# * Wave Optics (Basic) *

## Newton's corpscular theory :- (2 or 4 marks)

1. Newton preposed that a light source emits tany particle. These particle (rigid, elastics & massless) known as corpsaular. (कणिका)

2. These particle travels through a transparent medium at very high speed ($3 \times 10^8$ m/sec) in all directions along a stright line.

3. When these particle enter in our eyes produce a sensation or vision.

4. Due to different size of the particle they produce different types of colours.

*5. These light particles repelled by reflective surfaces and attracted by transparant surface.

## Advantage of Newton's corpsuclar Theory :-

1. Newton's theory explains reflection & refraction phenomena separately.

2. It explain the Rectilinear propagation of light.

## Disadvantage of Newton's theory :-

1. Newton's theory fails to explain the phenomena of Interference, Diffraction and polarisation of light.

2. He couldn't explain the concept of partial reflection & partial refraction.

3. According to this theory velocity of light particle is larger ~~th~~ in denser medium comparetive to rarer medium. (This is practically wrong.)

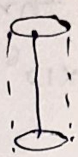
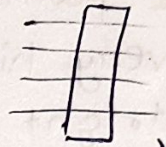
## Wave optics :- 

wave optics is a disturbance of light which have wavelength, frequences, apm amplitude, phase and phase-difference.

## Wave Front :-
(तरंगाग्र)

wave front is locus of all the points which are vibrating in same phase.

- (i) Point Source → spherical

- (ii) Line-Source → Cylindrical

- (iii) At infinite → Plane wave front


## * Coherent Sources :- (कलासम्बद्ध)

(i) Same wavelength
(ii) Same frequence
(iii) Same phase or same phase diff.
(iv) Same amplitude

Types of coherent sources

- Fully cohered Sources
  Ex. Laser
- Partially Coherent Sources
  Ex. Sunlight and all natural Sources.

Wave

- Mechanical wave (in medium)
  - Longituinal wave (water wave,
  - ~~Transverse~~
  - Transverse wave (Sound wave,
- Electro-megnatic wave (with out medium)
  X-ray, a

## * Interference :-

(light / waves)

when two coherent sources propagating in same direction superimpose each other then re-distribution of light intensity is called " interferenc

There are two types of interference -

| (i) Constructive Intereference (Maxima) | (ii) Distructive interfence (Minima) |
|---|---|
| after intereference of two light source we get maximum intensity then it is called constructive interference. | after intereference of two light source we get minimum intensity them it is called distructive interference. |

(Marks - 2)

**Q 1** While two independent sources can not be coherent source?

**Ans** Because they do not emit same wave. and not have ~~sham~~ same phase or constant phase difference between them.

### * Production method of interference :-

(i) By devision of wave front.

Ex. (i) Young's double slit experiment

(ii) Loyed's mirror method

(iii) Fresnel's Bi prism method

(ii) By devision of amplitude.

Ex.

(i) Thin ~~flim~~ film interfrence

(ii) Newton's Rings

(iii) Wedge shape interferenc

(Marks - 4, 2)

**Q 2** What are the condition for sustained interference?

(i) ~~Fre~~ Amplitude of both waves should be same.

(ii) frequences should be same, wave length, phase & phase difference should be same.

(iii) Point sources should be narrow. ( संकीर्ण )

(iv) The distance between both sources should be minimum

# Thomas Young's Double Slit experiment

- Mathematical Analysis of young's double slit exp.

Displacement equation for any general wave :-

$$y = a\sin(\omega t + \delta)$$

whereas

$y$ = displacement, $\omega$ = angular frequence
$a$ = amplitude, $\delta$ = Phase diff.

Let us assume

$$y_1 = A_1 \sin \omega t \quad \text{—(i) 1st wave}$$

$$y_2 = A_2 \sin(\omega t + \delta) \quad \text{2nd wave}$$

from the superimposition principle-

$$y = y_1 + y_2$$

$$y = a_1 \sin\omega t + a_2 \sin(\omega t + \delta)$$

$$y = a_1 \sin\omega t + a_2 \sin\omega t \cos\delta + a_2 \sin\delta \cos\omega t$$

$$y = (a_1 + a_2\cos\delta)\sin\omega t + a_2 \sin\delta \cos\omega t$$

let $a_1 + a_2\cos\delta = A\cos\theta$ —(ii)

$a_2 \sin\delta = A\sin\theta$ —(iii)

where as
A = new amplitude

$$y = A\cos\theta \sin\omega t + A\sin\theta \cos\omega t$$

$$y = A\sin(\omega t + \theta) \quad \text{—(iv)}$$

By squaring eq. (iii) & (ii) and adding

$$a_1^2 + a_2^2\cos^2\delta + 2a_1a_2\cos\delta + a_2^2\sin^2\delta = A^2\cos^2\theta + A^2\sin^2\theta$$

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

$$\boxed{A = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\delta}} \quad \text{—(v)}$$

# Redistributing Resultant Intensity

$I \propto A^2$ $\qquad$ $I_1 \propto a_1^2$

$A^2 = a_1^2 + a_2^2 + 2a_1a_2\cos\delta$ $\qquad$ $I_2 \propto a_2^2$

$$\boxed{I = I_1 + I_2 + 2\sqrt{I_1I_2}\cos\delta} \text{ —(ii)}$$

where as $I_1, I_2$ घटक की Intensity.

If $a_1 = a_2 = a$

$I_1 = I_2 = I$

then eq (v)

$A = \sqrt{a^2 + a^2 + 2a^2\cos\delta}$

$\boxed{\cancel{A = 2a\sqrt{\cos\delta}}}$

$A = \sqrt{2a^2 + 2a^2\cos\delta}$

$\boxed{A = 2a\cos\delta/2}$

By eq (ii)

$I = I + I + 2I\cos\delta$

$\boxed{I = 2I\cos\delta + 2I}$

$I = 2I(\cos\delta + 1)$

$I = 2I(2\cos^2\delta/2)$

$\boxed{I = 4I\cos^2\delta/2}$

## Relation between path difference and phase diff-

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

where as
$\Delta x$ = Path diff
$\Delta\phi$ = Phase diff.

