = 1$

Q In the Youngs double slite experiment, the intensity of light at a point on the screen is given by where the path difference is λ is K (λ being the wavelength of the light used). The intensity at a point where the path difference is $\lambda/4$ will be

(A) K

(b) K/4

(c) K/2

(d) zero

Ans for λ path diff $\Delta\phi = 2\pi$

$$I = I_{max} = 4I_0 = K$$

for $\lambda/4$ path difference $\Delta\phi = \frac{\pi}{2}$

$$I = 4I_0 \cos^2 \frac{\pi}{4}$$

$$I = \frac{4I_0}{2} = \frac{K}{2}$$

Q The intensity of 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 $D = 10d$?

a) I_0

b) $I_0/9$

c) $\frac{3}{4} I_0$

(d) $I_0/2$

Ans $I_{max} = I_0$

$y = \frac{5\lambda}{2}$

$D = 50\lambda$

$d = 5\lambda$

$\frac{5\lambda}{2} = (2n-1)\frac{\lambda D}{2d}$

$\frac{5\lambda}{2} = (2n-1)\frac{\lambda \cdot 50\lambda}{2 \cdot 5\lambda}$

$1 = 4n - 2$

Date / /
Page No.

Ans $I_{max} = I_0$

$\Delta x = \frac{Yd}{D}$

$\Delta x = \frac{5\lambda \frac{8}{2} Y}{1050 X}$

$\Delta x = \frac{\lambda}{4}$

$\Delta\phi = \frac{\cancel{\lambda} \times 2\pi}{4 \times \cancel{\lambda}} = \frac{\pi}{2}$

$I = I_0 \cos^2 \frac{\pi}{4}$

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

Q In Youngs double slit experiment, the slits are 2mm apart and are illuminated by photons of two wavelengths $\lambda_1 = 12000\,\mathring{A}$ and $\lambda_2 = 10000\,\mathring{A}$. At what minimum distance from the common central bright fringe on the screen 2m from the slit will a bright fringe from one interference pattern coincide with a bright fringe from the other?

a) 4mm

b) 3mm

c) 8 mm

d) 6mm

Ans $d = 2mm$

$\lambda_1 = 12000\,\mathring{A}$

$\lambda_2 = 10000\,\mathring{A}$

$D = 2m$

$Y = same$

$\frac{n_1 \lambda D}{d} = \frac{n_2 \lambda_2 D}{d}$

$\frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1} = \frac{5}{6}\frac{10000}{12000}$

If $n_1 = 5$
then $n_2 = 6$

$Y_1 = \frac{n_1 \lambda_1 D}{d}$

$Y = \frac{5 \times 12000 \times \cancel{2} \times 10^{-10}}{\cancel{2} \times 10^{-3}}$

$Y = 60 \times 10^{-4}$

$Y = 6 \times 10^{-3} m$

Q In Youngs double slit experiment the fringe width is found to be 0.4 mm. If the whole apparatus is immersed in liquid (water) of refractive index 4/3 without disturbing the geometrical growth arrangement the new image fring width will be.

a) 0.30 mm
b) 0.40 mm
c) 0.53 mm
d) 450 micron.

Ans $\beta = 0.4mm$

$\beta' = \frac{0.4}{4} \times 3 = 0.3mm.$

Q whose fringe width will be more, the one for red light or the one for yellow light, all other things be the same!

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

$\beta \propto \lambda$

$\therefore \beta$ more for red light

Q Fringe width in a particular YDSE is measured to be β. What will be the fringe width if wavelength of the light is doubled and separation b/w them the slits is halved? Separation between the screen and slits is tripled.

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

$\beta' = \frac{2 \times 2}{1} \beta = 4\beta$

$\beta'' = \frac{1}{3}\beta$

Q In a Young's double slit setup using monochromatic light of wavelength λ, the intensity of light at a point where path difference is 2λ, is found to be I_0. What will be the intensity at a point where path difference is $\lambda/3$?

Ans $I_{max} = I_0$

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

$I = I_0 \cos^2 \frac{2\pi}{3\pi}$

$I = \frac{I_0}{4}$ Ans

Q In YDSE $d = 2mm$, $D = 2m$ and $\lambda = 500nm$. If intensity of two slits are I_0 and $9I_0$ then find intensity at $y = \frac{1}{6}$ mm

Ans
a) $7I_0$
b) $10I_0$
c) $16I_0$
d) $4I_0$

Ans $d = 2mm$

$D = 2m$

$\lambda = 500\,nm$

$\Delta x = \frac{yD}{d} = \frac{\frac{1}{6} \times 10^{-3} \times 2}{2 \times 10^{-3}}$ ⇒

$\Delta\phi = \frac{1}{3 \cdot 6} \frac{2\pi}{2\lambda}$

$\Delta x = \frac{yd}{D}$

$\Delta x = \frac{\frac{1}{6} mm \times 2mm}{2m}$

$\Delta x = \frac{1}{6} \times 10^{-6}$

$\Delta\phi = \frac{\Delta x}{\lambda} 2\pi = \frac{\frac{1}{6} \times 10^{-6} \times 10^{9} \times 2\pi}{500}$

$\frac{1}{6} \times \frac{10}{5} \times 2\pi$

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

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

$I_{net} = 7I_0$

Q 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

a) 1.59
b) 1.69
~~c)~~ 1.78
d) 1.25

Ans

$$\frac{8 \times \lambda D}{\eta\, d} = \frac{9\lambda}{2}\frac{D}{d}$$

$$\eta = \frac{16}{9} = 1.78$$

★ Q Two monochromatic waves, each of amplitude a, have random phase difference between them. When these superimpose then the amplitude of resultant wave is given by.

~~a)~~ $\sqrt{2}a$ (b) $2a$
c) $4a$ (d) zero

Ans

$$I_{net} = I_1 + I_2$$

$$A_{net} = \sqrt{A_1^2 + A_2^2}$$

$$A_{net} = \sqrt{2}a$$

Date / /
Page No.

Q Two light of wavelength $\lambda_1 > \lambda_2$ is used in YDSE ; then central maxima and 1^{st} maxima will.

