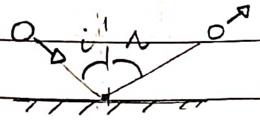
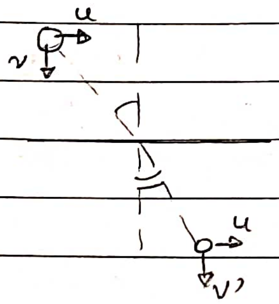
WAVE OPTICS

22/09/2023

- Newton's Corpuscular Theory –



Light particles suffer elastic collision



u remains same

$v \rightarrow v'$ (due to μ)

$\Downarrow$

Angle changes

→ Huygen's Theory of Secondary Wavelets

- Wavefront – Surface on which all waves are in same phase.

Dirⁿ of propogation of wave is normal to wavefronts

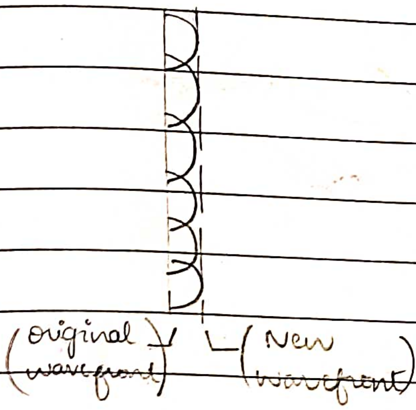
If the posⁿ. of wavefront is known to us at any instant, then its position after time 't' can be predicted

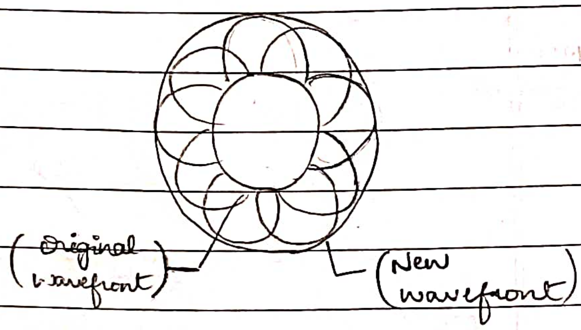
Statements :–

1. Each particle (wave) in the wavefront acts as a pt. source of secondary wave which

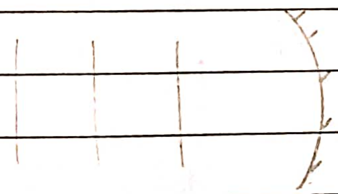
propogates wave in fwd dirxn only.

2. The surface touching all the secondary wavefronts will give the new posn. of primary wavefront.

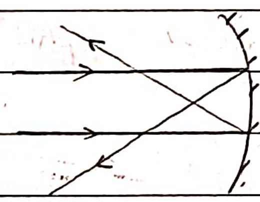




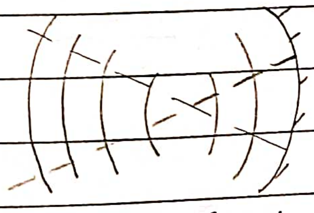
NOTE: To determine wavefronts after striking mirror & lens, we draw the path of light using ray optics & draw surfaces normal to that path to obtain the wavefront.



Incident Wavefronts

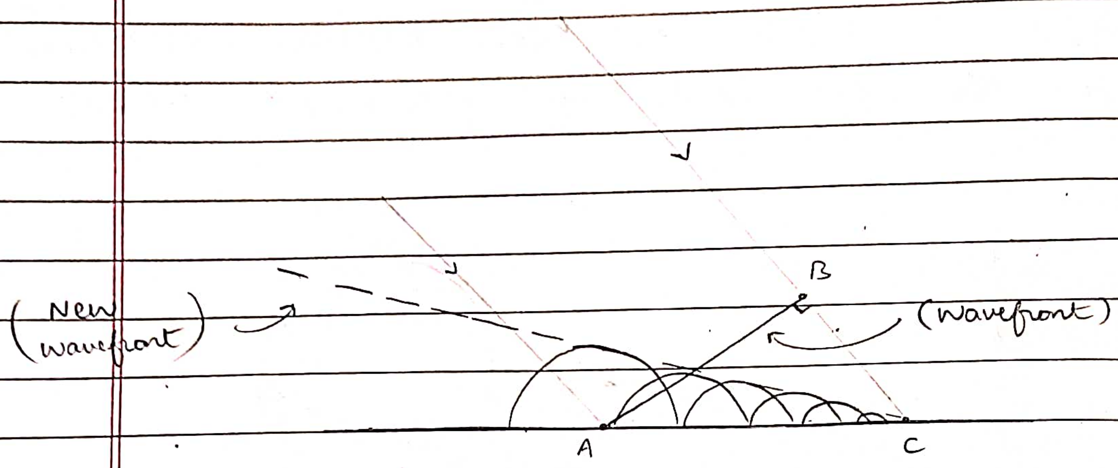


Light



Reflected Wavefronts

Law of Reflection



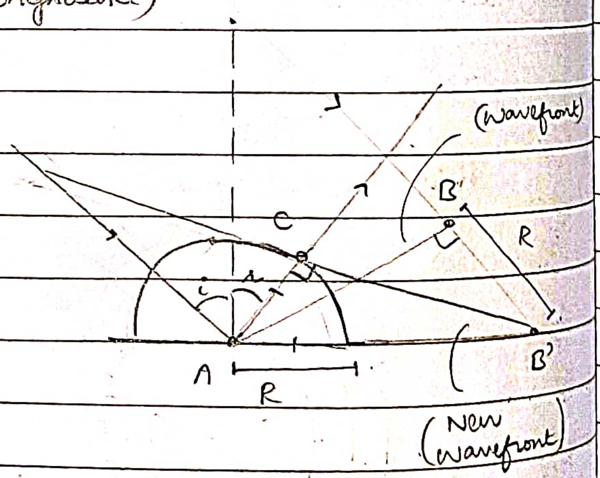
We have taken 2 || rays of light.

Since pts. A & B are in phase, by the time light at B reaches C (let's say the light reflected at A must have travelled a dist. equal to BC.

Using this fact, we will draw the wavefront after time dt.

$\Delta ABB' \cong \Delta B'CA$ (by RHS congruence)

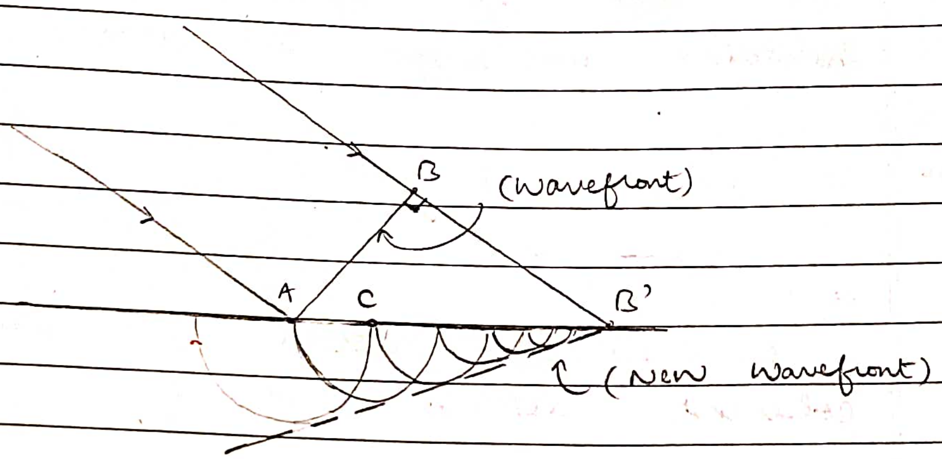
$\Rightarrow \angle CB'A = \angle BAB'$



$\Rightarrow$ $\boxed{i = r}$

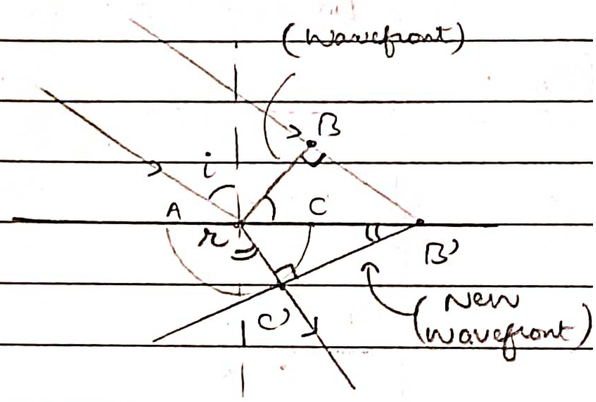
• Law of Refraction

AB in same phase. By the time B reaches B',
A's secondary wavefront reaches C.



