'WAVE NATURE OF LIGHT'

Hygen Theory of Light

Light is a Mechanical Wave wich require medium to propagate just like sound wave, water ripples wave.
In universe or in space a medium is ⊕nt named ether, In wich light propagate.

Hygen Explanation of Wave propagation

* It said light propagate in the same way as water Wave propagate.
* Light travel in the direction ⊥ to the Wave Front.

Wave Front:→ Surface over wich all disturbance are in same phase known as Wave Front.

Each point on a Wave Front act as a source wich produce tiny wavelet & surface tangent over these wavelet give as a new position of wave Front.

Type of Wave Front

(a) → Planer Wave Front :→

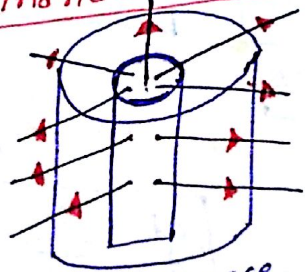
Intensity const *

(b) → Spherical Wave Front :→

Intensity $\propto \frac{1}{r^2}$ *

$r \Rightarrow$ distance of point from source.

(c) → Cyllindrical Wave Front :→

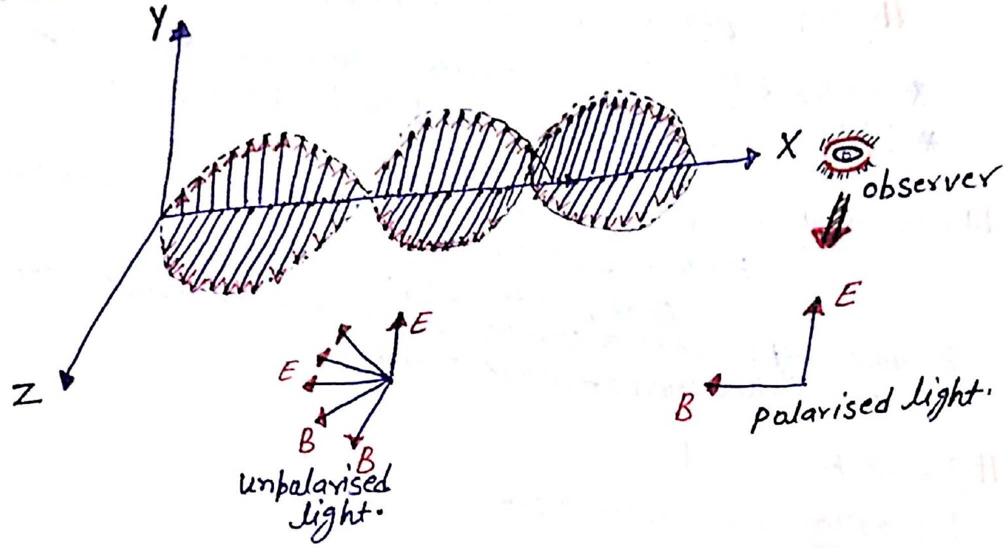


Intensity $\propto \frac{1}{r}$ *

NOTE →
* Planer Wave Front into into spherical by using screen with pinhole.
* Spherical into planer by using conversing lens.

Maxwell Theory of Light :→

* → Light is an electromagnetic wave, wich does not need any medium to pragate.
* → Light consist of oscillatory Electric (E) $ magnetic (B) Field. where plane of E $ B are mutually ⊥ as well as ⊥ to direction of propagation.
* → Frequency of osscilation of 'E' $ 'B' is same.
* → Phase of 'E' $ 'B' is same.



Interference :→

Two Light Wave having same Freq, same polarising state having same or, nearly same amplitude moving nearly same direction when superimpose on each other then it some point it produce maxima $ minima of Intensity. This redistribution of energy is called Interference.

NOTE → All type of Wave (longitudnal, transverse) show Interference $ differection phenomena.

Ex → Two light Wave superimpose on each other with phase diff.

$y_1 = a_1 \sin \omega t$

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

$y = y_1 + y_2$

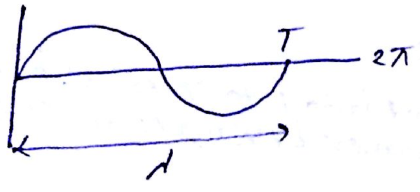
$$A^2 = a_1^2 + a_2^2 + 2a_1a_2\cos\phi$$

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

Average Intensity

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

* Relation b/w phase difference, path difference $ Time difference.



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

Constructive Interference [C.I]

When light ray superimpose in each other in same phase. then they produce maxima of Intensity & Amplitude.