Ans Central maximal at same position

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

if $n = 0$

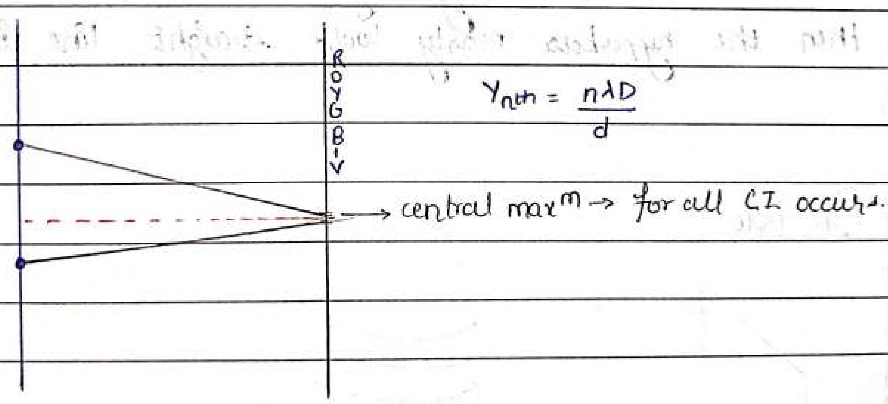
$Y = 0$ for both light

$Y \propto \lambda$

Position of 1^{st} bright fringe of λ_1 is greater that 1^{st} bright fringe of λ_2

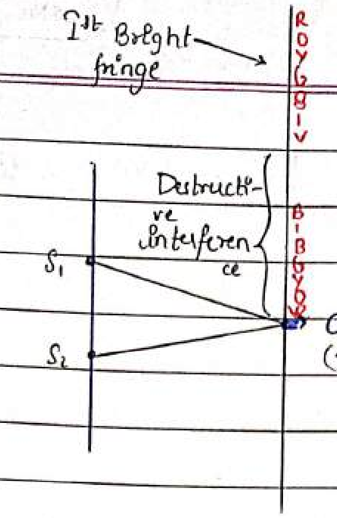
White light

★ White light is used to find central maxima experimentally



$$Y_{nth} = \frac{n\lambda D}{d}$$

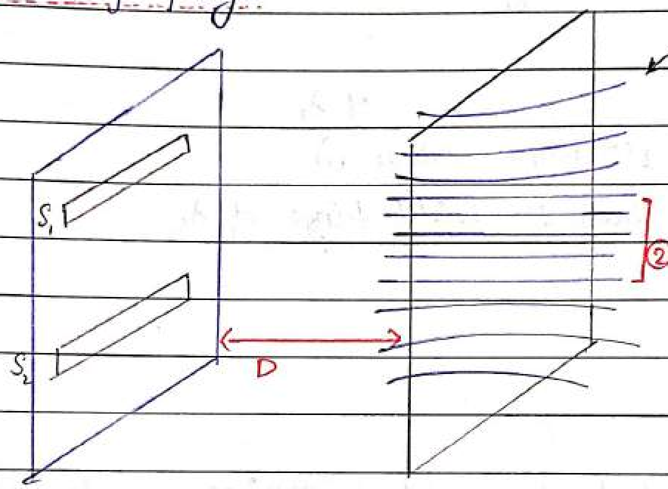
Which colour will appear first = Red ⇝ near central max^m.
Which colour have maxima first = Violet



= for all CI occurs

there is 1st D.I. (minima) b/w central max^m & 1st max^m

Shape of fringe



Ideal (D>>>d) Hyperbolic fring

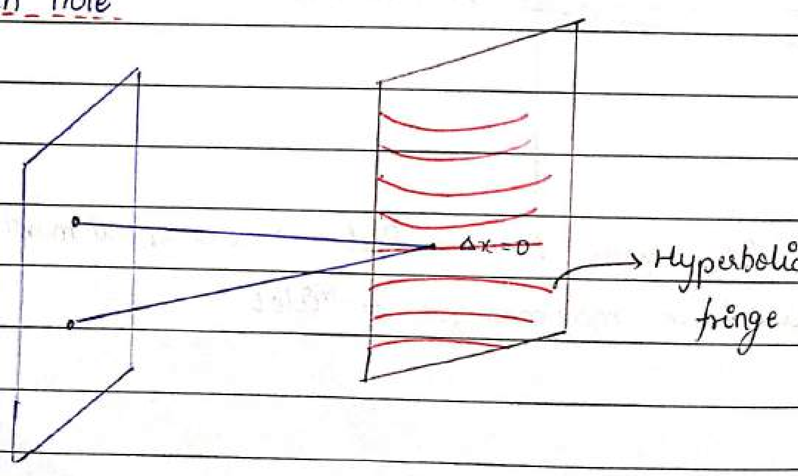
If D is small

OR

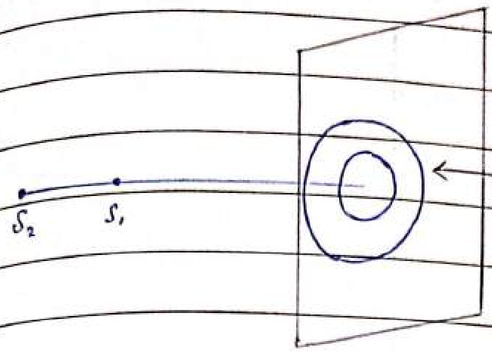
We can consider small② part of screen then shape of fring is straight

* Shapes of fringes on the screen is hyperbolic. But, if the screen is placed at very large distance from slits, then the hyperbola nearly looks straight line in shape.

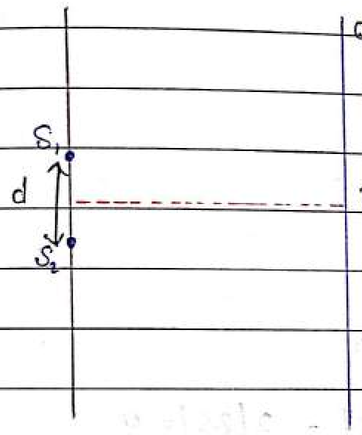
Pin hole



Two hole along the line joining of source & screen.



Number of bright and dark fringe



No. of dark fringe = $\left[\frac{d}{\lambda} + \frac{1}{2}\right]_{min}$

No. of bright fringe = $\frac{d}{\lambda}$

central maxm

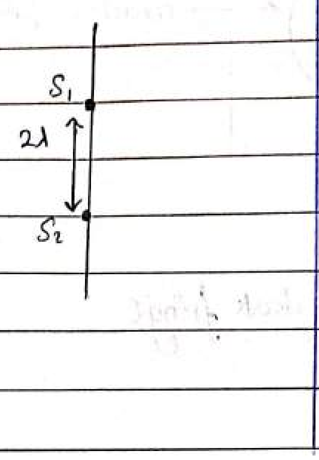
No of bright fringe = $\frac{d}{\lambda}$

No of dark fringe = $\left[\frac{d}{\lambda} + \frac{1}{2}\right]_{min}$

Total no of bright fringe :- $\left(\frac{2d}{\lambda}\right)_{min} + 1$

Total no of dark fringe :- $2\left[\frac{d}{\lambda} + \frac{1}{2}\right]_{min}$

Q Find no. of dark and bright fringe.