Since diff. medium,

$$\frac{AC}{c_2} = \frac{BB'}{c_1}$$



$AC = AC' = AB' \sin r$

$BB' = AB' \sin i$

$$\Rightarrow \frac{AC}{BB'} = \frac{\sin r}{\sin i} \Rightarrow \frac{\sin r}{\sin i} = \frac{c_2}{c_1}$$

$$\Rightarrow \boxed{\mu_1 \sin i = \mu_2 \sin r} \quad ; \quad \mu_1 = \frac{c}{c_1} \;\&\; \mu_2 = \frac{c}{c_2}$$

INTERFERENCE

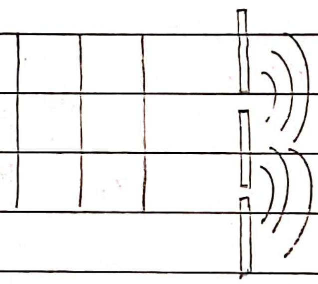
- Coherent sources – 2 sources are said to be coherent if at any pt., the phase diff. b/w waves produced by them remains unchanged with time.

$$\Rightarrow \omega_1 = \omega_2$$

2 unidentical sources can never be coherent in case of light.

To obtain coherent sources, we can do the following:–

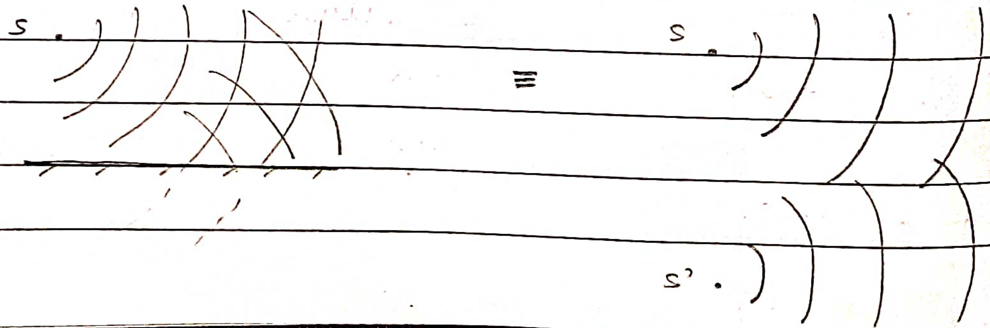
1. Division of Wavefront



By Huygen's Principle, each acts as an indep. source.
They are coherent since they are derived from a single source.

2. Division of Amplitude

Placing source in front of a mirror results in its image being an apparent coherent source



Coherent sources are necessary for interference.

$$\left.\begin{aligned} y_1 &= A_1\, s(\omega t - kx) \\ y_2 &= A_2\, s(\omega t - kx + \varphi) \end{aligned}\right\} \Rightarrow \quad y = y_1 + y_2$$

(Principle of Superposition)

$$= A_1 s(\omega t - kx) + A_2 s(\omega t - kx)\, c\varphi + A_2\, c(\omega t - kx)\, s\varphi$$

$$\Rightarrow \quad y = s(\omega t - kx)\underbrace{(A_1 + A_2 c\varphi)}_{A c\delta} + \underbrace{(A_2 s\varphi)}_{A s\delta} c(\omega t - kx)$$

$$= A\, s(\omega t - kx + \delta)$$

$$\boxed{A^2 = A_1^2 + A_2^2 + 2A_1A_2\, c\varphi} \qquad \boxed{t\delta = \frac{A_2 s\varphi}{A_1 + A_2 c\varphi}}$$

$A_{max} = A_1 + A_2 \longrightarrow$ Constructive Interference

$c\varphi = 1 \Rightarrow \varphi = 2n\pi$ — Maxima

Bright Fringe (for light)

Since $I \propto A^2$

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

$A_{min} = |A_1 - A_2| \longrightarrow$ Destructive Interference

$c\varphi = -1 \Rightarrow \varphi = (2n+1)\pi$ — Minima

Dark Fringe (for light)

- Path diff. b/w 2 waves –

$$\boxed{\Delta\varphi = k\Delta x = \frac{2\pi}{\lambda}\Delta x}$$

→ Young's Double slit Experiment

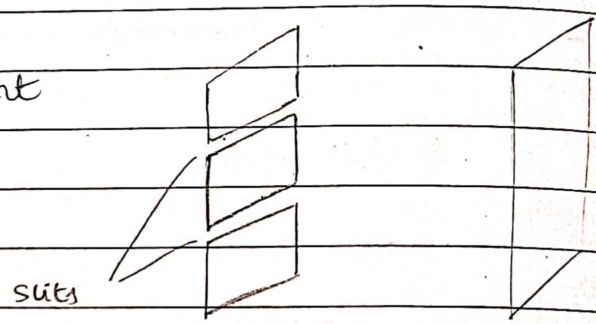
Long slit

⇓

Cylinderical wavefront

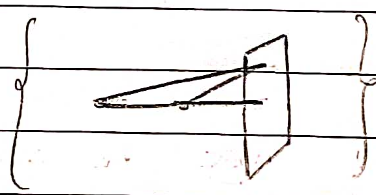
⇓

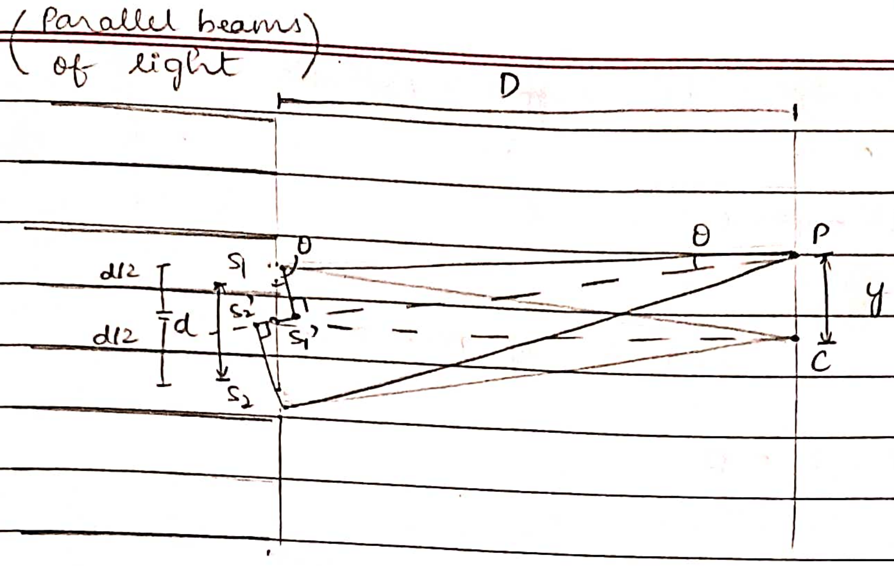
Pts. on a line || to slit are in phase



NOTE:

Slit Type	Interference pattern
1. Long slits ⇒	Bands
2. Pinhole used ⇒	Hyperbolic pattern
3. Line joining sources ⊥ to screen ⇒	Circular pattern