$\phi = 0, 2\pi, 4\pi, \ldots 2n\pi$

$\Delta x = 0, \lambda, 2\lambda, \ldots n\lambda$

$\Delta T = 0, T, 2T, \ldots nT$

$$\cos\phi_{max} = 1$$ *

$$A_{max} = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos\phi}$$ *

$= a_1 + a_2 \qquad a_1 = a_2 = a_0$

$A_{max} = 2a_0$

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

$I_1 = I_2$

$$I_{max} = 4I_0$$ *

Distructive Interference [D.I]

In this Interference Intensity & Amplitude is minimum.

condition For distructive Interference

$$\cos\phi = -1$$ *

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

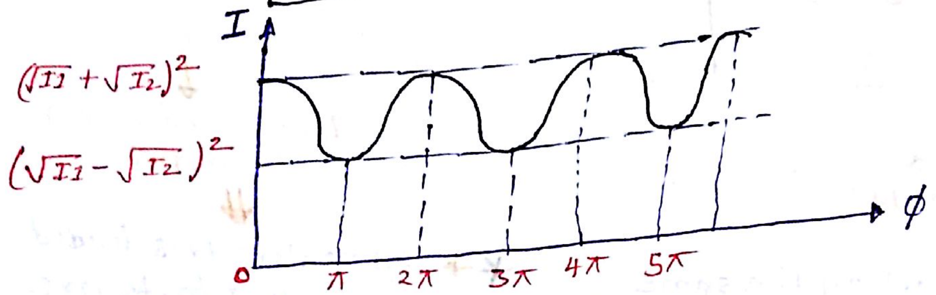
$$\phi = (2n-1)\pi$$ *

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

$$I_{min} = 0, \quad A_{min} = 0$$

$\Delta x = \frac{\lambda}{2}, \frac{3\lambda}{2}, \frac{5\lambda}{2}, \ldots$

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



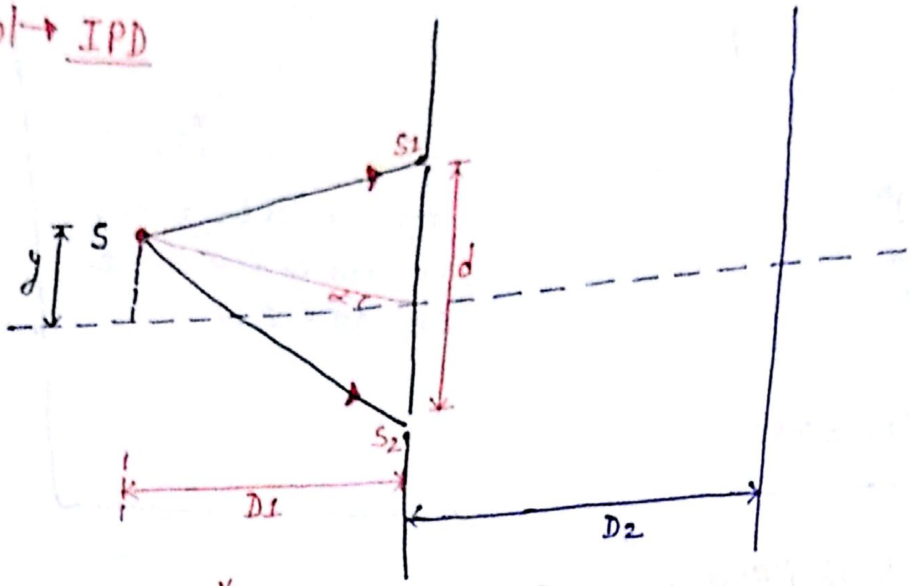
When $I_1 = I_2$ then maxima will be completelly bright & minima completelly dark & in this condition const. of fringe pattern will be maximum. ***

$$\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{I_1} + \sqrt{I_2}}{\sqrt{I_1} - \sqrt{I_2}}\right)^2 = \left(\frac{\sqrt{I_1/I_2} + 1}{\sqrt{I_1/I_2} - 1}\right)^2$$ *

$$\frac{I_{max}}{I_{min}} = \frac{A^2_{max}}{A^2_{min}} = \left(\frac{a_1 + a_2}{a_1 - a_2}\right)^2 = \frac{a_1/a_2 - 1}{a_1/a_2 - 1}$$ *

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

|b| → IPD



* $IPD = SS_2 - SS_1$

* If $D_1 >>> d$

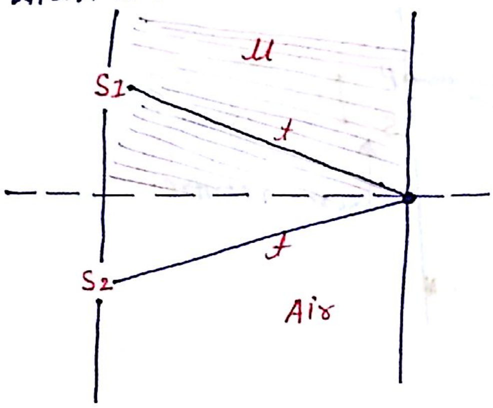
$IPD = d\sin\alpha$ *

* IF 'y' is very small

$IPD = \frac{dy}{D_1}$ *

|c| → OPD

Before reaching the screen light confront with some optical event wich introduce extra path & give OPD.