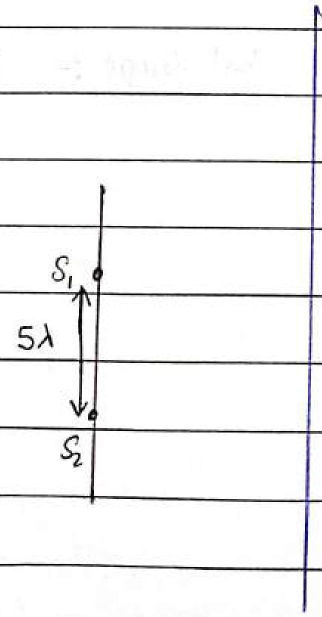
No. of bright fringe $= \left(\frac{2d}{\lambda}\right)_{min} + 1$

$\Rightarrow \left(\frac{2 \times 2\lambda}{\lambda}\right) + 1 = 5$

No. of dark fringe $= 2\left[\frac{d}{\lambda} + \frac{1}{2}\right]_{min}$

$\Rightarrow 2\left[\frac{2\lambda}{\lambda} + 0.5\right] = 2[2.5]_{min} = 4$

Q Find no. of dark and bright fringe.



Total no. of Bright fring = $\left(\frac{2d}{\lambda}\right)_{min} + 1$

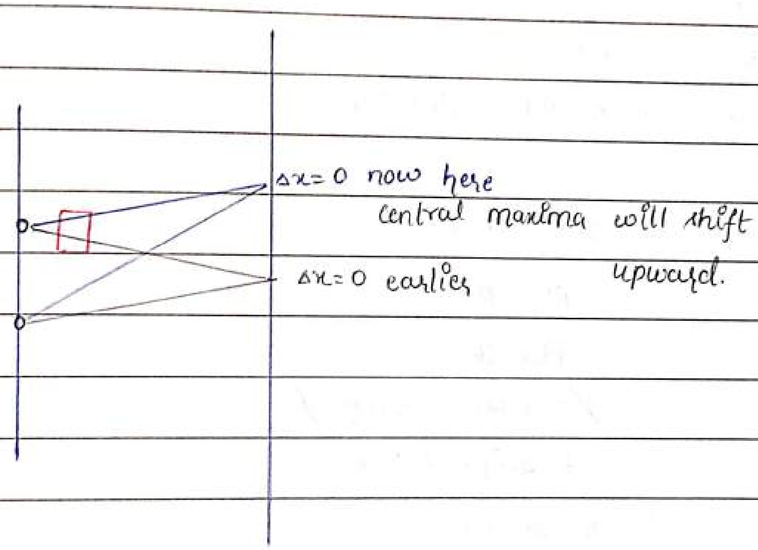
$= \left(\frac{2 \times 5\lambda}{\lambda}\right) + 1 = 11$ Ans

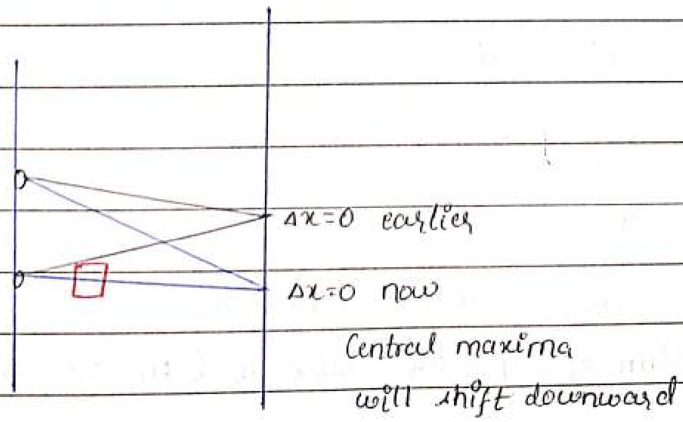
Total no of dark fringe = $2\left[\frac{d}{\lambda} + \frac{1}{2}\right]_{min}$

$= 2\left[\frac{5\lambda}{\lambda} + 0.5\right]$

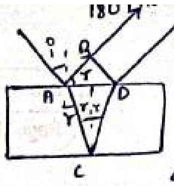
$= 10$ Ans

Glass plate inserted in front of one slit.





Thin film interference



for constructive interference

$\Delta x = \underbrace{(AC + DC)\mu}_{\text{optical path}} - AB = \frac{(2n-1)\lambda}{2}$

$\Delta x = 2\mu t \cos r$

$AC = DC$

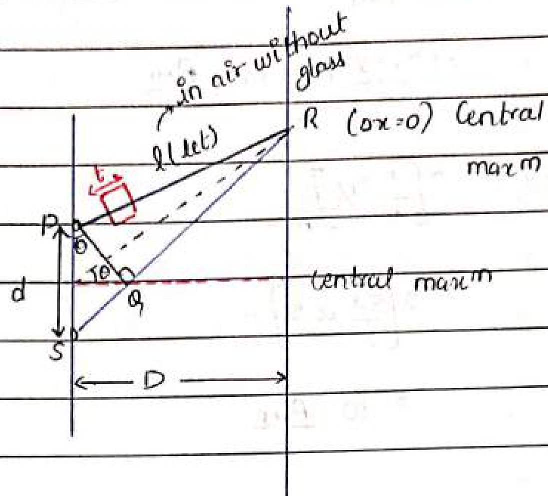
if r not given then $r = 0°$

For destructive interference

$\Delta x = \underbrace{(AC + DC)\mu}_{\text{optical path}} - AB = n\lambda$

the formula is like this because these two rays already have a path difference of $\frac{\lambda}{2}$

What is the shift in central maxima?



$PR = l - t + \mu t$

$SR = SQ + QR$

$SR = d\sin\theta + QR = d\sin\theta + l$

For central max^m

$PR - SR = 0$

$PR = SR$

$\cancel{l} - t + \mu t = d\sin\theta + \cancel{l}$

$t(\mu - 1) = d\sin\theta$

$\theta = \text{small}$

$t(\mu - 1) = d\tan\theta$

$t(\mu - 1) = \frac{dy}{D}$

Position of central Bright fringe from centre

$Y = \frac{D\,t(\mu - 1)}{d}$

Fringe width remains same

* If two medium of refractive index μ_1 & μ_2 are kept then

$$Y = \frac{\left(t_1(\mu_1 - 1) + t_2(\mu_2 - 1)\right)D}{d}$$

Date / /
Page No.

Q In YDSE, find the ~~distance~~ thickness of glass slab ($1.5 = \mu$) which should be placed at S_1 so the central maxima lies at point where 5^{th} bright fringes was lying earlier ($\lambda = 5000\text{Å}$)

Ans
$$\frac{5\lambda \cancel{D}}{\cancel{d}} = \frac{\cancel{D}}{\cancel{d}} t(\mu - 1)$$

$$5\lambda = t\left(\frac{1}{2}\right)$$

$$t = 10 \times 5000\text{Å}$$
$$= 5 \times 10^{-6} m \quad \text{Ans}$$

Q In YDSE, a thin film ($\mu = 1.6$) of thickness 0.01 mm is placed at 1^{st} slit, the central maximum shift to 10^{th} bright fringes earlier, then wavelength of wave is.