Assumptions : $d, y << D$

$$\Delta x = S_2P - S_1P \sim S_2'P - S_1'P = \frac{d}{2}s\theta + \frac{d}{2}s\theta = ds\theta$$

$$\sim \frac{dy}{D} \qquad \sim d\tan\theta$$

$$\boxed{\Delta x = \frac{dy}{D}}$$ ← (Diff b/w the path diff. of waves at 2 pts. P & Q separated by a distance 'y' on screen)

$$\Delta\varphi = \frac{2\pi}{\lambda}(\Delta x) = 2n\pi \quad \text{(for Bright Fringe)}$$

$$\Rightarrow \boxed{\Delta x = n\lambda}$$

(order of Bright Fringe)

$n = 0 \Leftrightarrow$ Zeroth Bright Fringe
Central Bright Fringe

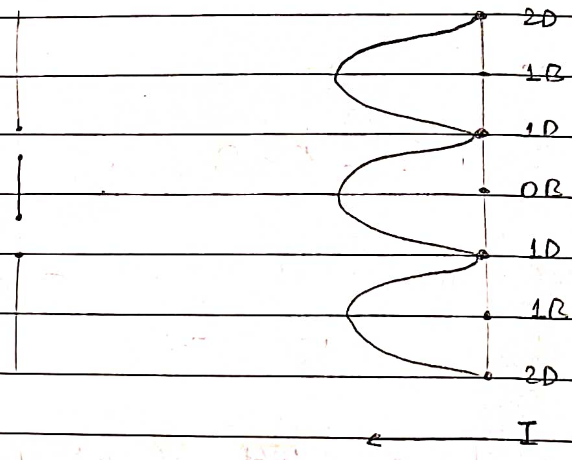
NOTE: Central Bright Fringe need not be at the centre of the screen.
It is formed where $\Delta\varphi = 0$. $(\Delta\varphi_{initial} + \Delta\varphi_{Path\ diff} = 0)$
If initially, $\Delta\varphi \neq 0$, $\Rightarrow$ CBF shifts upwards or downward (& interference pattern)

$$\Delta\varphi = \frac{2\pi}{\lambda}(\Delta x) = (2n-1)\pi \quad \text{(for Dark Fringe)}$$

$$\Rightarrow \boxed{\Delta x = (2n-1)\frac{\lambda}{2}}$$

(order of Dark Fringe)

For $\Delta\varphi_{initial} = 0$



If $I_1 = I_2 = I_0 \Rightarrow I = I_0 + I_0 + 2\sqrt{I_0 I_0}\,c_\varphi$

$$= 4 I_0 \, c^2_{\frac{\varphi}{2}}$$

- <u>Fringe width (β)</u> – Dist. b/w adjacent bright or adjacent dark fringes

If $\Delta\varphi_{initial} = 0$

$$\Delta x = \frac{dy}{D} \Rightarrow n\lambda = \frac{d\,y_{n(B)}}{D} \Rightarrow y_{n(B)} = n\left(\frac{D\lambda}{d}\right)$$

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

Also, $(2n-1)\frac{\lambda}{2} = \frac{d\,y_{n(D)}}{D} \Rightarrow y_{n(D)} = \frac{(2n-1)}{2}\left(\frac{D\lambda}{d}\right)$

$$\boxed{\frac{\varphi}{2\pi} = \frac{\Delta x}{\lambda} = \frac{y}{\beta}}$$

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NOTE: 1. Order is defined wrt OB, <u>not</u> the centre of screen

2. If we want <u>dist</u> or <u>phase diff</u> at a given intensity, use

$$c\varphi = c\alpha \quad , \quad \alpha \in [0, \pi)$$

(given in Q as intensity given)

$$\Rightarrow \boxed{\varphi = 2n\pi \pm \alpha}$$

&

$$\boxed{y = n\beta \pm y_{min}}$$

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

$\Rightarrow \frac{\lambda}{2\pi}\alpha = \frac{d\, y_{min}}{D}$

$\Rightarrow \frac{y_{min}}{\beta} = \frac{\alpha}{2\pi}$

(+) $\longrightarrow$ b/w $n\beta$ & $(n+1)D$

(−) $\longrightarrow$ b/w $n\beta$ & nD

<u>Q</u>. $d = 1\,mm$

$D = 1\,m$

$\lambda = 500\,nm$

Intensity due to each slit $= I_0$

Find a) β

b) Dist. b/w 3D & 5B

i) same side

ii) Opp. side

of central fringe

c) i) $I_{(1.875\,mm \text{ from centre of screen})}$

ii) Dist. of pt. from centre of screen s.t $I = \frac{1}{4} I_{(\text{central fringe})}$ & it lies b/w 6B & 7D.

<u>A</u>. a) $\beta = \frac{D\lambda}{d} = \frac{500 \times 10^{-9}}{10^{-3}}$

$= \underline{5 \times 10^{-4}\,m}$

b) i) $y_{5(B)} - y_{3(D)}$

$= 5\beta - \frac{5}{2}\beta = \underline{\frac{5\beta}{2}}$

ii) $y_{5(B)} - y_{-3(D)} = 5\beta + \frac{5\beta}{2} = \underline{\frac{15\beta}{2}}$

c) i) $\varphi = \frac{2\pi(\Delta x)}{\lambda} = \frac{2\pi}{\lambda} \frac{dy}{D} = \frac{2\pi y}{\beta}$

$\varphi = 2\pi\left(\frac{1.875}{0.5}\right) = \frac{15\pi}{2}$ $\Rightarrow$ $I = 4I_0 \cos^2_{\varphi/2}$

$= 2I_0$

ii) $I = \frac{1}{4}(4I_0 \cos^2 0) = I_0 = 4I_0\cos^2\frac{\varphi}{2}$ $\Rightarrow$ $\cos\frac{\varphi}{2} = \frac{1}{2}$ $(\because \varphi$

$\Rightarrow \frac{\varphi}{2} = \frac{\pi}{3}$

$\frac{\varphi}{2\pi} = \frac{y_{min}}{\beta}$ $\Rightarrow \varphi = \frac{2\pi}{3}$

$\Rightarrow y_{min} = \left(\frac{1}{3}\right)(5\times10^{-4}) = \frac{5}{3}\times10^{-4}\,m$

$y = 6\beta + y_{min} = \frac{95}{3}\times10^{-4}\,m$

- Cond^{n}s for sustained interference in YDSE

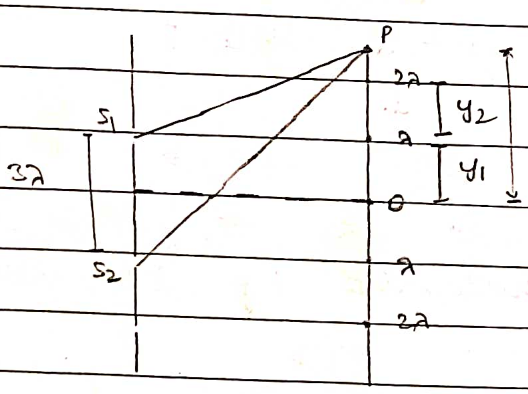
1. $d << D$ — If d & D are comparable, then the intensity due to a single slit will not remain the same.

This cond^n is necessary to ensure the intensity of all Bs is same.

For a long source, $I \propto 1/r$

2. $d >> \lambda$ — To ensure const. fringe width

eg.



By Δ ineq.,

$|S_1P - S_2P| < 3\lambda$

$\Rightarrow \underline{\Delta x < 3\lambda}$

$\Downarrow$

$\Delta x \geq 3\lambda$ never obtained.

Also, $y_1 \neq y_2$

3. The intensity due to each slit on the screen should be equal or nearly equal for observing the pattern clearly.

eg $\quad I_1 = I_0 \quad I_2 = 100 I_0 \Rightarrow I_{max} = 121 I_0 \quad I_{min} = 81 I_0 \Rightarrow$ (Difficult to distinguish)

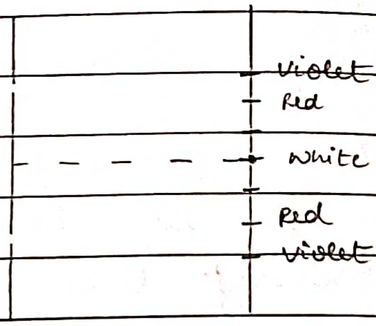
4. Sources must be coherent.