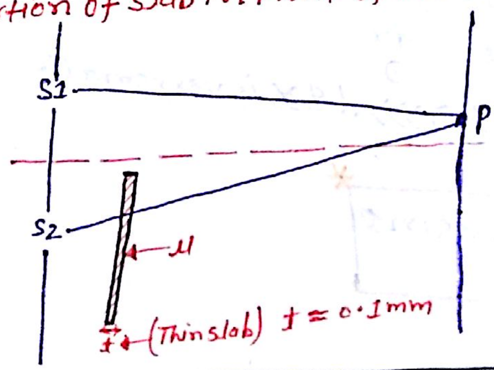


Equivalent path-

distance 't' in 'μ' ≃ dist 'μt' in Air *

distance 't' in μ_1 ≃ $\frac{\mu_1 t_1}{\mu_2}$ dis in μ_2.

** Insertion of slab in Front of slit introduce OPD

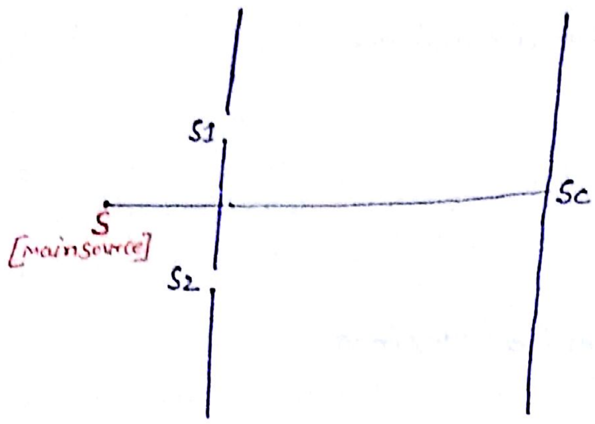


path difference = $(S_2P - t)_{air} + t_{in\,\mu} - S_1P_{air}$

$OPD = (\mu - 1)t$ *

Simple YDSE/YDHE

(young Double slit/Hole Experiment)



*→ Main source 'S' is placed symmetric in YDSE.

Interference pattern [I.P]

→ I.P consist of alternate bright & dark spot & Locus of these spots correspond to same path difference is known as bright or, dark Fringe.

→ Distance b/w two consecutive bright fringe or, two consecutive dark fringe is known as Fringe width (β)

NOTE →

*→ IF white light is used in YDSE then we get central white Fringe surrounded by Few coloured Fringes.

*→ To locate the position of central maxima we use white light.

*→ IF both the slit are covered by Red Film then all the Maxima will be Red.

A/R *→ IF both the slit are covered by Film of different colour we will not get Interference pattern bcoz of their different Freq.

*→ IF one slit is covered by opaque film we will not get Interference.

*→ Intensity is directelly propertional to the slit width.

$$I \propto \omega \quad \text{(slit width)}$$

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

*→ For better contrast $\omega_1 = \omega_2$ *

Nomenclature of Fringe

Fringe at screen centre (sc)

*→ Fringe Formed at screen centre is known as Fringe at sc.

*→ Intensity at screen centre can have any value depend on the value of Δx & thus $\Delta\phi$.

Central Fringe or, central maxima

*→ Fringe crospond to zero path difference is known as central Fringe.

*→ central Fringe can be Formed at any place where Δx is equal to zero.

*→ Intencity of this Fringe is Max.

*→ It is also known as zeroth order maxima.

First Bright fringe or First order Maxima

*→ Fringe crosspond to $\boxed{\Delta x = \lambda}$
*→ Intensity of this fringe is Max.
*→ It is the Ist bright fringe from central maxima.
*→ ✓

'n'th order Maxima

* Fringe crospond to $\Delta x = n\lambda$
* Intensity of this Fringe is Max.
* It is the 'n'th bright fringe From central maxima.

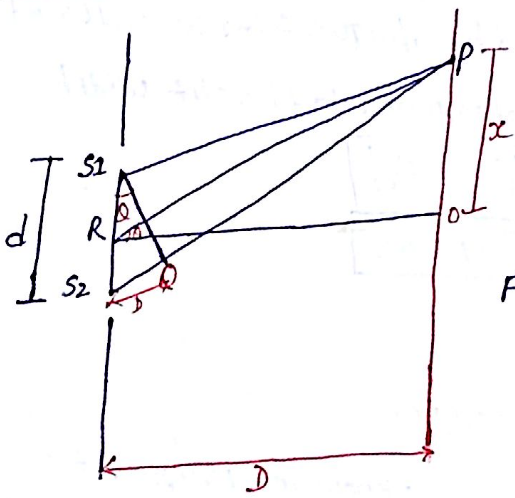
First order Minima

*→ Fringe crospond to $\Delta x = \lambda/2$
*→ Intensity is Minimum.
*→ It is the Ist dark From from CM.