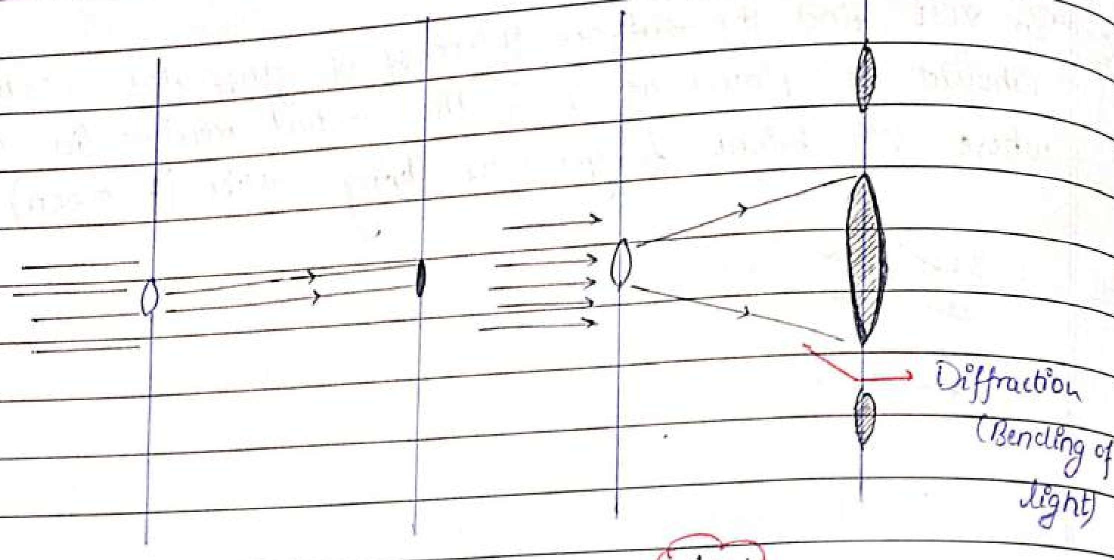
Ans
$$\frac{10\lambda \cancel{D}}{\cancel{d}} = \frac{\cancel{D}}{\cancel{d}} t(\mu - 1)$$

$$10\lambda = 1 \times 10^{-5}\left(\frac{6}{10}\right)$$

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

No of fringes shifted $= \dfrac{Y \text{ (Shift of C.B.)}}{\text{fringe width}}$

* Bending of sound is easier than bending of light



diameter of hole = d

$d >>> \lambda$

$d \approx \lambda$

diameter of hole

Diffraction. (Interference of single slit of infinite source)

Bending of light rays from sharp edges of an opaque obstacle or aperture and its spreading in the geometrical shadow region is defined as diffraction of light or deviation of light from its rectilinear propagation tendency is called diffraction of light.

Types of diffraction.

1) Fresnel diffraction

(i) Source and screen are at finite distance
(ii) Spherical wavefront

2) Fraunhofer diffraction

(i) Source and screen are at infinite distance this condition can be achieved by placing convex lens, and screen at focal of lens.

(ii) ~~Spherical~~ Planar wavefront

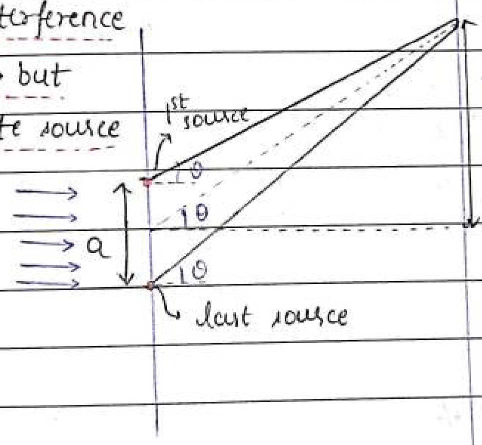
In the fraunhofer class of diffraction, the source and the screen are at infinite distances from the aperture and this condition is achieved by placing the source on the focal plane of a convex lens and placing the screen on the focal plane of another convex lens.

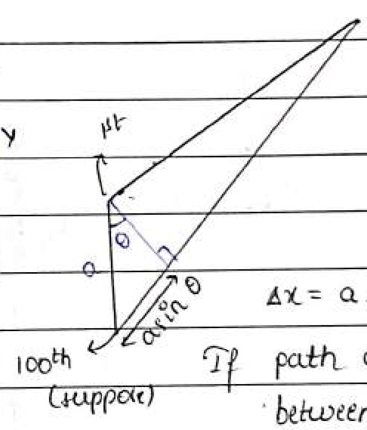
size of hole = a

Two slits → two source in interference

one hole → but infinite source

Parallel light beam.





$\Delta x = a \sin\theta$

If path difference between 1st & 100th → λ

Path difference b/w 1st & 50th $\Rightarrow \lambda/2$

" " " 2nd & 51th $\Rightarrow \lambda/2$

" " " 3rd & 52nd $\Rightarrow \lambda/2$

" " 50th & 100th $\Rightarrow \lambda/2$

Condition for 1st Destructive interference

$\Delta x = a \sin\theta = \lambda$

$a \tan\theta = \lambda$

$a \frac{y}{D} = \lambda$

$y = \frac{D\lambda}{a}$

$Y = \frac{D\lambda}{a}$ —— (1)

↓

position of 1^{st} dark fringe

Position of n^{th} dark fringe $= \frac{n\lambda D}{da}$

$\Delta x = n\lambda \rightarrow$ D.I

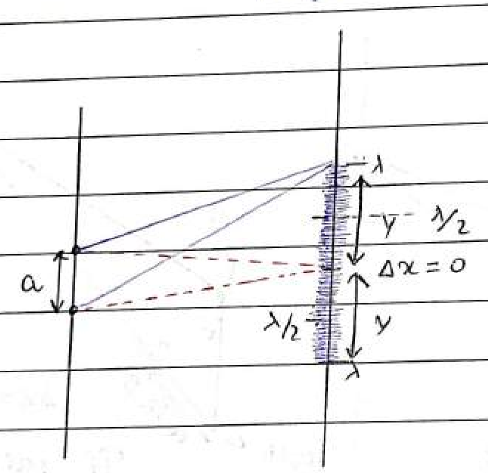
$n = 1, 2, 3, 4 \ldots$

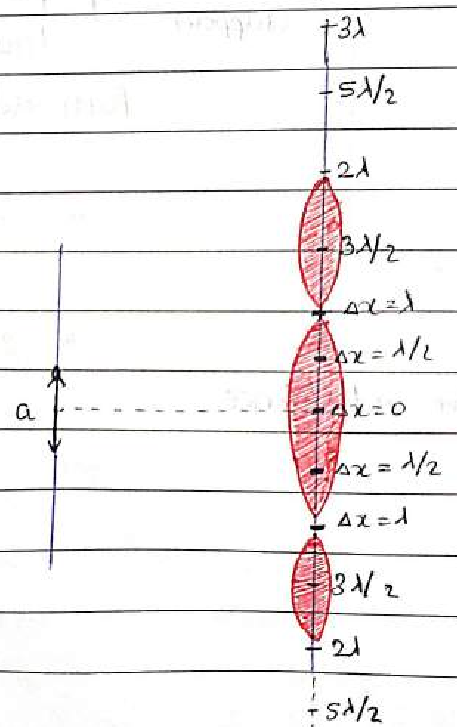
Width of Central bright fringe $= 2y = \frac{2yD}{da} \quad \frac{2\lambda D}{a}$

Angular width $= \theta$

$\cancel{D} 2\theta = \frac{2\lambda \cancel{D}}{a}$

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





Date / /
Page No.