2. 28/09/2023

Q. What will happen to interference pattern of YDSE if the monochromatic light is replaced with white light?

A. 1. Central Bright Fringe will be white

2. CBF will be surrounded by 1st order coloured fringes



Q. How will we distinguish b/w posⁿ. of CBF & other B.Fs in YDSE

A. We will replace monochrome. light with white light. White band thus produce will be the CBF.

Q. $d = 1$ mm, $D = 1$ m, $y = 2$mm
Which wavelengths will be missing at a dist. of 2 mm from CBF in visible region?

A. $\Delta x = \frac{dy}{D} = \frac{(10^{-3})(2\times10^{-3})}{1} = 2000$ nm

For missing λ, $\Delta x = (2n-1)\frac{\lambda}{2} \Rightarrow \lambda = \frac{4000}{(2n-1)}$ nm

Visible light $\in [480, 780]$ nm $\Rightarrow \lambda = \frac{4000}{7}, \frac{4000}{9}$

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Q. Determine the fringe pattern (White light) $\to$ λ_1 filter

$\to$ λ_2 filter

A. NO fringe pattern since incoherent sources

i.e $\lambda_1 \neq \lambda_2 \Rightarrow \omega_1 \neq \omega_2$

Q What happens to fringe pattern when bi-chrome light used.

A. patterns of λ_1 & λ_2 form separately & overlap.

Q Find order of fringes of λ_1 which will overlap with the fringes of λ_2.
Also find the min. dist. b/w 2 completely dark or bright posts.

A. $d = n_1\beta_1 = n_2\beta_2 \Rightarrow n_1\lambda_1 = n_2\lambda_2 \Rightarrow \frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1}$

(Req. dist) $\gcd(\lambda_2, \lambda_1) = 1$

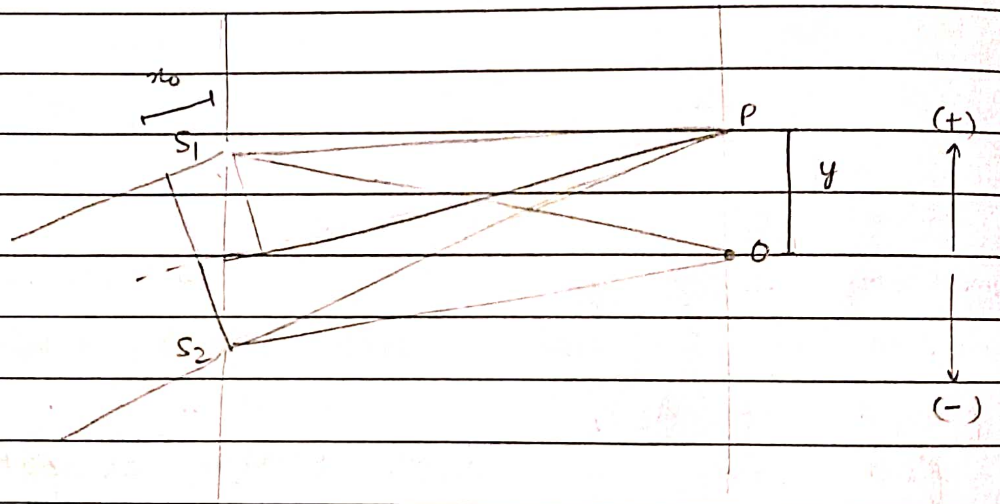
Q What will happen if the YDSE apparatus is submerged in a liq. (μ)

A 1. CBF remains same

2. $f = f_{medium} \Rightarrow \lambda = \lambda_{medium}\,\mu$

$\Rightarrow \beta \downarrow$

• $\Delta\varphi_{initial} \neq 0$



Let $S_1O - S_2O = x_0$

$$\boxed{\Delta\varphi_{net} = \left|\frac{dy}{D} - x_0\right|}$$

(light at S_1 is 'x_0' behind the light at S_2 in terms of optical path)

$$\left(\begin{array}{c}\text{Due to YDSE} \\ \text{path diff}\end{array}\right) \quad \boxed{\frac{\varphi}{2\pi} = \frac{\Delta x}{\lambda} = \frac{y - y_0}{\beta}} \quad \left(\begin{array}{c}\text{Dist from centre of screen}\end{array}\right)$$

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– Posn. of CBF from centre of screen –

$$\frac{dy}{D} - x_0 = 0 \Rightarrow \underline{y = \frac{Dx_0}{d}}$$ → Towards dirⁿ where $\Delta x > 0$

(Here, towards S_1)

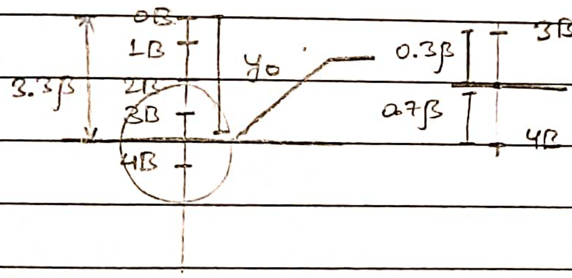
Q. If one of the slits covered with film, how many fringes pass through the centre?

A. Since CBF : $0 \to y_0 \Rightarrow \underline{\left(\frac{y_0}{\beta}\right)}$ ← dist. ← # dist/fringe

$y_0 = \frac{Dx_0}{d}$ (New posn of CBF)

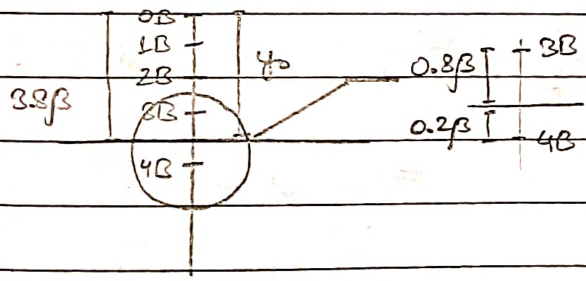
– Bright Fringe closest to centre of screen –

eg (i)



$\frac{y_0}{\beta} = 3.3 \Rightarrow \underline{0.3\beta}$

(ii)

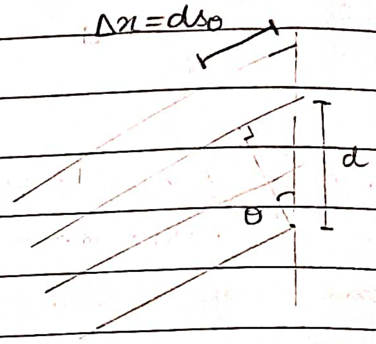


$\frac{y_0}{\beta} = 3.8 \Rightarrow \underline{0.2\beta}$

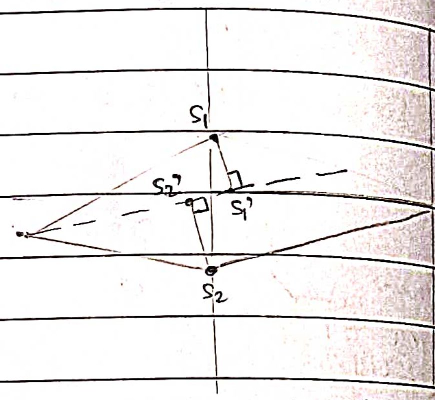
In general, dist of closest bright $= \left|\frac{y_0}{\beta} - \left[\frac{y_0}{\beta} + \frac{1}{2}\right]\right|$

- <u>Method for introducing Δx at centre of screen</u>

I. Light incident at an angle



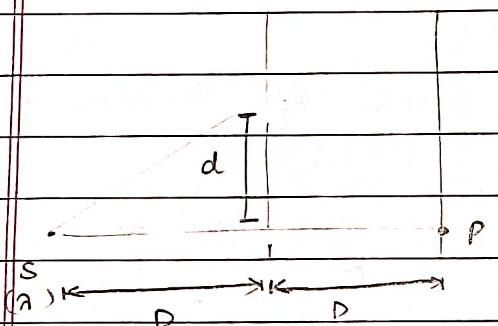
II. Source placed asymmetrically b/w slits