'n'th order Minima

*→ Fringe crospond to $\Delta x = (2n-1)\lambda/2$
*→ Intensity is Minimum.
*→ It is nth dark Fringe From CM

Mathematical analysis of YDSE



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

*Distance of maxima From Fringe centre 'o'

$$\boxed{x_n = \frac{n\lambda D}{d}}$$ *

*Distance of minimum From From Fringe centre 'o'

$$\boxed{x_{n'} = \frac{(2n-1)\lambda}{2d}}$$ *

* $\beta \propto \lambda$, So Fringe width maximum For Red & Minimum For violet.

$$\beta_w = \frac{\lambda D}{\mu_w d} = \frac{\beta_{air}}{\mu_w} = \frac{3\beta_{air}}{4}$$ * → Fringe width of water.

* on ↑ D Fringe width ↑ but intensity of maxima ↓.

$$I \propto \frac{d}{D^2}$$ *

* on ↓ sepration b/w slit fringe width ↑ when small 'd' become zero we will not get Interference on sceen.

* If n_1th maxima of λ_1 concide with n_2th maxima of λ_2.

$$n_1\lambda_1 = n_2\lambda_2$$ *

* If n_1th of wavelength λ_1 concide with n_2th minima of λ_2.

$$(2n_1-1)\lambda = (2n_2-1)\lambda_2$$ *

* Angular position of 'n'th maxima.

$$\theta = \sin^{-1}\left(\frac{D}{d}\right)$$

$$\theta = \sin^{-1}\left(\frac{n\lambda}{d}\right) = \sin^{-1}\left(\frac{n\beta}{D}\right)$$ *

* Angular position of 'n'th Minima

$$\theta' = \sin^{-1}\left(\frac{(2n-1)\lambda}{2d}\right) = \sin^{-1}\left(\frac{(2n-1)\beta}{2D}\right)$$ *

* Effect of thin Film in YDSE

$$n = \frac{t(\mu-1)}{\lambda}$$ t ⇒ thicknes.

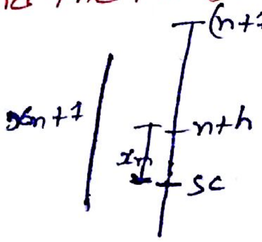
* Distance From 'n'th order maxima From SC.

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

* Distance of 'n'th order minima From SC.

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

Find the Fringe width as well as angular Fring width.



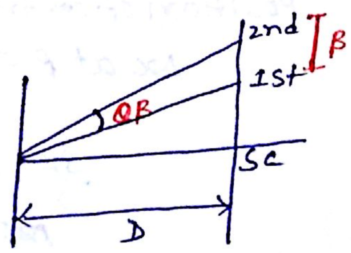
* Fringe width.

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

NOTE → Fringes to SC are equally spaced as β is independent of 'n'.

* Angular Fringe width

$$\theta_\beta = \frac{\lambda}{d}$$ *



IF YDSE setup is immerged in liquid then effect on I-P pattern.

* C.M will remain at SC.
* β get decrease as $\lambda \downarrow$.

NOTE → If wavelength of light use in YDSE get change then also 'β' get changed.

*

To calculate total no. maxima on the screen.

Steps →

* calculate Δx at extreme point of screen.
* convert Δx in term of λ.
* use simple logic to calculate.
* No. of maxima.

***

NOTE → * → In simple YDSE If $d \leq \lambda$ then will get only one maxima on the screen thus we are unable to watch 'I' pattern.

* → In simple YDSE is $d \leq 0.5\lambda$ then we are unable to watch 'I' pattern.

What is the minimum distance from SC at wich intensity is half intensity at SC. *

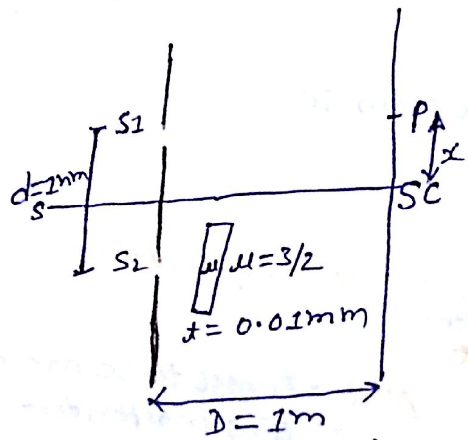
$$x = \frac{D\lambda}{2d}$$

Modification In YDSE

~~Modification~~

- Insertion of slab in front of slit

$\lambda = 3 \times 10^{-4}$ nm.