At $\Delta x = 0 \Rightarrow$ All the particles constitute for the intensity $\therefore$ brightest region.
At $\Delta x = \lambda/2 \Rightarrow$ Extremist particles do not take part in increasing the brightness.

At $\Delta x = \lambda \Rightarrow$ No particle constitute for making intensity i.e. minima
At $\Delta x = 3\lambda/2 \Rightarrow$

$\lambda/2 \{$ 1 – 33.33 $\}$
$\lambda/2 \{$ 66.66 $\}$ get cancelled
$\lambda/2 \{$ 100 $\}$ → constitute for the energy therefore less bright than central maximum.

At $\Delta x = 2\lambda$

get cancelled: 1 – ~~20~~ 25 $\}\lambda/2$; ~~40~~ 50 $\}\lambda/2$
get cancelled: ~~60~~ 75 $\}\lambda/2$; ~~80~~ 100 $\}\lambda/2$
↓
$\therefore$ minima.

At $\Delta x = 5\lambda/2$

$\lambda/2 \{$ 1 – 20 $\}$ cancelled
$\lambda/2 \{$ 40 $\}$
$\lambda/2 \{$ 60 $\}$ cancelled
$\lambda/2 \{$ 80 $\}$
$\lambda/2 \{$ 100 $\}$ remains → constitute for the energy

$\therefore$ As we move away from central maxima on either side the no. of particles constituting the energy decreases $\therefore$ intensity goes on decreasing

YDSE

$$Y_{n\text{th bright fringe}} = \frac{n\lambda D}{d} \quad (n=0,1,2,3\ldots)$$

$\Delta x = n\lambda$ $(n=0,1,2,3,4\ldots)$
(for bright fringe)

$$Y_{n\text{th dark}} = \frac{(2n-1)\lambda D}{2d}$$

Diffraction

$$Y_{n\text{th dark fringe}} = \frac{n\lambda D}{a} \quad n=1,2,3\ldots$$

$\boxed{\Delta x = n\lambda}$ $(n=1,2,3,4\ldots)$
dark fringe path difference

$$Y_{(n-1)\text{th bright}} = \frac{(2n-1)\lambda D}{2a} \quad (n=2,3,4\ldots)$$

$\Delta x = \frac{3\lambda}{2}, \frac{5\lambda}{2}, \frac{7\lambda}{2}$ $\boxed{\Delta x = \frac{(2n-1)\lambda}{2}}$ $(n=2,3,4\ldots)$

1st maxima — bright fringe path diff

Central maxima $\Delta x = 0, \Delta x = \frac{\lambda}{2}$

Width of Central maxm $= \frac{2\lambda D}{a}$

Width of secondary maxm $= \frac{\lambda D}{a}$ (Constant)

Angular width of central maxm $\theta \approx \tan\theta = \frac{Y}{D} = \frac{2\lambda D}{a} = \frac{2\lambda}{a}$

Angular width of secondary maxm $\theta = \tan\theta = \frac{Y}{D} = \frac{\lambda}{a}$

Intensity $I = \frac{I_0 \sin^2 \phi/2}{(\phi/2)^2}$ ϕ = phase difference

Imp

YDSE

$$Y_{n\text{th Bright fringe}} = \frac{n\lambda D}{d} \quad [n=1,2,3\ldots]$$

$$Y_{n\text{th Dark fringe}} = \frac{(2n-1)\lambda D}{2d} \quad [n=1,2,3\ldots]$$

Diffraction

$$Y_{n\text{th Bright fringe}} = \frac{(2n+1)\lambda D}{2a} \quad [n=1,2,3\ldots]$$

$$Y_{n\text{th Dark fringe}} = \frac{n\lambda D}{a} \quad [n=1,2,3\ldots]$$

Q Angular width of the central maxima in the Fraunhofer diffraction for $\lambda = 6000 \mathring{A}$ 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.

a) $420 \mathring{A}$
b) $1800 \mathring{A}$
c) $4200 \mathring{A}$
d) $6000 \mathring{A}$

Ans $\theta = \frac{2\lambda}{d}$

$\theta \propto \lambda$

$\frac{\theta_1}{\theta_2} = \frac{\lambda_1}{\lambda_2}$

$\frac{1}{0.7} = \frac{6000 \mathring{A}}{\lambda_2}$

$\lambda_2 = 4200 \mathring{A}$ Ans

Q In a diffraction pattern due to a single slit of width 'a', the first minimum is observed at an angle 30° when light of wavelength 5000 Å is incident on the slit. The first secondary maximum is observed at an angle of.

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

Ans $\cancel{a} \sin\theta = \cancel{\lambda}$

$\cancel{a} \sin\theta' = \frac{3\cancel{\lambda}}{2}$

$\sin\theta \frac{1}{2} = \frac{2}{3}$

$\theta = \sin^{-1}\left(\frac{3}{4}\right)$ Ans

Q For a parallel beam of monochromatic light of wavelength 'λ', the 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.

a) $\frac{D\lambda}{a}$

b) $\frac{Da}{\lambda}$

c) $\frac{2Da}{\lambda}$

(d) $\frac{2D\lambda}{a}$

Q At the first minima adjacent to the central maximum of a single slit diffraction pattern, the phase differaction difference between the Huygen's wavelet from the edge of the slit and the wavelet from the mid point of the slit is.

a) $\pi/2$ radian (d) $\pi/4$ radian

(b) π radian

c) $\pi/8$ radian

Ans $\Delta x = \frac{\lambda}{2}$

$\Delta \phi = \pi$ Ans

Q 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.

a) 1.2cm

b) 12mm

c) 2.4cm

d) 24mm

Ans Width of central max^m $= \frac{2\lambda D}{a} = \frac{2 \times 600 \times 10^{-9} \times 2}{10^{-3}}$

$= 24mm$

Q A parallel beam of monochromatic light of wavelength 5000Å is incident normally on a single narrow slit of width 0.001 mm. The light is focused by a convex lens on a screen placed in focal plane. The first minimum will be formed for the angle of diffraction equal to.

Difference between interference and diffraction (for fraunhofer single slit).

Interference	Fraunhofer Diffraction.
1) It is the phenomenon of superposition of two waves coming from two different coherent sources.	1) It is the phenomenon of superposition of two waves coming from two different parts of the same wavefront.
2) In interference pattern, all bright lines are equally bright and spaced	2) All bright lines are not equally bright and equally wide. Brightness and width goes on decreasing with the angle of diffraction.
3) All dark lines are totally dark.	3) Dark lines are perfectly dark. Their contrast with bright lines and width goes on decreasing with angle of diffraction.
4) In interference bands are large in number	4) In diffraction bands are few in number.