(Pythagoras thm to be used for approx. Δx)

$(PS_1 - PS_2) \sim (PS_1' - PS_2')$

★ Q. Find min. d for which dark fringe at P ($d << D$)



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

$\sim\left(1+\frac{d^2}{2D^2}\right)$

For min d, $\Delta x = \frac{\lambda}{2}$ $\Rightarrow$ $\frac{\lambda}{2} = 2D\left(\sqrt{1+\frac{d^2}{D^2}} - 1\right)$

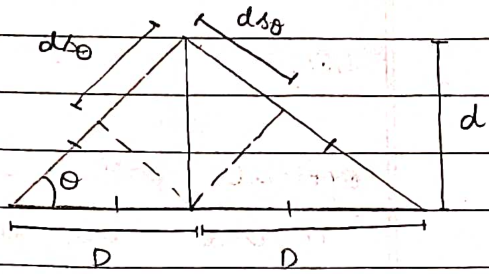
$\Rightarrow$ $d = \sqrt{\frac{D\lambda}{2}}$

•

Alternate Method

$$\Delta\varphi_{net} = 2d\sin\theta = \left(\frac{2d^2}{D}\right) \times$$

(But this is diff. from what we got earlier)



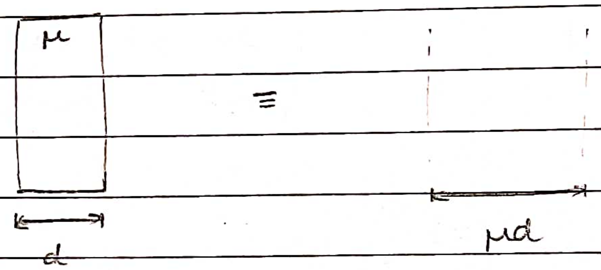
$(\theta <<)$

So, if we want to approx., we need to use the line joining source & midpt. of S_1 & S_2

III. Covering slits by a film

- <u>optical path</u> – Dist. that light would have covered in a particular medium given it had been travelling in that medium for the same amt. of time it was travelling in another medium.

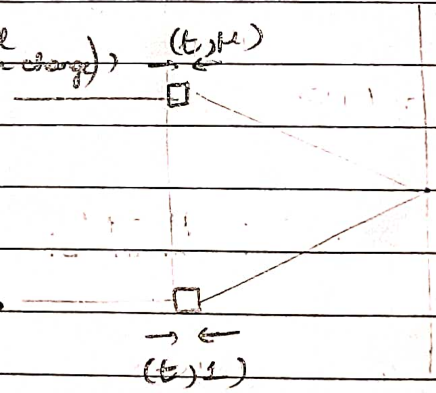
Time taken to cross film $= \dfrac{d}{c_\mu} = \dfrac{\mu d}{c}$



Dist. travelled in air $= ct = c\left(\dfrac{\mu d}{c}\right) = \underline{\mu d}$, ← (optical path of film in air for geometric path in the film)

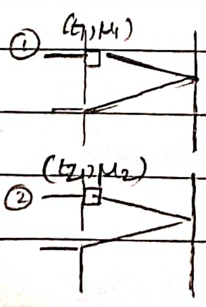
If $\Delta x_{initial} = 0$, $\Delta x_{optical}$ (medium change),

$$\boxed{\begin{aligned}\Delta x &= \mu t - t \\ &= (\mu - 1)t\end{aligned}}$$



{ path diff. in a medium is the diff. b/w <u>optical</u> paths of 2 waves in that medium }

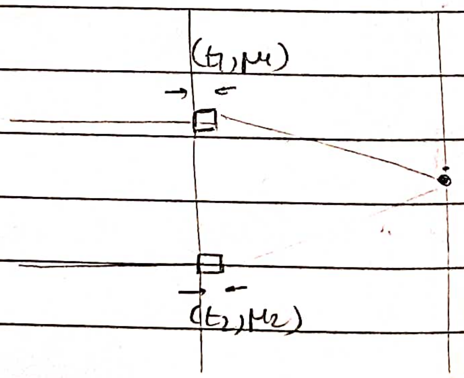
$$\boxed{\Delta x = (\mu_1 - 1)t_1 - (\mu_2 - 1)t_2}$$



$\Delta x_1 = (\mu_1 - 1)t_1$

$\Delta x_2 = (\mu_2 - 1)t_2$

$\Delta x = \Delta x_1 - \Delta x_2$



(path diff in medium 1) $\boxed{\mu_1 \Delta x_1 = \mu_2 \Delta x_2}$ (Path diff in medium 2)

(by def.) $\left[\because \ \overline{t_1 = t_2}\right]$

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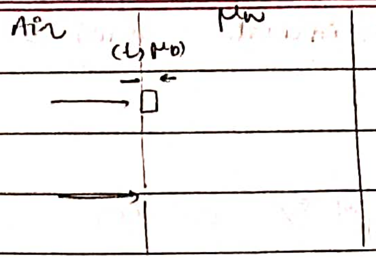
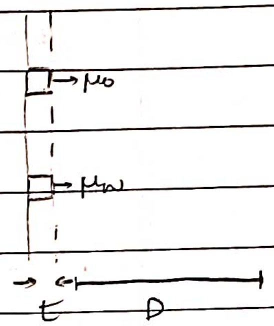
Q. Find eq. path diff in air & water at the centre of screen

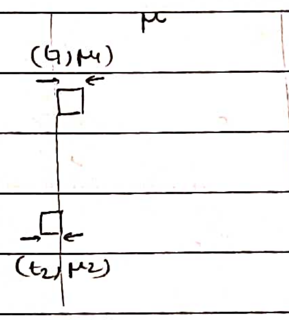


A. $\Delta x_{air} = \left[(\mu_0 - 1)t + (\mu_w - 1)D\right]$
$- \left[(\mu_w - 1)t + (\mu_w - 1)D\right]$
$= (\mu_0 - 1)t - (\mu_w - 1)t$
$= \underline{(\mu_0 - \mu_w)t}$

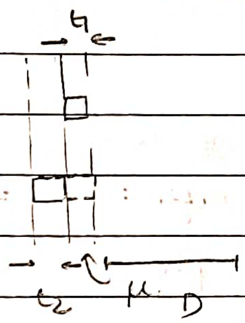


$\Delta x_w = \dfrac{\Delta x_{air}}{\mu_w} = \underline{\left(\dfrac{\mu_0}{\mu_w} - 1\right)t}$

Q. Find path diff at centre of screen in air



A. $\Delta x = \left[(1-1)t_2 + (\mu_1 - 1)t_1 + (\mu - 1)D\right]$
$- \left[(\mu_2 - 1)t_2 + (\mu - 1)t_1 + (\mu - 1)D\right]$



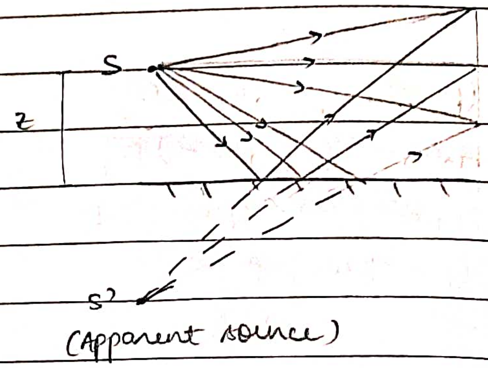
$= (\mu_1 - \mu)t_1 - (\mu_2 - 1)t_2$

$= \underline{(\mu_1 t_1 + t_2) - (\mu t_1 + \mu_2 t_2)}$

- Experiments equivalent to YDSE

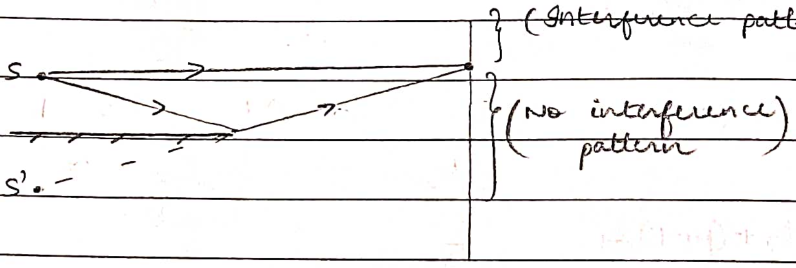
I Lloyd's mirror

$d = 2z$



Limitations :-

1.