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

$\cancel{I = a_1^2 + a}$ $\qquad$ $I = I_1 + I_2 + 2\sqrt{I_1I_2}\cos\delta$

for max intensity

$\Delta\phi = 2n\pi$

$\Delta x = \frac{\lambda}{2\pi} \times 2n\pi$

$\Delta x = 2n\lambda/2$ (even mult. of half of wavelength)

for min intensity

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

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

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

(odd mult. of half of $\lambda$)

(80-82 ms Calculator)

## Comparision of Intensities at maxima & minima:-

$I \propto a^2$

$I_1 = k a_1^2$

$I_2 = k a_2^2$

Then

$$\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2}$$

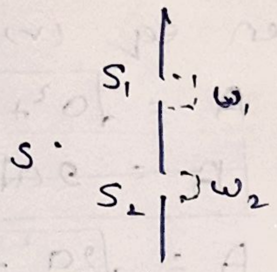
$$\boxed{\frac{a_1}{a_2} = \sqrt{\frac{I_1}{I_2}}}$$

$$\frac{I_{max}}{I_{min}} = \frac{(a_1+a_2)^2}{(a_1-a_2)^2}$$

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

if $r = \frac{a_1}{a_2}$

$$\boxed{\frac{I_{max}}{I_{min}} = \frac{(r+1)^2}{(r-1)^2}}$$




$$\boxed{\frac{w_1}{w_2} = \frac{a_1^2}{a_2^2} = \frac{I_1}{I_2}}$$

where $w_1$ = width of Slit of 1
$w_2$ = width of Slit 2

Numerical

Q Two coherent sources have intensities in the ratio of 25 : 16, find the ratio of maxima to minima intensities after interference of light

$\frac{I_1}{I_2} = \frac{25}{16}$ $\qquad \frac{a_1}{a_2} = \frac{5}{4}$

$$\frac{I_{max}}{I_{min}} = \frac{(5/4+1)^2}{(5/4-1)^2}$$

$$\boxed{\frac{I_{max}}{I_{min}} = \frac{81}{1}}$$ Ans

Q The ratio of the intensities minima to maxima in the Young's double slit experiment is 9 : 25. Find the ratio of the width of the two slits.

$$\because \frac{I_{max}}{I_{min}} = \frac{25}{9} = \frac{(r+1)^2}{(r-1)^2}$$

$$\therefore \boxed{r=4}$$

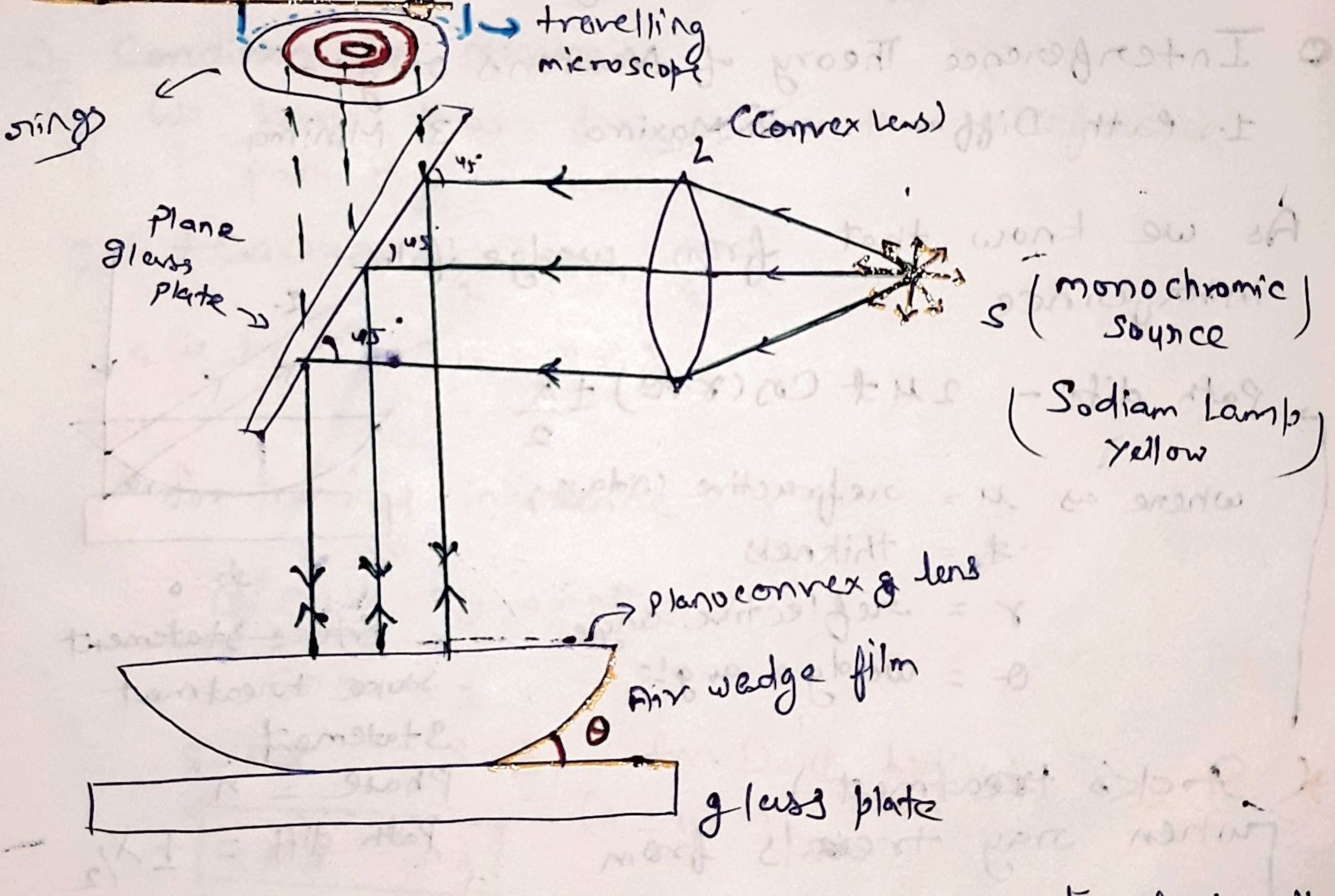
$$r = \frac{a_1}{a_2} = \frac{4}{1}$$

$$\frac{I_1}{I_2} = \frac{a_1^2}{a_2^2} = \frac{16}{1}$$

then width

$$\frac{w_1}{w_2} = \frac{I_1}{I_2} = \frac{16}{1} \text{ Ans}$$

## * Newton's Ring :-




1. When a planoconvex lens of Large Focal Length is placed on a plane glass plate with its convex surface in contact with Glass plate.

2. An air Film of very small thickness is enclosed between the lower surface of planoconvex lens and upper surface of the glass plate, that is called "**Air wedge Film.**"

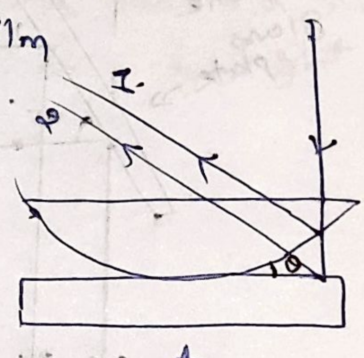
3. When a beam of light from a ~~fr~~ mono-chromatic source is made to fall normally on the combination of plano convex lens at plane glass-plate.

4. Concentric rings are observed of alternating dark & bright with the center at the point where the lens and plate meet. these rings obsererved by a travelling microscope.