Date / /
Page No.
Shivalal

Polarisation.

Electromagnetic wave is EM Wave (transverse wave) Electric and magnetic fields are perpendicular to each other and perpendicular to wave.

Magnitude of electric field is much larger than magnetic field (B). So light is prefarably described as the oscillation of electric field only.

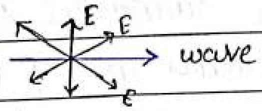
The phenomenon of restricting the vibration of light (electric vector). in a particular direction perpendicular to the direction of propagation of wave is called polarisation of light.

In polarised light, the vibration of the electric vector occur in a plane perpendicular to the direction of propagation of light and are confined to a single direction in the plane (do not occur symmetrically in all possible directions)

After polarisation the vibrations become asymmetrical about the direction of propagation of light.

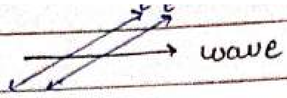
Unpolarised light

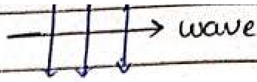
Ordinary light vibrating in all direction in plane perpendicular to propagation.



Polarised light

Light wave vibrating in a particular direction in plane perpendicular to the propagation of light





Polariser

Tourmaline crystal

When light is passed through a tourmaline crystal cut parallel to its optic axis, the vibrations of the light carrying out of the tourmaline crystal are confined only by to one direction in a plane perpendicular to the direction of propagation of light

The emergent light from the crystal is said to be plane polarised light.

Nicol Prism

A nicol prism is an optical device which is used for the production and detection of plane polarised light.

It was invented by William Nicol in 1828.

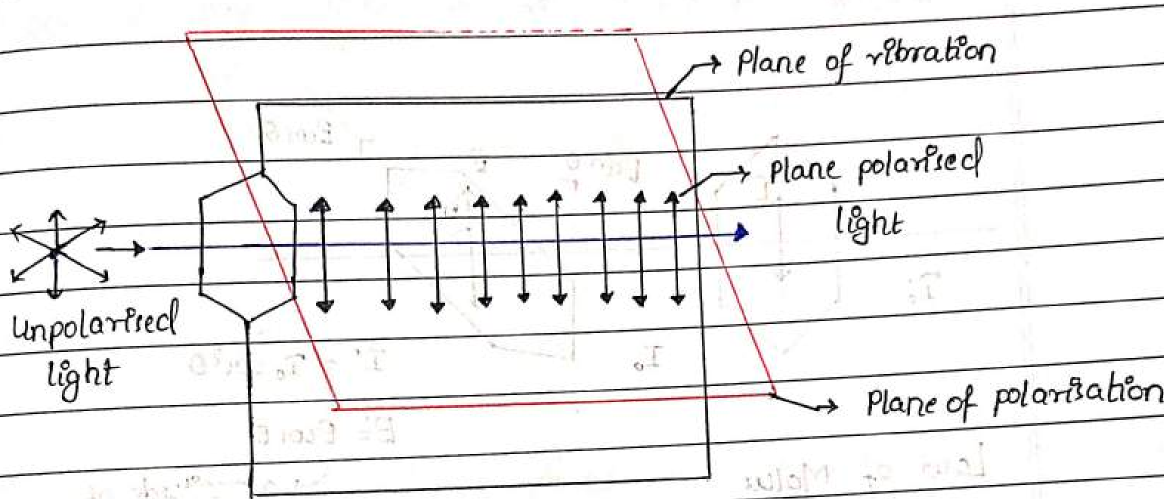
Polaroid

A polaroid is a thin commercial sheet in the form of circular disc which makes use of the property of selective absorption to produce an intense beam of plane polarised light.

Plane of polarisation and plane of vibration.

The plane in which vibrations of light vector and the direction of propagation lie is known as plane of vibration.

A plane normal to the plane of vibration and in which no vibration takes place is known as plane of polarisation.



Angle between the direction of propagation of light and plane of polarisation ⇒ 0°

" " " vibration ⇒ 0°

" " plane of polarisation & plane of vibration → 90°

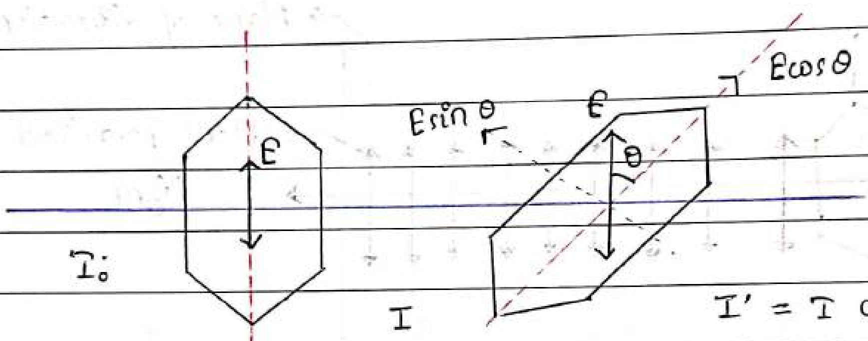
Polarised light ↓ Intensity = $\frac{I_0}{2}$

Unpolarised light Intensity = I_0

Law of Malus.

When a completely plane polarised light beam is incident on analyser; then intensity of emergent light varies as the square of cosine of the angle between the planes of transmission axis of the analyser and the polariser.

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



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

$E' = E\cos\theta$ ↳ amplitude of electric field

Law of Malus

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

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

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

$I \rightarrow$ Intensity before analyser

$I' \rightarrow$ Intensity after analyser

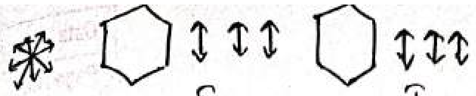
$\theta \rightarrow$ angle between the transmission axis of the two polaroids

Malus law for unpolarised light

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

$\langle I \rangle = I_0 \frac{1}{2}$

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



$\theta = 0^\circ$

I_0 $\quad \frac{I_0}{2}$ $\quad \frac{I_0}{2}$ $\quad I' = \frac{I_0}{2}\cos^2 0^\circ = \frac{I_0}{2}$

Date / /
Page No.
Shivalal

Unpolarised light $\quad$ Polariser $\quad$ Analyser

I_0 $\quad \frac{I_0}{2}$ $\quad \frac{I_0}{2}\cos^2\theta$

Q A plane polarised light with intensity I_0 is incident on a polaroid with electric field vector making and angle of 60° with transmission axis of polaroid. The intensity of the resulting light will be.

a) I_0 $\qquad$ Ans: $I' = I_0 \cos^2\theta = I_0 \frac{1}{4} = \frac{I_0}{4}$

~~b)~~ $I_0/4$

c) $I_0/2$

d) $I_0/8$

Q Two polaroids P_1 and P_2 are placed with their axis perpendicular to each other. Unpolarised light I_0 is incident on P_1. A third polaroid P_3 is kept in between P_1 and P_2 such that its axis makes an angle 45° with that of P_1. The intensity of transmitted light through P_2 is.