Position of central maxima.

Δx at $P \Rightarrow \frac{dx}{D} + (\mu - 1)t$

$$\frac{dx}{D} + (\mu-1)t = 0$$

$$x = \frac{(1-\mu)tD}{d} = \frac{(1 - 3/2) \times 0.01 \times \times 10^{3}}{1 \times 10^{2}}$$

$$= -5\text{mm}.$$

10

Find the Fringe width of I pattern.

$$\frac{dx_n}{D} + (\mu-1)t = n\lambda \quad \text{--- (1)}$$

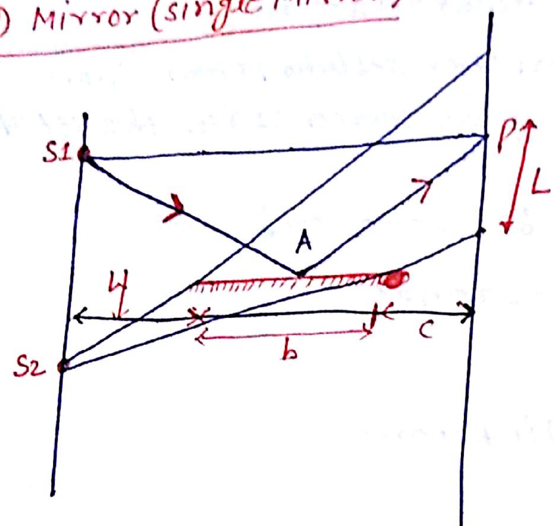
$$\frac{dx_{n+1}}{D} + (\mu-1)t = (n+1)\lambda \quad \text{--- (2)}$$

$$\boxed{x_{n+1} - x_n = \frac{\lambda D}{d} = \beta}$$

So, Fringe width does not change by putting slab.

*** **NOTE→** By putting slab in front of on slit, central maxima along with whole interference pattern get shift towards the slit front of wich slab was put.

LyoD Mirror (single mirror)



When Light reflect while going from rarer medium to densor medium then it get Extra path of $\lambda/2$ (optical path.

$$\Delta x = S_1A + AP + \frac{\lambda}{2} - S_1P$$

$$\Delta x = S_2A + AP - S_1P + \lambda/2$$

$$\Delta x = [S_2P - S_1P] + \lambda/2$$

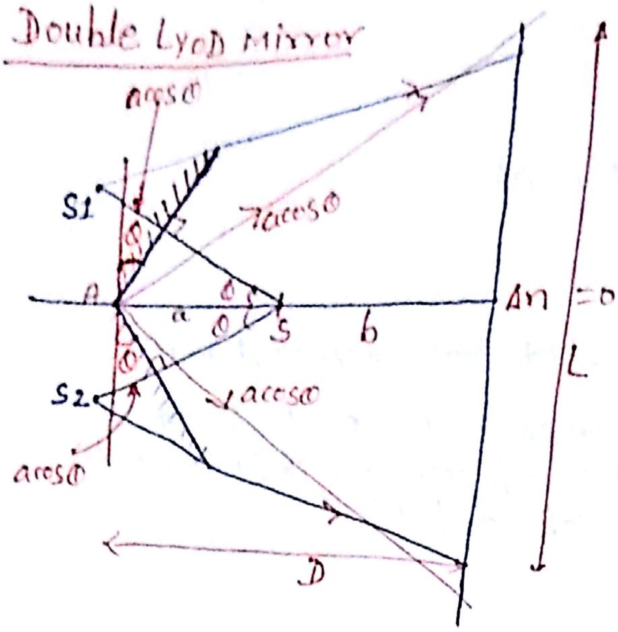
Length of Interference zone = L

Fringe with $= \frac{\lambda D}{d} = \frac{\lambda D}{2a}$

* C.M does not Form here.

* No. of Maxima = G.IF. = [ ]

Double Lyod Mirror



θ very small
θ → 0.

* Light is not allowed to fall directelly on screen.
* Light will Reach on the screen after Reflection From mirror.
* It seems that Light is coming two source S1 & S2, this set up seems YDSE setup.

Imp* $\beta = \frac{\lambda D}{d}$ Imp* $D = AS + b = 2a\cos^2\theta + b$

* $d = 2AS_1 = 4a\sin\theta\cos\theta = 2a\sin 2\theta$

*
$D = 2a + b$
$d = 4a\theta$
$\beta = \frac{\lambda(2a+b)}{4a\theta}$

* θ in Radian.