- Interference Theory of Newton's ring :-

1. Path Diff.   2. Maxima   3. Minima

As we know that from wedge film interference.




path diff - $2\mu t \cos(r+\theta) \pm \frac{\lambda}{2}$

where as $\mu$ = refractive index
$t$ = thikness
$r$ = reflective angle
$\theta$ = wedge angle

~~Stoke statement~~
Stoke treatment
Statement
Phase = $\pi$
Path diff = $\pm \lambda/2$

*( Stock's treatment )
[when ray trevals from rarer to denser medium]

1. Condition for maxima :-

We know that for Constructive interference

path diff = even × $\lambda/2$

$$2\mu t \cos(r+\theta) \pm \lambda/2 = 2n \times \lambda/2$$

$$2\mu t \cos(r+\theta) = (2n-1)\lambda/2$$

for normal incidence -

$\theta =$ $r = 0$

$\theta \approx$ very small ( $\theta \to 0$)

$\cos\theta \to 1$

$$\boxed{2\mu t = (2n-1)\lambda/2}$$ for bright rings

( $n = 1, 2, 3, \dots$ )

2. Condition for minima :-

We know that for Distructive interference

path diff = odd × $\lambda/2$

$$2\mu t \cos(r+\theta) + \lambda/2 = (2n+1)\lambda/2$$

$$2\mu t \cos(r+\theta) = 2n\lambda/2$$

for normal incidence

$r = 0$

& $\theta$ is very small

$\theta \to 0$

$\cos\theta \to 1$

$$2\mu t = 2n\left(\frac{\lambda}{2}\right)$$ for Dark frings

($n = 1, 2, 3 \dots$)

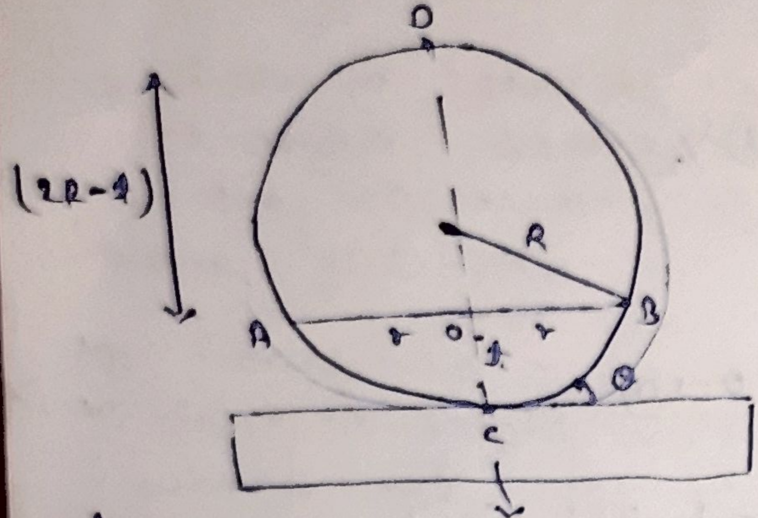
$$\boxed{2\mu t = n\lambda}$$

**

## * Diameter of newton's ring :-

→ Bright ring

→ Dark ring




$t$ :> thickness   C = Contact point

R = Radius of curvature.

from the property of circle (theorem)

$OD \times OC = OA \times OB$   (diagonal of )

$(2R-t) \times t = r \cdot r$

$t = \dfrac{r^2}{2R-t}$   $2R >>> t$

$t \to 0$

$$\boxed{t = \frac{r^2}{2R}} \text{ --- (i)}$$

(i) Diameter of Bright ring -

we know that path diff. = even $\times \lambda/2$

$2\mu t \cos(r+\theta) + \lambda/2 = 2n \cdot \lambda/2$

for normal incidence

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

for air $\mu = 1$

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

value of $t = \frac{r^2}{2R}$

$$2 \cdot \frac{r^2}{2R} = (2n-1)\lambda/2$$

$$\frac{r^2}{R} = (2n-1)\lambda/2$$

$$\boxed{r^2 = (2n-1)R\frac{\lambda}{2}}$$

$\because \frac{D_n}{2} = r$

$$\left(\frac{D_n}{2}\right)^2 = (2n-1)\frac{R\lambda}{2}$$

$$D_n^2 = 4(2n-1)\frac{R\lambda}{2}$$

$$\boxed{D_n^2 = 2(2n-1)R\lambda}$$

(ii) Diameter of Dark ring—

we know that Path diff = odd $\times \lambda/2$

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

$$2\mu t\cos(r+\theta) + \lambda/2 = (2n+1)\lambda/2$$

$$2\mu t\cos(r+\theta) = 2n\lambda/2$$

$\theta \to 0$

$r = 0$

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

for air $\mu = 1$

$$t = n\lambda$$

$\because t = \frac{r^2}{2R}$

$$2 \times \frac{r^2}{2R} = n\lambda$$

$$\boxed{r^2 = n R\lambda}$$

$\because \frac{D_n}{2} = r$

$\left(\frac{D_n}{2}\right)^2 = 2nR\lambda$

$D_n^2 = 4nR\lambda$

$\boxed{D_n = \sqrt{4nR\lambda}}$ for Dark ring. $(D_n \propto \sqrt{n})$

## Note

1. Diameter for bright rings are proportional to square root of odd natural number.

$D_n \propto \sqrt{(2n-1)}$

2. The separation between successive bright rings are in ratio.

3. In dark rings diameter if $n = 0$

$D_n = \sqrt{4nR\lambda}$

$D_0 = 0$

* So center rings of Newton's rings is dark.

4.

Q Newton's rings are observed in Reflecting light of wavelength 5900 Å, Diameter of the 10th dark ring is 0.50 cm. Find the radius of the curvature of the lense.

Given

$\lambda = 5900\,\text{Å} = 59 \times 10^{-6}$ cm

$D_{10} = 0.50$ cm

$n = 10$

$R = ?$

$D_n = \sqrt{4nR\lambda}$

$(0.50) = \sqrt{4 \times 10 \times R \cdot 5900 \times 10^{-8}}$

$(0.50)^2 = 40 \times 5900 \times 10^{-8} \times R$

$25 \times 10^{-2} = 59 \times 4 \times 10^{-5} \times R$

$\frac{25 \times \cancel{1000}^{250}}{59 \times 4} = R \Rightarrow R = 1.053\text{m}$

$\boxed{R = 105.3\text{cm}}$

$$\begin{array}{r} 59\,)\,6250\,(1.06 \\ 59 \\ \hline 350 \\ 354 \end{array}$$

Q In a newton's ring experiment, the diameter of the 10th dark ring changes from 1.4 cm to 1.27 cm when a liquid is introduced between the lens and the plate. calculate the Refractive index of the liquid.