a) $I_0/2$

b) $I_0/4$ $\qquad$ Ans $\Rightarrow$ $I' = \frac{I_0}{2}\cos^2\theta_1 \cos^2\theta_2 \Rightarrow \frac{I_0}{2}\frac{1}{2}\times\frac{1}{2} = \frac{I_0}{8}$

~~c)~~ $I_0/8$

d) $I_0/16$

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

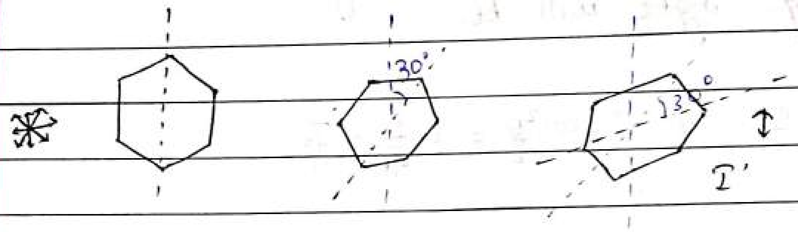
a) 1/2

b) 3/4

c) 7/8

d) 3/8

ANS $I' = \frac{I_0}{2}\cos^2 30° = \frac{I_0}{2}\frac{3}{4} = \frac{3I_0}{8}$



ANS $I' = \frac{I_0}{2}\cos^2 30° \cos^2 30°$

$\Rightarrow \frac{I_0}{2}\frac{3}{4} \times \frac{3}{4} = \frac{9I_0}{32}$ ANS

Q Two nicols are oriented with, then principal planes making an angle of 60°. The percentage of incident unpolarised light which passes through the system is:

a) 50%

b) 100%

c) 12.5%

d) 37.5%

ANS $I' = \frac{I_0}{2}\cos^2 60° = \frac{I_0}{8} = 12.5\%$

Methods of obtaining plane polarised light

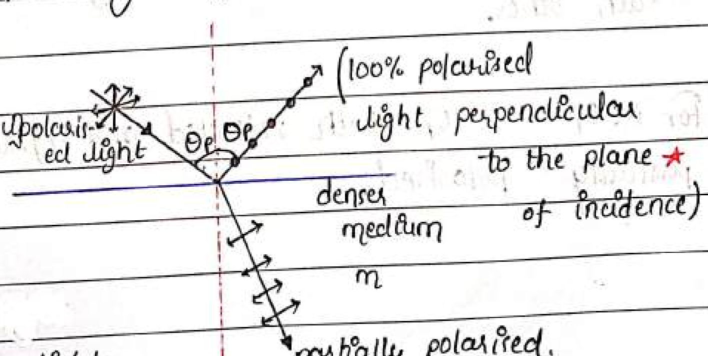
Polarisation by Reflection

The simplest method to produce plane polarised light is by reflection. This method was discovered by Malus in 1808.

When a beam of ordinary light is reflected from a surface, the reflected light is partially polarised.

The degree of polarisation of the polarised light in the reflected beam is greatest when it is incident at an angle called polarising angle or Brewster angle.

$\tan \theta_p = \frac{\mu_d}{\mu_r}$



For this phenomenon light always travels from rarer to denser.

Brewster's law

When unpolarised light strikes at polarising angle θ_P on an interface separating a rarer medium from a denser medium of refractive index μ, such that $\mu = \tan\theta_P$ then the reflected light (light in rare medium) is completely polarised.

Also reflected & refracted rays are normal to each other

This relation is known as Brewster's law.

Polarising angle.

Polarising angle is that angle of incidence at which the reflected light is completely plane polarised.

In case of polarisation by reflection.

(i) For $i = \theta_P$ refracted light is partially polarised & reflected is 100% polarised.

(ii) For $i = \theta_P$, reflected and refracted rays are perpendicular to each other.

(iii) For $i < \theta_P$ or $i > \theta_P$ both reflected and refracted light become partially polarised.

Q The critical angle of a certain medium is $\sin^{-1}\left(\frac{3}{5}\right)$. The polarizing angle of medium is.

(A) $\sin^{-1}\left(\frac{4}{5}\right)$

(B) $\tan^{-1}\left(\frac{5}{3}\right)$

(C) $\tan^{-1}\left(\frac{3}{4}\right)$

(D) $\tan^{-1}\left(\frac{4}{3}\right)$

Ans $\sin\theta_c = \frac{1}{\mu}$

$\sin\theta_c = \frac{3}{5} \quad \mu = \frac{5}{3}$

$\tan\theta_P = \mu$

$\theta_P = \tan^{-1}\left(\frac{5}{3}\right)$

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

a) Reflected light is polarised with its electric vector parallel to the plane of incidence

b) Reflected light is polarised with its electric vector perpendicular to the plane of incidence.

c) $i = \tan^{-1}\left(\frac{1}{\mu}\right)$

d) $i = \sin^{-1}\left(\frac{1}{\mu}\right)$

Polarisation by Scattering

When light is incident on the small particles of atmosphere such as dust, air molecules it is absorbed by the electrons in the molecules, hence electrons start vibrating.

These vibrating electrons emit radiations in all directions except in its own line of vibration.

The emitted radiations (light) scattered in a diagram direction perpendicular to direction of incident light is plane polarised.

The light in all other directions are partially polarised.
The scattering of light by molecules was intensively investigated by C.V. Raman and his collaborates in Kolkata in the 1920. For this work he was awarded with Nobel prize for physics in 1930.

Q Which of the following phenomenon is not common to sound and light waves?

a) Interference
b) Diffraction
c) Polarisation
d) Reflection

Date / /
Page No.

Q When unpolarised light beam is incident from air onto glass ($\eta = 1.5$) at the polarising angle. ---

a) reflected beam is polarised 100%

b) reflected beam and refracted beams are partially polarised

c) the reason for option (a) is that almost all the light is reflected.

d) All of the above.