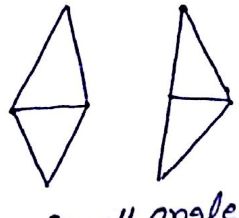
* Length of Interference zone = L
$L = (a+b)4\theta = 4(a+b)\theta$

* central maxima (C.M) will form at symmetric point of Interference zone.

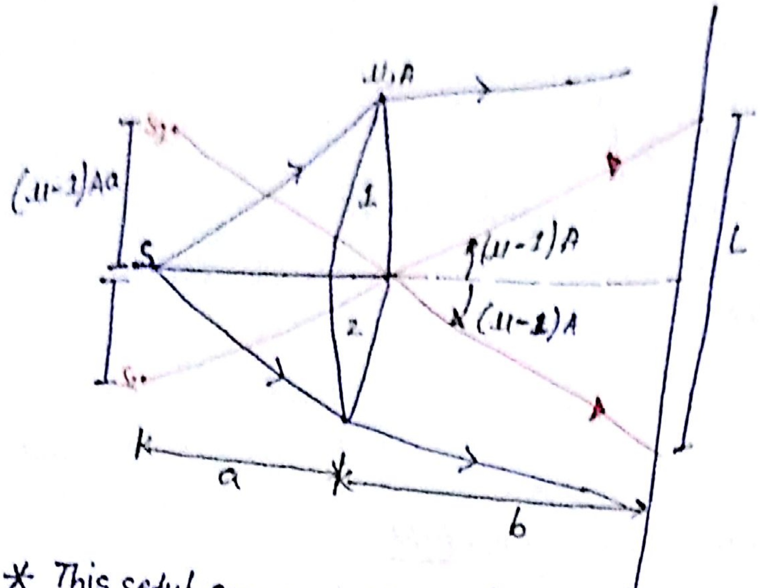
* $1 + \left[\frac{L}{2\beta}\right] \times 2$ = no. of Fringe ; [·] → GIF.

Frensal Biprism

Biprism – Two prism combination.



Small angled biprism.



* This setup seems as YDSE where S1 & S2 are two virtual source.
* Length of Interference zone = L

  $L = 2b(\mu-1)A$ (A ⇒ Radian) ↑ Angle of prism.
* Fringe Width $= \beta = \frac{\lambda D}{d} = \frac{\lambda(a+b)}{2(\mu-1)A\times a}$ *

* central Maxima (CM) will be symmetric point of Interference zone.
* No. of Maxima $= \left[\frac{2L}{2\beta}\right]\times 2 + 1$, [ ] → GIF.

IF Frensal biprism is immerged in water, then what will happen to β.

* β will ↑

$$\beta_{water} = \frac{\frac{\lambda}{\mu_w}(a+b)}{2\left(\frac{\mu}{\mu_w}-1\right)Aa} = \frac{\lambda(a+b)}{2A\times a(\mu-\mu_w)}$$

$$\beta_{old} = \frac{\lambda(a+b)}{2(\mu-1)Aa}$$

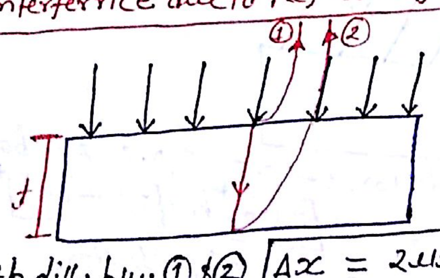
so, $\beta_{water} > \beta_{old}$ *

Intensity Devision Technique

Intensity due to thin Film —

Case I → Light is Incident Normally.

case (A) → Interfernce due to Reflect light.



path diff. b/w ① & ② $\Delta x = 2\mu t - \lambda/2$ *

* Constructive Interference

$\Delta x = n\lambda$

$$2\mu t = (2n+1)\lambda/2$$ *

$n = 0, 1, 2, 3 \ldots$

$2\mu t$ = odd multiple of $\lambda/2$

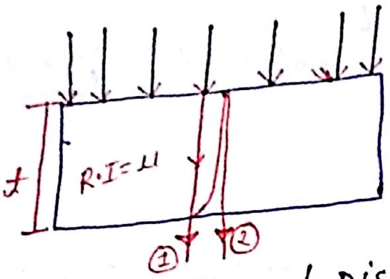
* Destructive Interference

$\Delta x = (2n-1)\lambda/2$

$$2\mu t = n\lambda$$

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

Case-(B) → Interference due to transmitted light.



$\Delta x = 2\mu t$

Constructive Interference.