2. Whenever wave reflects from denser medium, in gains π phase or $\lambda/2$ path

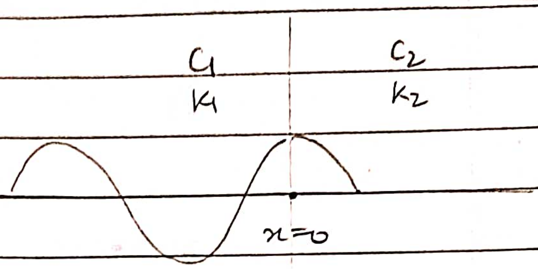
So, in Lloyd's mirror, $\boxed{\Delta x = \left|\left(\frac{dy}{D}\right) + \frac{\lambda}{2}\right|}$

(sign of y to be considered)

So, at centre, we obtain a Central Dark Fringe (CDF) instead of CBF.

Transmission & Reflection of Wave

C_1 k_1 | C_2 k_2



Incident wave $\rightarrow y_i = A_i \sin(\omega t - k_1 x)$

Transmitted wave $\rightarrow y_t = A_t \sin(\omega t - k_2 x)$

Reflected wave $\rightarrow y_r = A_r \sin(\omega t + k_1 x)$

Boundary condns -

1. $\omega_1 = \omega_2 \Rightarrow k_1 c_1 = k_2 c_2$

2. Continuous fxn $\Rightarrow (y_i + y_r)\big|_{x=0} = y_t\big|_{x=0} \Rightarrow A_i + A_r = A_t$

3. Differentiable fxn $\Rightarrow \left(\frac{\partial y_i}{\partial x} + \frac{\partial y_r}{\partial x}\right)\Bigg|_{x=0} = \frac{\partial y_t}{\partial x}\Bigg|_{x=0}$

$$\Rightarrow k_1 A_i - k_1 A_r = k_2 A_t$$

$$\Rightarrow A_t = \left(\frac{2k_1}{k_1 + k_2}\right) A_i \qquad A_r = \left(\frac{k_1 - k_2}{k_1 + k_2}\right) A_i$$

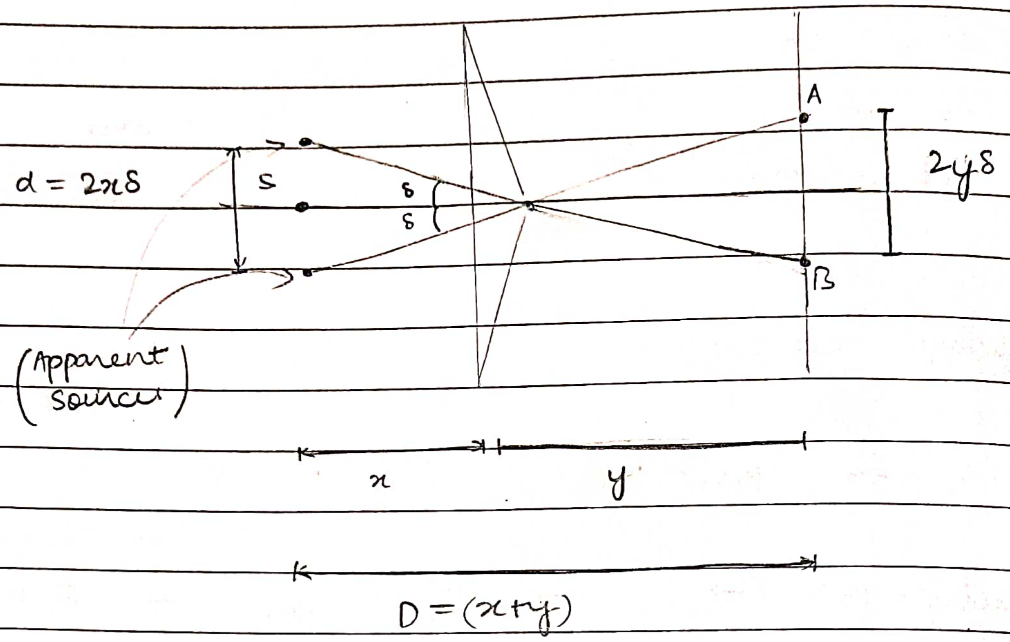
$$\Rightarrow \boxed{A_t = \left(\frac{2c_2}{c_2 + c_1}\right) A_i} \qquad \boxed{A_r = \left(\frac{c_2 - c_1}{c_2 + c_1}\right) A_i}$$

If $c_2 < c_1 \Rightarrow \mu_2 > \mu_1 \Rightarrow$ Light: Rarer $\rightarrow$ Denser

$\Rightarrow A_r < 0$. But this is not possible as amplitude is always +ve

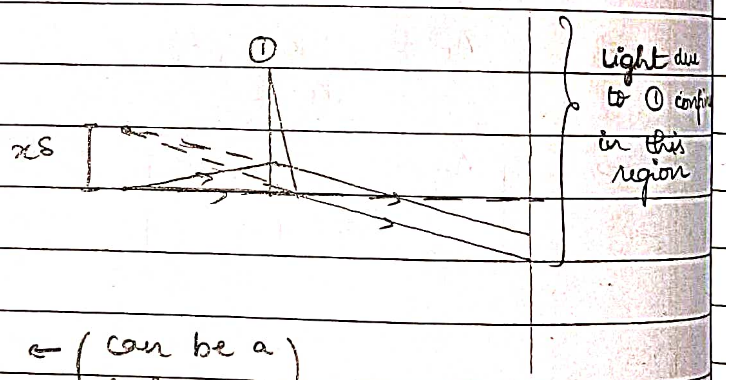
So, we take -ve sign inside the sin( ) & express is as a phase gain of π.

II. Fresnel Biprism



Limitation :-

1. Limited region of interference

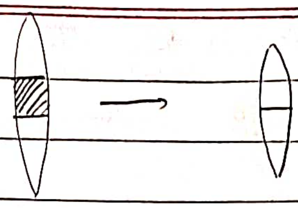


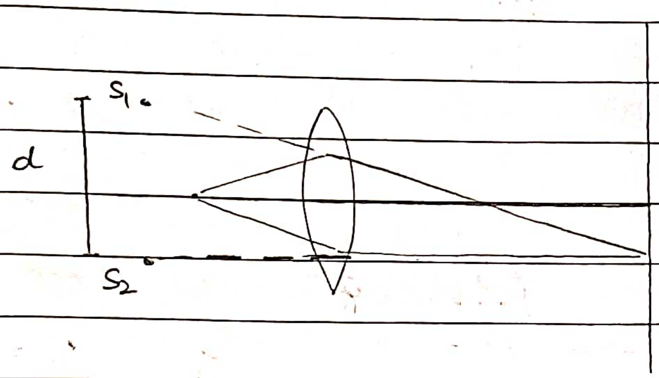
$$(\# \text{Fringes}) = \left(\frac{2y\delta}{\beta}\right) \leftarrow \left(\text{can be a decimal no.}\right)$$

$$\left(\# \text{Bright Fringes}\right) = 2\left\lfloor \frac{y\delta}{\beta} \right\rfloor + 1$$

$$\left(\# \text{Dark Fringes}\right) = 2\left\lfloor \frac{y\delta}{\beta} + \frac{1}{2} \right\rfloor$$

III. Split Lens

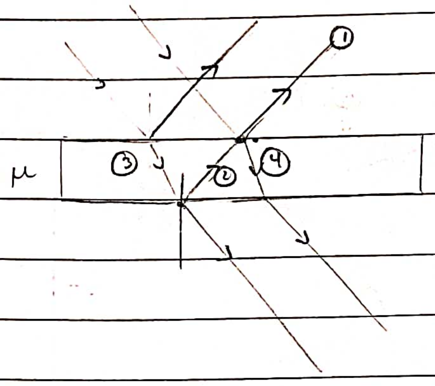




This setup is identical to Fresnel Biprism.