Given

$n = 10$

$D_0 = 1.4$ cm

$D_\mu = 1.27$ cm

$\because D = \sqrt{\frac{4Rn\lambda}{\mu}}$

$D_\mu \propto \frac{1}{(\mu)^{1/2}}$

$\frac{D_0}{D_\mu} = \frac{(\mu)^{1/2}}{1}$

$\frac{1.4}{1.27} = \frac{(\mu)^{1/2}}{1}$

$\sqrt{\mu} = 1.102$

$\boxed{\mu = 1.215}$ Ans

$$\begin{array}{r} 1.102 \\ 127 \overline{)140.0} \\ 127 \\ \hline 130 \\ -127 \\ \hline 300 \end{array}$$

Q In newtons ring experiment, Diameter of 5th ring (dark) was 0.336 cm. Find the radius of curvature of the planoconvex lens, if the wavelength of light used is 5800 Å also find out the Radius of 15th dark ring. ($\mu = 1$)

Given

$D_5 = 0.336$ cm.

$R = ?$

$\lambda = 5800$ Å

$\mu = 1$

$D_{15} \rightarrow r_{15}$ ??

$D_n = \sqrt{\frac{4Rn\lambda}{\mu}}$

$n = 5$

$(0.336)^2 = \sqrt{\frac{4 \times R \times 5 \times 5800 \times 10^{-8}}{1}}$

$0.113 = 116 \times 10^{-5} \times R$

$R = \frac{0.113}{116} \times 10^{+5}$

$R = 973$ cm

$$D_{15} = \sqrt{\frac{15R\lambda \times 4}{\mu}}$$

Same - Same molecule

↳ Cohesive force (सस्संगत)

Diff. molecule

Adhesive force (असंगत)

$r_{15} = \sqrt{R\lambda \times 15}$

$r_{15} = \sqrt{973 \times 5800 \times 10^{-8} \times 15}$

$r_{15} = 0.29$ cm

05/09/24

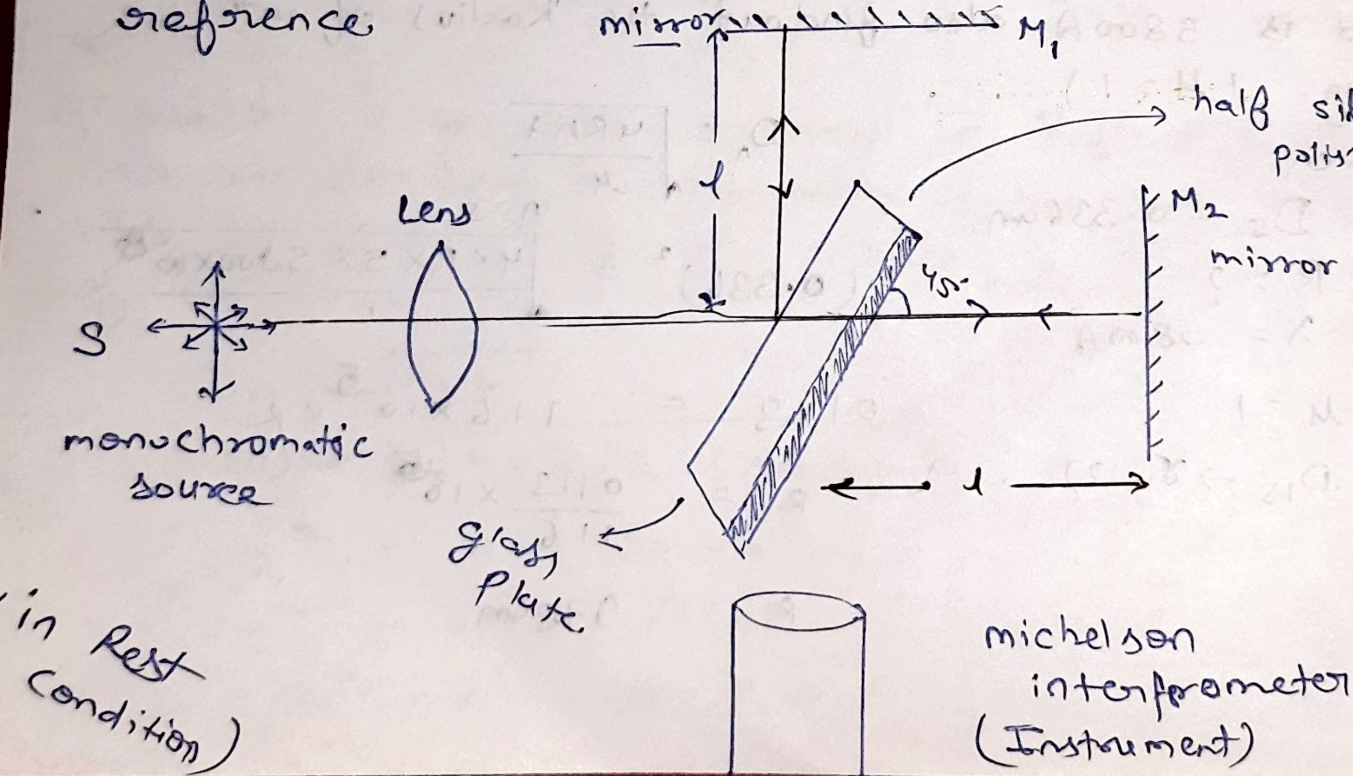
- **Michelson moreley experiment :-**

Obect to measure relative motion between earth & ether. to verify the presence of ether medium.

Q What is ether medium. (2)

Ans 1. Ether is a hypothetical medium. 2. It is used to explain how light waves reach us from the sun, through the free space.

3. Ether is considered as a transperent medium, highly elastic which provides a fitch frame of refrence.



## Principle



What is the principle of michelson interferometer?

Ans This instrument based on the interference of light.

### Working

1. When a parallel beem of light coming from a monochromatic source of light is incident on half silvered glass plate.

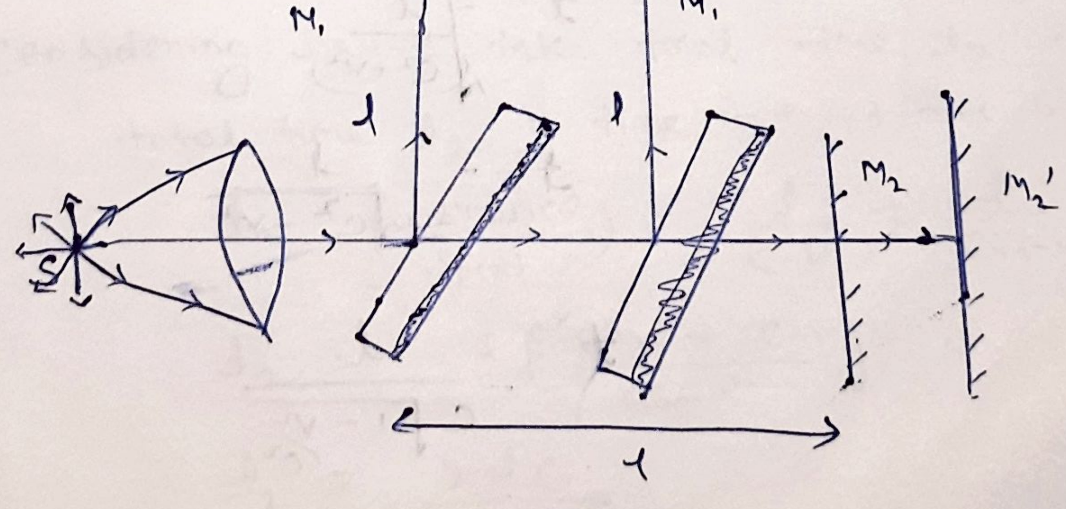
2. It is devided into two parts
   (i) One part is reflected wave and
   (ii) other part is refrected wave.
   and both are coharent waves.