$\Delta x = n\lambda$

$$2\mu t = n\lambda$$ *

$n = 0, 1, 2, 3 \ldots$

Distructive Interference

$\Delta x = (2n-1)\lambda/2$

$$2\mu t = (2n-1)\lambda/2$$ *

$n = 1, 2, 3 \ldots$

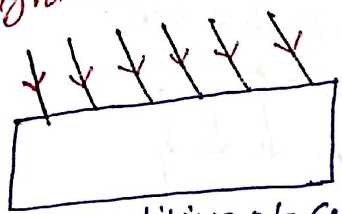
NOTE →

*→ Light wavelength wich satisfy the condition of constructive Interference is known as strongelly transmitted or, strongelly Reflected light. & the wavelength wich satisfy the condition of destructive interference is known as weakely Reflected or, transmitted light.

*→ Light which is strongly Reflected will be transmitted weakly.

*→ When white light is Incident on thin Film of non-uniform or, uniform thickness, then Maxima of different colour of white light light will form & Film will appear colourfull.

Case-(II) → When light is Incident at an angle of Incidence.

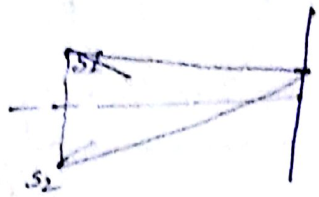


Then fore condition of C.I & D.I For both case (A) & case (B) replace $\boxed{2\mu t}$* by $\boxed{2\mu t \cos r}$*

$r \Rightarrow$ angle of Reflection

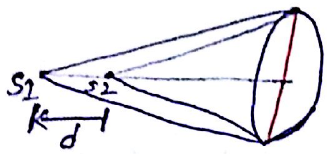
Shape of Fringe For various configuration.

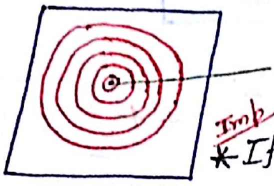
* simple YDSE



* $S_2P - S_1P$ = const.
* Shape ⇒ Hyperboloid. (Hyperbola) AIEEE 2015
* CM will of straight line (AIEEE)

* Line joining S_1 & S_2 is ⊥ to the screen.





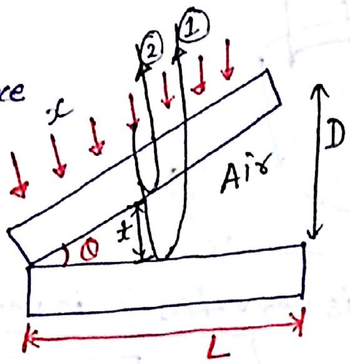
— Intensity of spot depend on 'd'

Imp * If $d = n\lambda$ then bright spot

Imp * If $d = (2n-1)\lambda/2$ then dark spot.

IIT * Air Wedge

* → Interference is taking place b/w light reflected from bottom surface of top plate & top surface of bottom plate.
* → path difference



θ ⇒ very small.

$$\boxed{\Delta x = t + t + \lambda/2}$$ *

$$\boxed{\begin{array}{l}\Delta x = 2t + \lambda/2 \\ \Delta x = 2t + \lambda/2\end{array}}$$ *

* → Shape of Fringe will be of straight line.
* → All Fringe are equispaced.
* → Fringe width (β)

$$\boxed{\begin{array}{l}\beta = x_{n+1} - x_n \\ \Delta x = 2t + \lambda/2\end{array}}$$

Relation b/w t & x

$t = x \sin\theta$

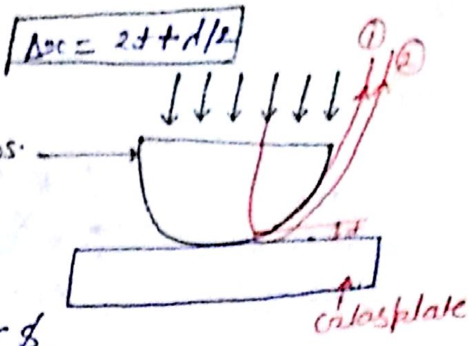
$t = x \tan\theta$ [θ → very small]

$t = \frac{xD}{L}$

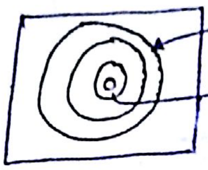
* $$\boxed{\beta = \frac{\lambda L}{2D}}$$

* → All the intersection of both glass plate minima will form as $\boxed{\Delta x = \lambda/2}$ *

* Newton Ring



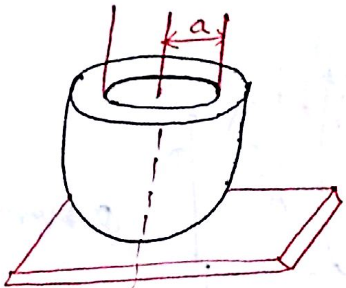
* → Interference takes place b/w light wave Reflected from curved surface of lens & Top surface of glass plate.
* → Shape of Fringe will be circular & this Fringe is known as Newton Ring.
* → Newton Ring will be not be equispaced.
* → Near the centre Fringe will be at greater spacing.