Q The Brewster's angle i_b for an interface should be

a) $30° < i_b < 90°$

b) $45° < i_b < 90°$

c) $i_b = 90°$

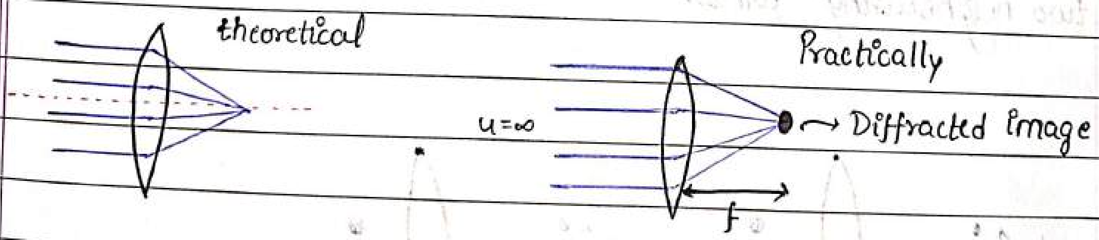
d) $0° < i_b < 30°$

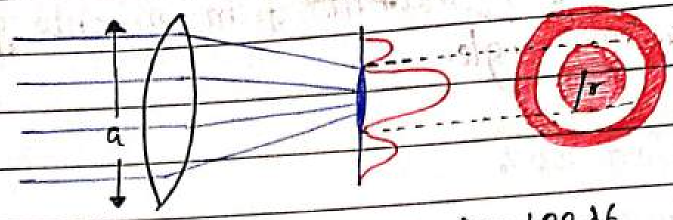
Ans $\tan \theta_p = \mu$

$1 < \tan \theta_p < \infty$

$\tan^{-1}(1) < \theta_p < \tan^{-1}(\infty)$

$45° < \theta_p < 90°$





$r = \frac{1.22\lambda f}{a}$ [a = diameter of aperture]

Resolving power $\propto \frac{1}{r}$

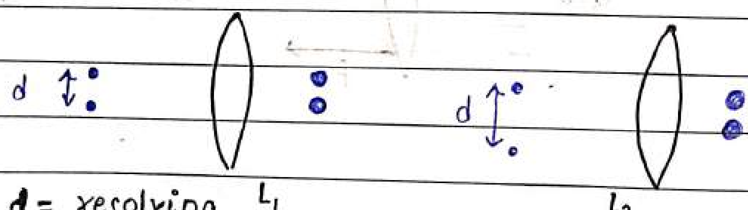
$R.P. = \frac{a}{1.22\lambda f}$ $R.P \propto \frac{1}{\lambda}$

Resolving power (R.P.)

A large numbers of images are formed as a consequence of light diffraction from a source.

If two sources are separated such that their central maxima do not overlap their images can be distinguished and are said to be resolved.

R.P. of an optical instrument is its ability to distinguish two neighbouring points.



d = resolving limit

Date / /
Page No.

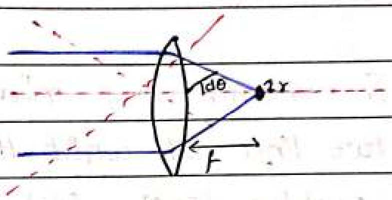
Resolving power of L_1 > L_2

Resolving power $\propto \frac{1}{\text{Resolving limit}}$

Telescope

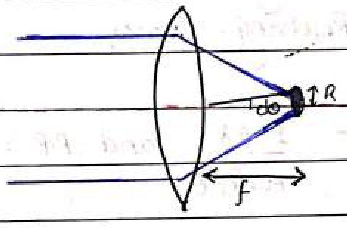
Smallest angular separations ($d\theta$) between two distant object, whose images are separated in the telescope is called resolving limit.

So resolving limit,



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

Angular resolving limit



and resolving power

$(R.P.) = \frac{1}{d\theta} = \frac{a}{1.22\lambda}$

$d\theta = \frac{R}{f}$

where a = aperture of objective.

Putting value of 'r' from resolving power

$d\theta = \frac{1.22\lambda f}{af} = \frac{1.22\lambda}{a}$

Q What is the approximate radius of central bright diffraction spot of light of wavelength $\lambda = 0.5\,\mu m$, if focal length of lens is 20 cm and radius of aperture of the lens is 5 cm.

Ans $r = \frac{1.22\lambda f}{a} = \frac{1.22 \times 0.5 \times 10^{-6} \times \cancel{20}^{2} \times \cancel{10^{-2}}}{\cancel{10} \times \cancel{10^{-2}}} = 1.22\ \mu m$

Q A light of wavelength 5000Å is coming from sun distant star what is limit of resolution of telescope whose objective has diameter of 200 cm.

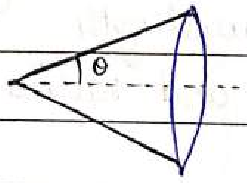
Ans Angular R.L. $= \frac{1.22\lambda}{a} = \frac{1.22 \times \overset{25}{5000} \overset{\circ}{A}}{200 \times 10^{-2}}$ Ans

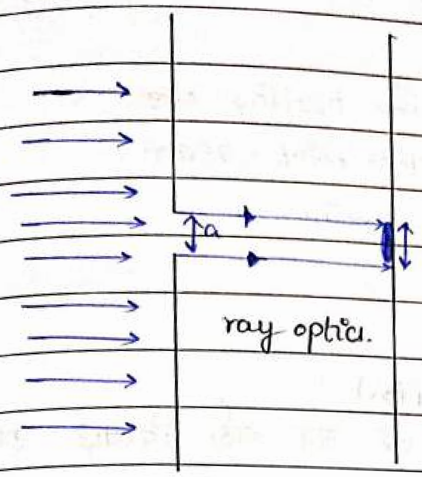
Microscope

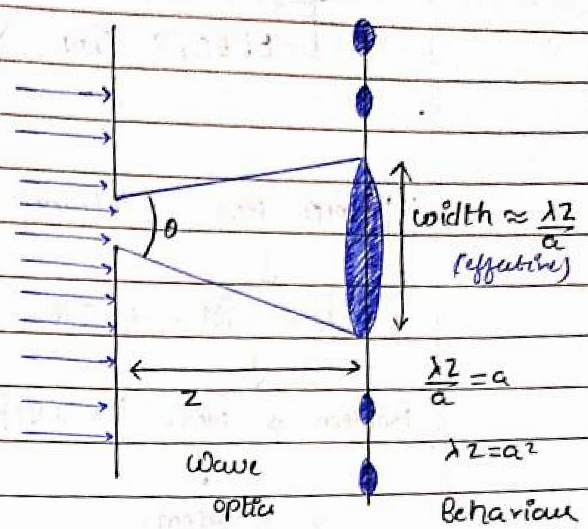
In refrence to a microscope, the minimum distance between two lines at which they are just distinct is called resolving limit (RL) and its reciprocal is called Resolving power.

R.L. $= \frac{1.22\lambda}{2\mu \sin\theta}$, and R.P. $= \frac{2\mu \sin\theta}{1.22\lambda}$ $\Rightarrow$ R.P $\propto \frac{1}{\lambda}$

$\lambda \Rightarrow$ Wavelength of light used for illuminating the object.
$\mu \Rightarrow$ Refractive index of the medium between object and objective lens.
$\theta \Rightarrow$ Half angle of the cone of light from the point object.







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

$\lambda z = a^2$

Behaviour of ray optics

$\lambda z > a^2$

Behaviour of wave optics.

Q For what distance is ray optics a good approximation when a plane light wave is incident on a circular aperture of width 2mm having wavelength 600 nm

a) 6.7m
b) 3.5m
c) 2.7m
d) 5.7m

Ans $\lambda z \approx a^2$

$z = \frac{a^2}{\lambda} = 6.7m$