3. In this experiment interference produced by the method of devision of amplitude.

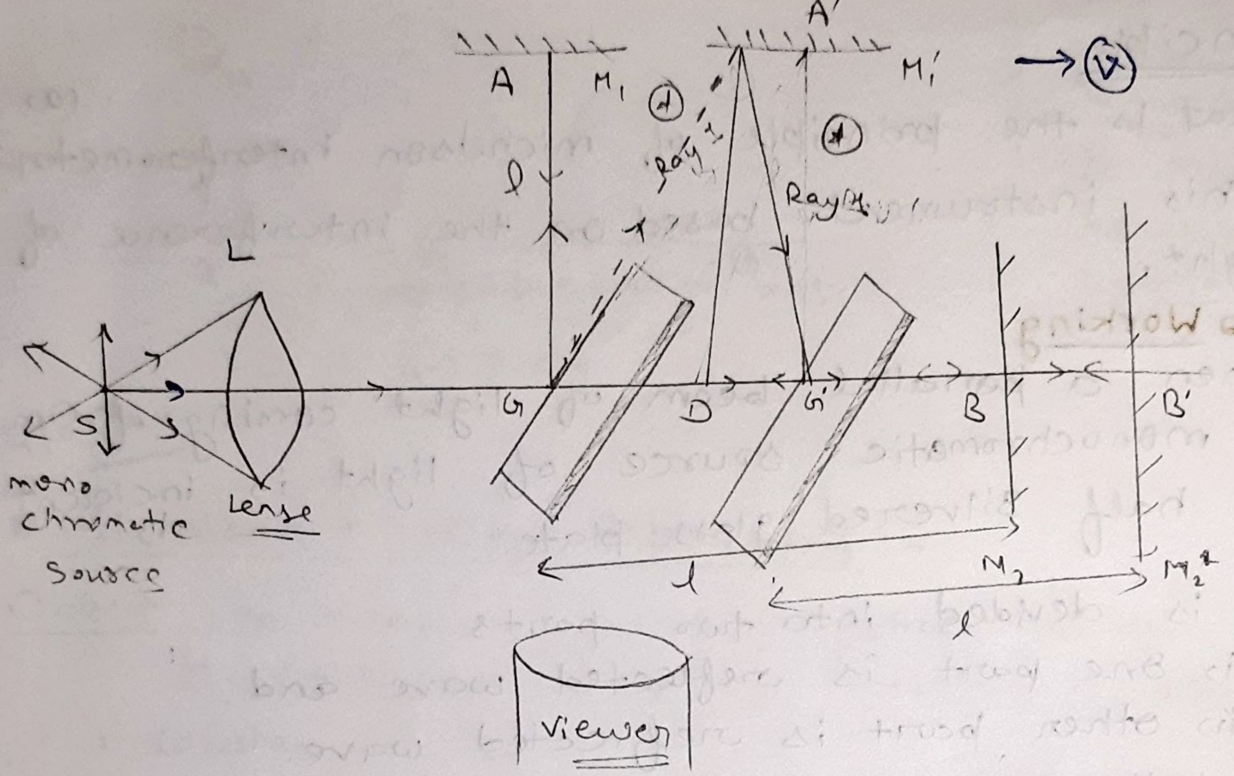
4. These waves ~~proceeds~~ proceeds in perpendicular direction and incidents normally on the mirror,

5. After reflection on the mirror when they suprrimpose, produce an interference.

### ~~Contst~~ Construction




moving

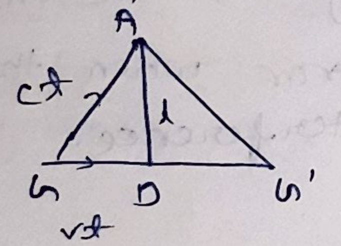



• Analysis for Ray 1

't' ~~to~~ let us time taken by Ray 1 to travel path GA'G'

Total time $\Rightarrow t_1 = t + t$

$t_1 = 2t$




in right angled $\Delta$ GA'D

$$(ct)^2 = l^2 + vt^2$$

$$l^2 = (c^2 - v^2)\,t^2$$

$$t^2 = \sqrt{\frac{l^2}{(c^2 - v^2)}}$$

$$t = \frac{l}{\sqrt{c^2 - v^2}}$$

$$t = \frac{l}{c\sqrt{1 - v^2/c^2}}$$

$$t = \frac{l}{c}\left(1-\frac{v^2}{c^2}\right)^{-1/2}$$

$$(1+x)^n = 1+nx \ldots$$

$$\left(1-\frac{v^2}{c^2}\right)^{-1/2} = 1-\frac{v^2}{c^2}\times\left(-\frac{1}{2}\right) = \left(1+\frac{v^2}{2c^2}\right)$$

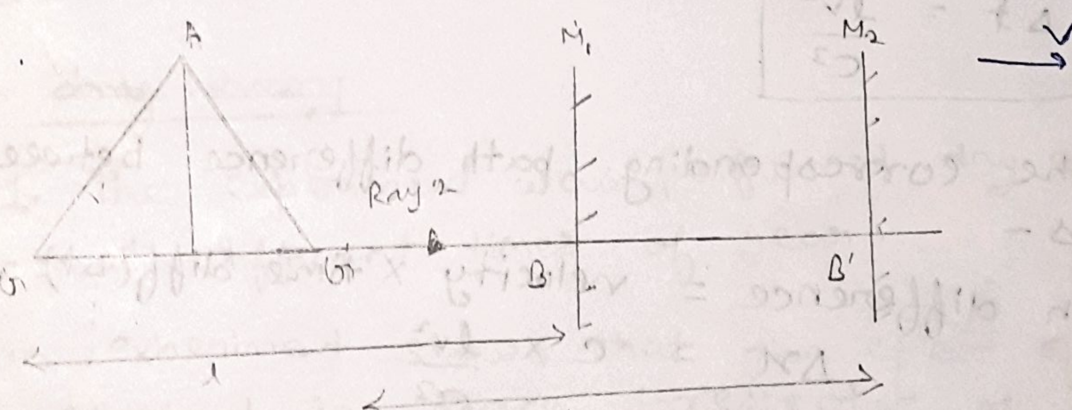
$$\boxed{t = \frac{l}{c}\left(1+\frac{v^2}{2c^2}\right)}$$