To find 'd', use lens formula.

→ Interference by Thin Film



In thin film, interference can occur by 2 ways :-

1. B/W reflected rays → 1 & 2
2. B/W transmitted rays → 3 & 4

Q. Parallel beam of light is incident on a thin transparent film. Find ratio of $\frac{I_{max}}{I_{min}}$ if interference is observed for

(i) reflected light

(ii) transmitted light

Assume at each surface 25% of light is reflected & rest is transmitted.

A. (i) $I_1 = 0.25\, I_0$ (reflected only once)

$I_2 = (0.75)(0.25)(0.75) I_0$ (transmitted, reflected & transmitted again)

$= (0.75)^2 I_1$

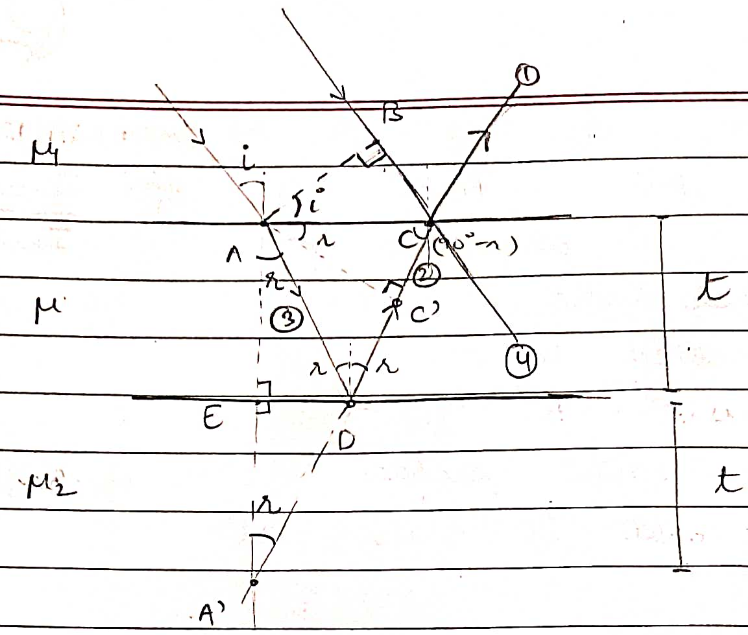
$$\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}\right)^2 = \left(\frac{1.75}{2.5}\right)^2 = 49$$

(ii) $I_1 = 0.75\, I_0$ (transmitted only once)

$I_2 = (0.75)(0.25)(0.25) I_0$ (transmitted & reflected twice)

$= (0.25)^2 I_1$

$$\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}\right)^2 = \left(\frac{1.25}{0.75}\right)^2 = \left(\frac{25}{9}\right)$$



$\Delta ADE \cong \Delta A'DE \Rightarrow AD = A'D$ & $\sin i = \dfrac{BC}{AC}$

$\Delta x = \mu(AD) + \mu(DC) - \mu_1(BC)$ $\qquad \sin r = \dfrac{CC'}{AC}$

$= \mu(A'D) + \mu(DC) - \mu_1(BC)$

$= \mu(A'C) - \mu_1(BC)$ $\qquad \Rightarrow \dfrac{\sin i}{\sin r} = \dfrac{BC}{CC'} = \dfrac{\mu}{\mu_1}$

$= \mu(A'C) - \mu(CC')$

$\boxed{A'C' = 2t\cos r}$ $= \mu(CC')$ $\qquad \Rightarrow \underline{\mu_1 BC = \mu CC'}$

$= \underline{2\mu t \cos r}$

But we have not yet considered the path difference that arises due to reflection.

For interference of reflected rays 1 & 2

Ray	Reflected by		
1	1× (Denser medium)	$(\mu > \mu_1)$	$\Rightarrow$ Phase$_1$ ↑ by π
2	1× (Rarer medium)	$(\mu > \mu_2)$	(gain)

$\Rightarrow \quad \Delta x_{①-②} \downarrow$ by $\lambda/2 \quad \Rightarrow \quad \underline{\Delta x = 2\mu t\cos r - \lambda/2}$

For interference of transmitted rays ③ & ④,

Ray	Reflected by
③	(–)
④	2X (Rarer medium)

$\Rightarrow$ No change in Δx

$\Rightarrow \quad \underline{\Delta x = 2\mu t\cos r}$

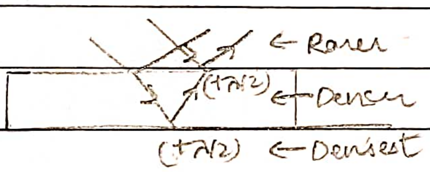
Q. Find thickness of oil film for which film appears dark in air.

oil

glass

A. When seen from air, interference in reflected light is observed.

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



$\Rightarrow \left(2\mu t\cos r + \frac{\lambda}{2} - \frac{\lambda}{2}\right) = \left(n+\frac{1}{2}\right)\lambda$

$\Rightarrow \quad \underline{t = \frac{\lambda}{2\mu}\left(n+\frac{1}{2}\right)}$

$\left\{ \begin{array}{c} \cos r = 1 \\ \text{for normal} \\ \text{incidence} \end{array} \right\}$

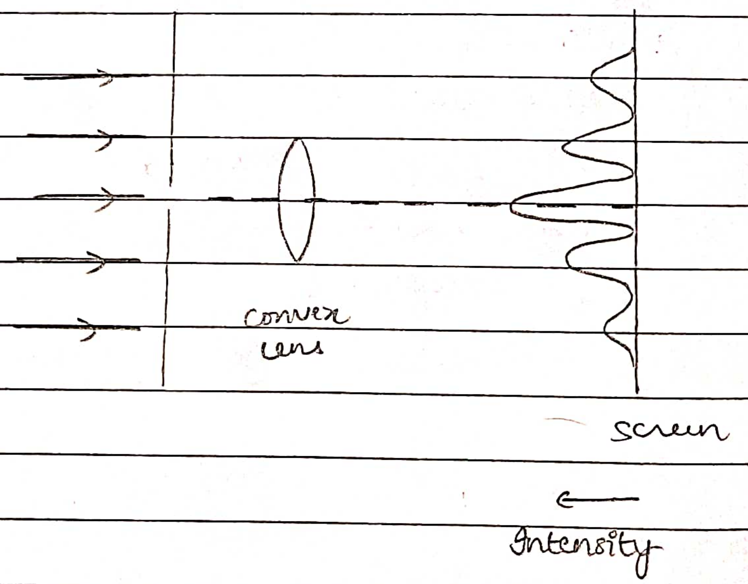
DIFFRACTION

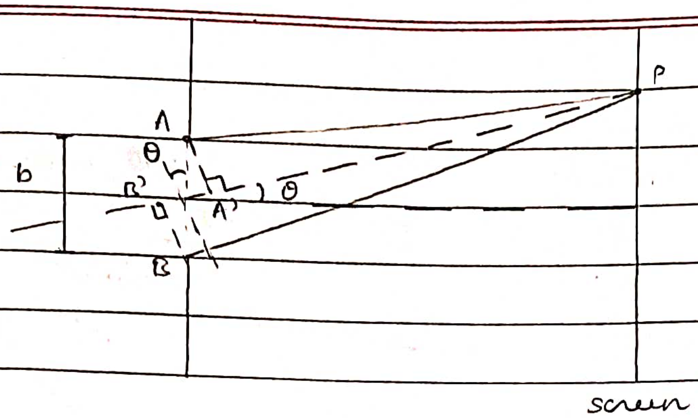
Defn: Bending of wave around an obstacle.

For diffraction to occur, the opening of obstacle should be of the order of wavelength of light

Diffraction
- Fresnel – (Both source & screen at finite dist. from obstacle)
- Fraunhofer – (Both source & screen at infinite dist. from obstacle)

To observe Fraunhofer diffraction, we use a convex lens to focus parallel beams of light from the source at the screen placed at its focal plane.