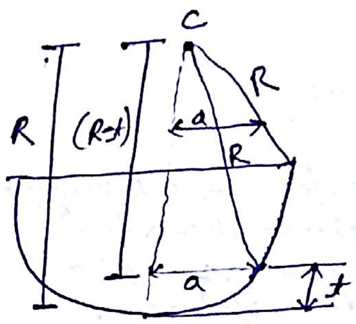


* Radius of Newton Ring

$$\Delta x = 2t + \frac{\lambda}{2} = n\lambda$$

Relation b/w 't' & 'a' wher 'a' is Radius of nth maxima.

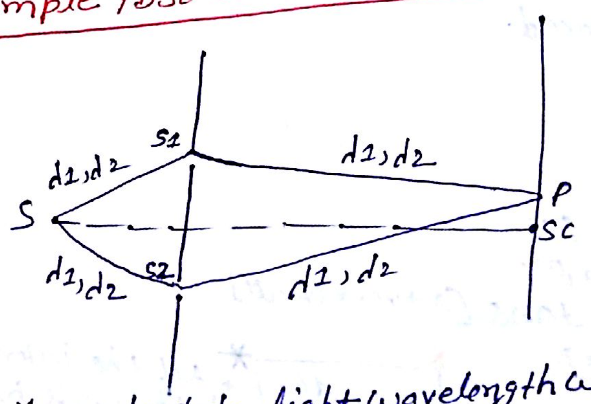




as lens is very thin 't' is very small.

$$a = \sqrt{\frac{(2n-1)\lambda R}{2}}$$

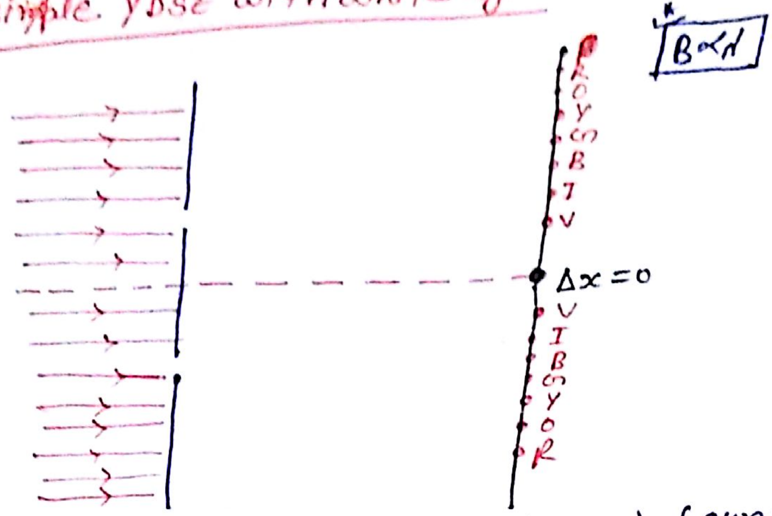
Simple YDSE with two Wavelength



* → d1 & d2 light wavelength will not Interfere with each other.

* At screen centre Δx for each wavelength will be zero, therefore both will make central maxima at sc.
* Intensity at 'p' is given by $I_{net1} + I_{net2}$. where I_{net1} & I_{net2} are Resultant Intensity due to Interference of λ_1 & λ_2 coming from S_1 & S_2 resp.
* At screen minima will formed at the point when intensity of light will be minimum.
* point where minima of both wavelength concide, is known as position of minima.

simple YDSE with white light



* → Different component (colour) of sunlight will form their Interference pattern.
* → At screen centre (sc) Δx is equal to zero for each component of sun light.
* → central maxima (cm) of each component will be at sc.
* → cm at sc will of white colour or, sunlight colour.
* → Ist order maxima of each component will be seen.
* → near sc voilet colour will be seen.
* → After Ist maxima due to overlapping of heigher order maxima of different component, screen will be seen uniformally illuminated.

Fraunhofer Differaction at a single slit.

* Linear width of central maximum $\frac{2D\lambda}{a} = \frac{2f\lambda}{a}$
* Angular width of central maximum $= \frac{2\lambda}{a}$
  * $\lambda \Rightarrow$ wavelength of light.
  * a = width of single slit.
  * $D \Rightarrow$ Distance of screen from slit.
  * f = focal length of convex lens.

NOTE → *→ A soap bubble or, oil film on water appear coloured in white light due to Interference of light Reflected from upper & lower surface of soap bubble.

* Scattering of light

* Blue colour of sky.
* Red colour of signal of danger.
* Black colour of sky in the absence of atm.
* Red colour of the time of sun Rise & sunset.
* Human Eye is most sensitive to yellow colour.

* For Rainbow Formation Angle b/w light & water drop is 42°