So for Ray 1

$$t_1 = 2t$$

$$\boxed{t_1 = \frac{2l}{2c}\left(1+\frac{v^2}{2c^2}\right)}$$

- Analysis for Ray 2




Considering ray-2 take total time $t_2$

total time $t_2$ = time G to B + time B' to G'

$$t_2 = \left(\frac{\text{distance}}{\text{Speed}}\right) = \frac{l}{c-v} + \frac{l}{c-(-v)}$$

$$t_2 = l\left[\frac{c+v+c-v}{c^2-v^2}\right]$$

$$t_2 = \frac{2lc}{c^2-v^2}$$

$$t_2 = \frac{2lc}{c^2(1-v^2/c^2)}$$

$$t_2 = \frac{2l}{c}\left(1-\frac{v^2}{c^2}\right)^{-1}$$ By using binomial.

$$\boxed{t_2 = \frac{2l}{c}\left(1+\frac{v^2}{c^2}\right)}$$

→ time difference

$$\Delta t = t_2 - t_1$$

$$\Delta t = \frac{2l}{c}\left(1+\frac{v^2}{c^2}\right) - \frac{2l}{c}\left(1+\frac{v^2}{2c^2}\right)$$

$$\Rightarrow \Delta t = \cancel{\frac{2l}{c}} + \frac{2lv^2}{c^3} - \cancel{\frac{2l}{c}} - \frac{\cancel{2}lv^2}{\cancel{2}\cdot c^3}$$

$$\Delta t = \frac{2lv^2 - lv^2}{c^3}$$

$$\boxed{\Delta t = \frac{lv^2}{c^3}}$$

* Now the corresponding path difference between two rays -

Path difference = velocity × time diff($\Delta t$)

$$\Delta x = c \times \frac{lv^2}{c^3}$$

$$\boxed{\Delta x = \frac{lv^2}{c^2}}$$

After the michelson turn their ~~approach~~ apparatus by 90°

Path difference $\boxed{\Delta x' = -\frac{lv^2}{c^2}}$

Hence Resultant path difference

$$\Delta x'' = \frac{lv^2}{c^2} - \left(-\frac{lv^2}{c^2}\right)$$

$$\boxed{\Delta x'' = \frac{2lv^2}{c^2}}$$

If the wavelength of incident light is $\lambda$ then fringe shift (n)

$$\boxed{n = \frac{\Delta x''}{\lambda} = \frac{2lv^2}{\lambda c^2}}$$

- Fringe shift [n or N]

$$N = \frac{2l}{\lambda}\left(\frac{v^2}{c^2}\right) \qquad \left[\because l = 11m, \ \lambda = 5500Å, \ v = 10^{-4} m/s\right]$$

$$\boxed{N = 0.4}$$

* ~~Ether drag theory~~

Note 1. The experiment was performed day and night and at different times of year.

2. This experiment shows that the speed of light is constant in space irrespective of the direction and speed of the initial frame.

3. So, it was concluded by michalsen that there is no medium like ether.

Types of fringes

- Fringes observation in Michleson - Morley exp.

Types of observed frings

(i) Circular Frings

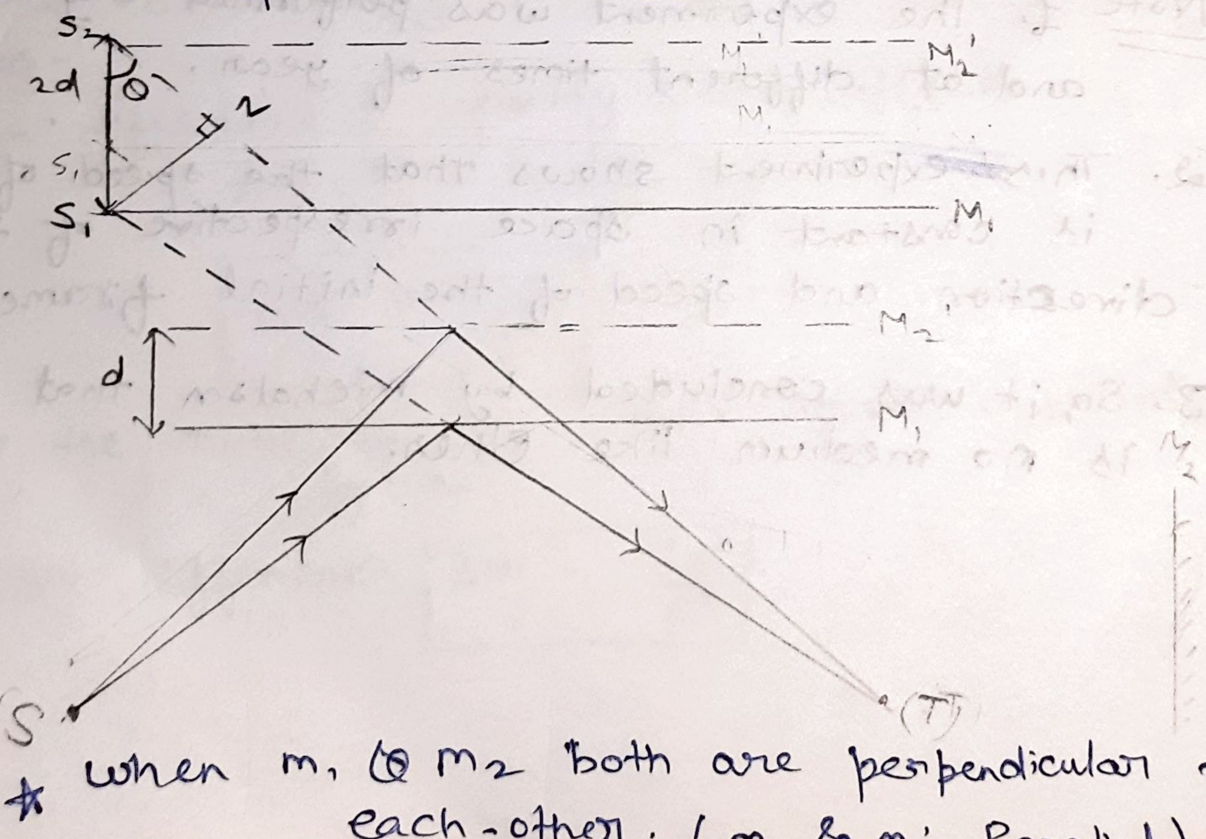
(ii) Localized frings.

(i) Circular Frings:-

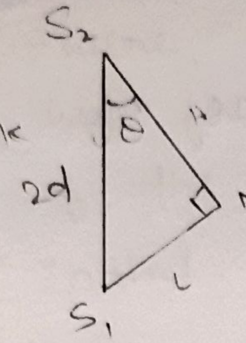
- When mirror $M_1$ is seen directly through telescope(T) in addition to it virtual image of mirror $M_2'$ of mirror $M_2$ is formed by reflection in Plate $G_1$ is also seen.