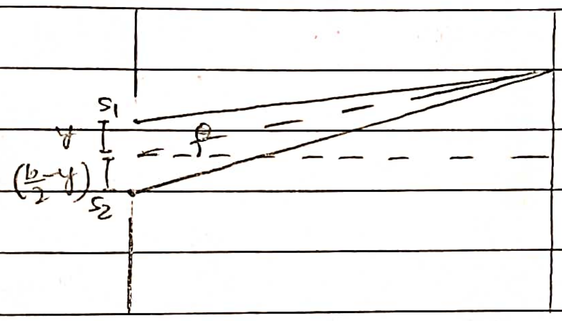


since AP & BP meet at ∞, $\angle APA'$ & $\angle BPB'$ are small

$\Rightarrow$ $PB - PA = PB' - PA' = \underline{b\sin\theta}$

(Phase difference b/w extreme pts.)

Consider 2 source, 'y' dist up & '$b/2 - y$' dist. down



$\Delta x_{S_1S_2} = (b/2 - y)\sin\theta + y\sin\theta = b/2 \sin\theta$

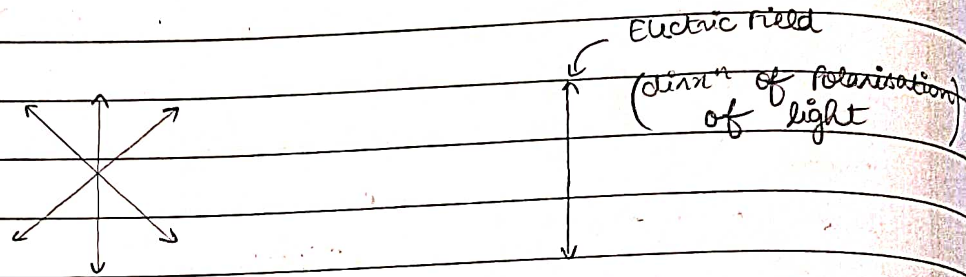
If $\boxed{b\sin\theta = n\lambda}$ $\Rightarrow$ $(b/2)\sin\theta = \frac{n\lambda}{2}$ $\Rightarrow$ Destructive Interference $\forall y$

$\Downarrow$

condn for Dark Regions

POLARISATION

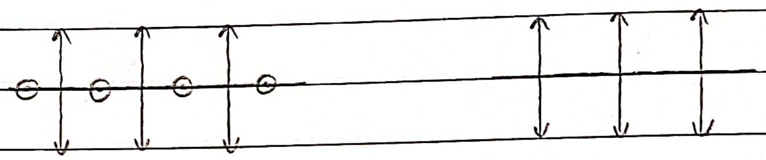
Polarisation happens only in Transverse Waves.



unpolarised light

Polarised light

Representation -

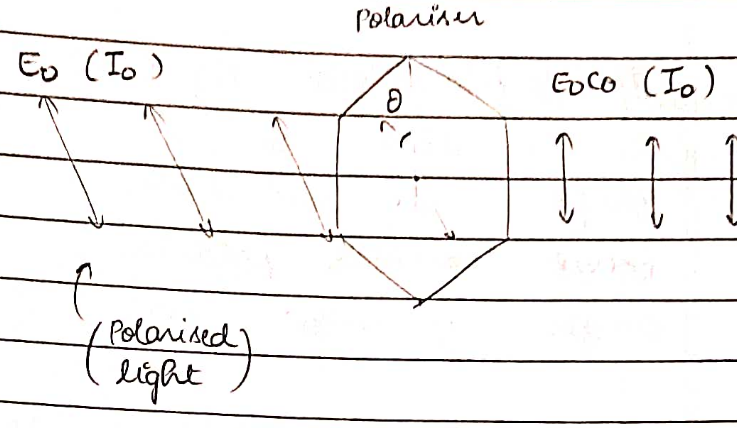


OR

- Polariser - Special crystal which allows light with a particular dirxn of E field to pass through it.

→ Malus law

$I \propto E$



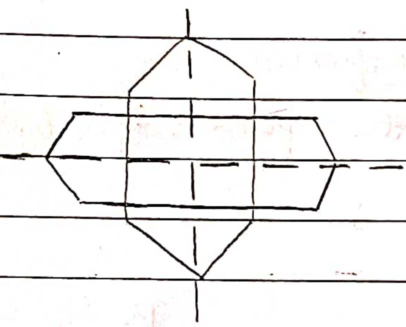
$\Rightarrow \boxed{I = I_0 c^2\theta}$

(for polarised light)

for unpolarised light, $c^2\theta_{(avg)} = 1/2$.

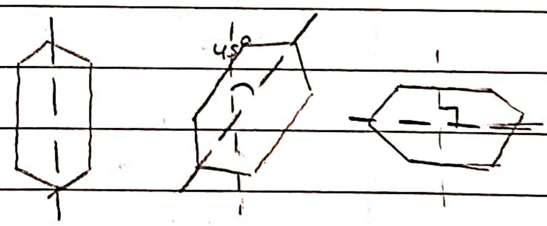
$\Rightarrow \quad I = I_0/2$

• Cross Polariser –



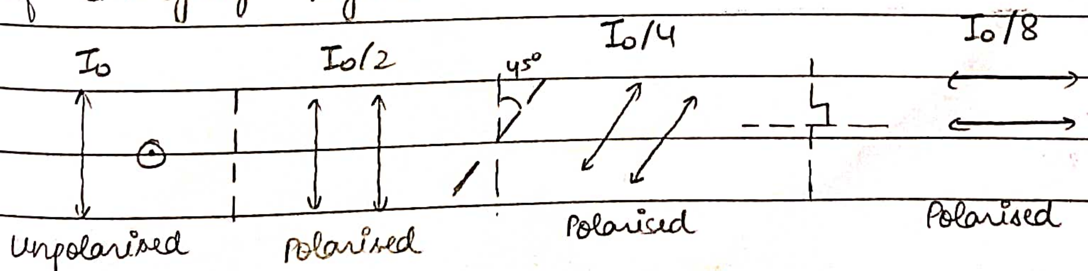
2 polarisers with axes at 90° to each other

Q. ① & ③ cross polarised and ② at 45°.

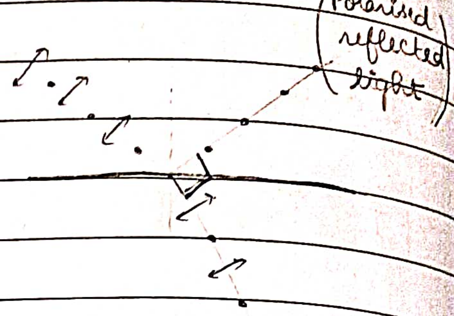


If unpolarised light of I_0 sent, find intensity of emerging light

A.



→ **Brewster's law**



If unpolarised light is incident on a surface at an angle equal to the polarising angle i_p :-

1. Reflected & Refracted ray are $\perp$ to each other

2. Reflected ray is 100% polarised $\perp$ to the plane of incidence.

3. Refracted ray is partially polarised $\parallel$ to the plane of incidence.

$$\mu_1 \sin i_p = \mu_2 \sin(90^\circ - i_p)$$

$$\Rightarrow \boxed{\tan i_p = \frac{\mu_2}{\mu_1}}$$

- Limit of Resolution – $\left(\frac{1.22\lambda}{D}\right)$
(Rayleigh's Criteria)

D — (Aperture Diameter of Objective Lens)

- Resolving Power – $\left(\frac{D}{1.22\lambda}\right)$

→ Doppler Effect in Light

$$\boxed{f = f_0 \sqrt{\frac{1 - v/c}{1 + v/c}}}$$

v → Relative velocity of object & source

If dist. ↓ ⇒ $v > 0$ & dist. ↑ ⇒ $v < 0$

⇓ ⇓

f ↑ f ↓

(Red shift)