- This forms system equivalent to air film enclosed between two mirror between $M_1$ & $M_2'$

- These two intersecting beams appear to come from virtual source $S_1$ & $S_2$ directed from single Source 'S'. Seperation between them is 'd'.




★ when $m_1$ & $m_2$ both are perpendicular to each-other. ($m_1$ & $m_2'$ Parallel)




in $\Delta S_1NS_2$

$S_2N = 2d\cos\theta$ = Path difference between two intersecting beams.

effective Path diff $= 2d\cos\theta - \lambda/2$

for Bright fringe

$\Delta x = n\lambda$

$2d\cos\theta - \lambda/2 = n\lambda$

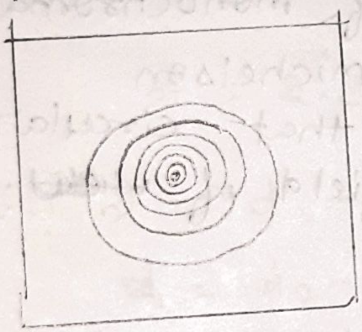
$$\boxed{2d\cos\theta = (2n+1)\lambda/2}$$

for dark finge

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

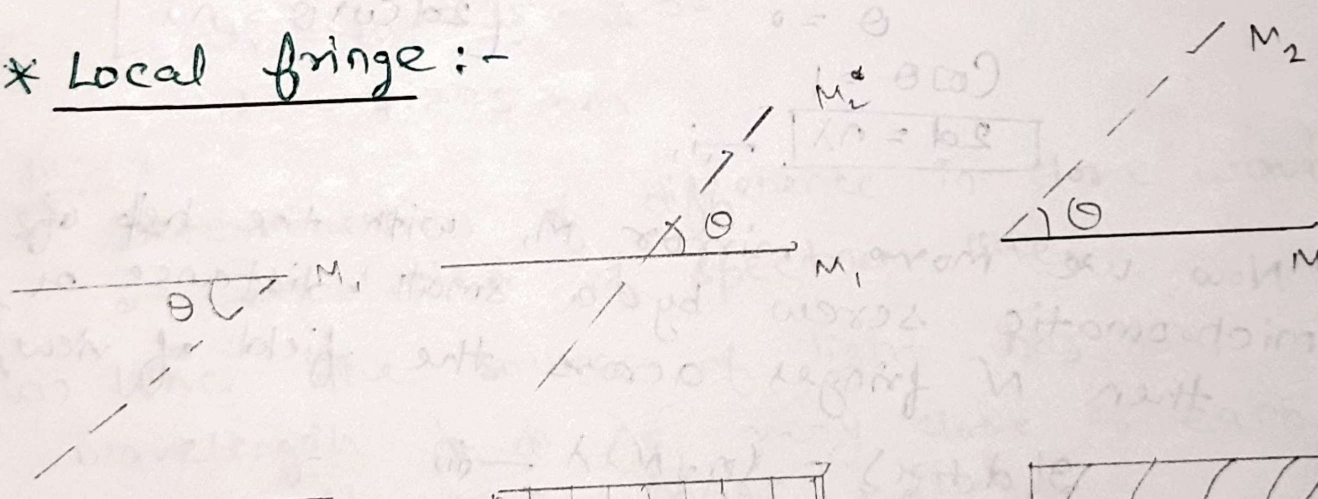
$2d\cos\theta - \lambda/2 = (2n-1)\lambda/2$

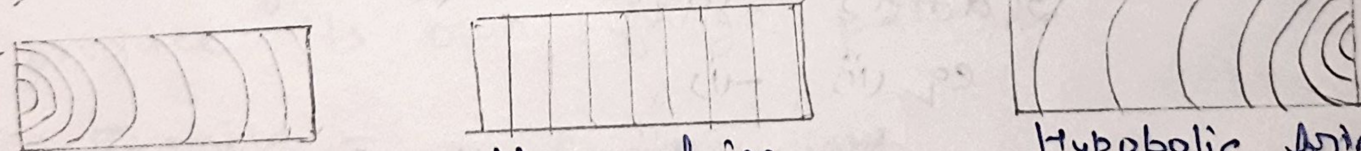
$$\boxed{2d\cos\theta = n\lambda}$$



← Circular Fringes or Haidinger fringes

* <u>Local fringe :-</u>



Hyperbolic fringe — Linear fringe — Hypobolic fringe

* Interference pattern is circular, concentric and alternate bright & dark frings.

* $2d\cos\theta$ is maximum if $\theta = 0$, so maximum order fringe lies at centre.
* When we move away from centre of pattern $\theta \uparrow$ & $\cos\theta \downarrow$ so

$$2d\cos\theta \downarrow$$

So $n$ is also decresing.

## Application of Michelson interferometer:-

App. 1

I. To determine the wavelength of monochromatic source of light -

(a) To determine the wavelength of monochromatic source of light we adjust michelson interfernometer in such a way that circular fringes are observed in the field of ~~view~~ view.

assume center is dark

at centre

$\theta = 0$ $\quad [2d\cos\theta = n\lambda]$

$\cos\theta = 1$

$$\boxed{2d = n\lambda} \quad \text{--- (i)}$$

(b) Now we move mirror $M_1$ with the help of michromatic screw by a small distance $x$, then $N$ fringes across the field of view,

$$2(d+x) = (n+N)\lambda \quad \text{--- (ii)}$$

eq (ii) − (i)

$$2(d+x) - 2d = \cancel{n}\lambda + N\lambda - n\lambda$$

$$2x = N\lambda$$

$$\boxed{\lambda = \frac{2x}{N}}$$

Q) In a michelson interferometer when 100 fringe were shifted, the final reading of the screw was found to be 10.735 mm. If the wavelength of the light was $5.92 \times 10^{-5}$ cm, what was the intial reading of the screw?

Sol$^n$

$$\lambda = \frac{2x}{N}$$

$d_2 = 10.735$ mm

$\lambda = 5.92 \times 10^{-5}$ cm

$N = 100$

$$x = \frac{\lambda N}{2}$$

$$x = \frac{5.92 \times 10^{-5} \times 100 \cancel{\times 10}}{2}$$

$$x = 2.96 \times 10^{-3} \text{ cm}$$

$$\therefore x = d_2 - d_1 = \Delta d$$

$$d_1 = d_2 - x$$

$$d_1 = 10.735 - 2.96$$

$$d_1 = 7.775 \text{ mm}$$

App 2

2. Determination of difference in close wavelength or resolution of spectrum line.

(a) When the source of light has two wavelength $\lambda_1$ & $\lambda_2$ very close to each other produce it's own fringe pattern.

(b) Example - Sodium light

$\lambda_1 = 5890$ Å

$\lambda_2 = 5896$ Å

(c) The position of the mirror $M_1$ is adjusted at the circular fringes observed the bright & distinct.

(d) In this position bright fringes dues to wavelength $\lambda_1$ coninside with the frings (bright) of the $\lambda_2$

Let in the case the thickness of virtual air film is 'd' and the order of the central fringes due to $\lambda_1$ & $\lambda_2$

$$x = d_2 - d_1$$

$$\lambda_1 - \lambda_2 = \frac{\lambda^2}{2x} \qquad \left[\lambda = \frac{\lambda_1 + \lambda_2}{2}\right]$$

Q In michelson experiment, the distance moved by the movable mirror between two consecutive position of maximum distinctness is 0.0289 mm. If the mean wavelength of the two components of the sodium light is 5893 Å. Determine the diff. between the wavelength.

$\lambda = 5893$ Å, $\quad \because \lambda_1 - \lambda_2 = \frac{\lambda^2}{2x}$

$x = 0.0289$ mm

$$\lambda_1 - \lambda_2 = \frac{(5893 \times 10^{-7})^2}{2 \times 0.0289} \times 10$$

$$\lambda_1 - \lambda_2 = 60082 \times 10^{-10}$$

$$\boxed{\lambda_1 - \lambda_2 = 60082 \text{ Å}}$$

# Difference between newton's ring and michelson's Interference / Interferrometer:-

→ There is a fundamental difference in the formation of frings, In newton's ring there is no splitting of light.

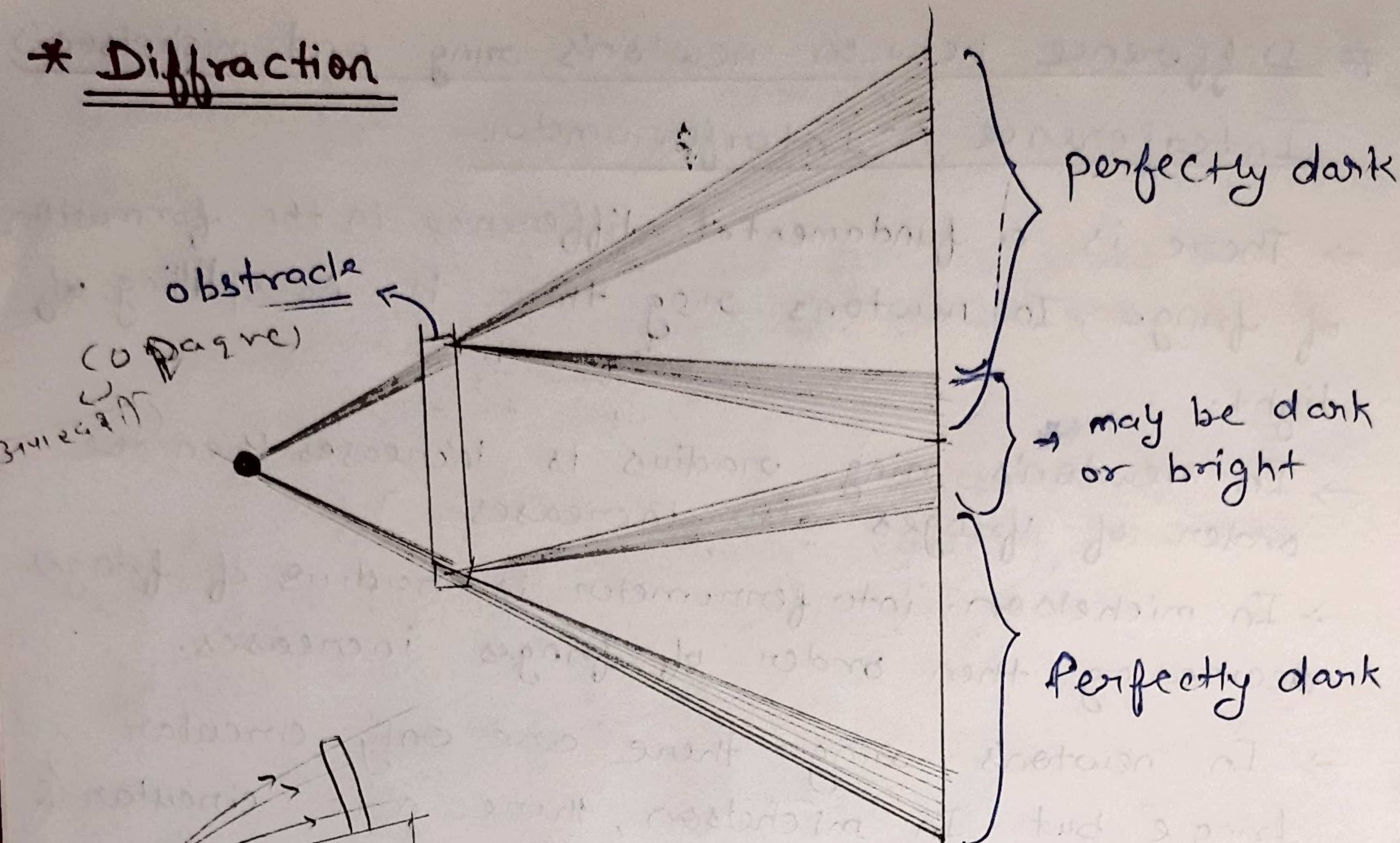
→ In newton's ring radius is increases then the order of fringes also increases.

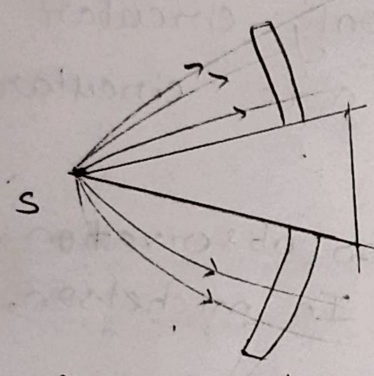
→ In michelson interferrometer is radius of fringes decreasing then order of fringes increases.

→ In newton's ring there are only circular fringe but In michelson, there are circular & localized frinzes.

→ In newton's ring for ~~michelson~~ observation of fringes, we use microscope and In michelson, we use telescope.

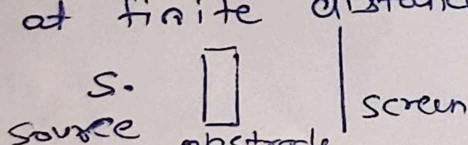
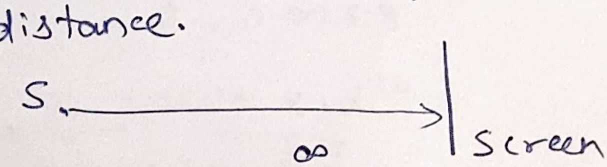
# * Diffraction



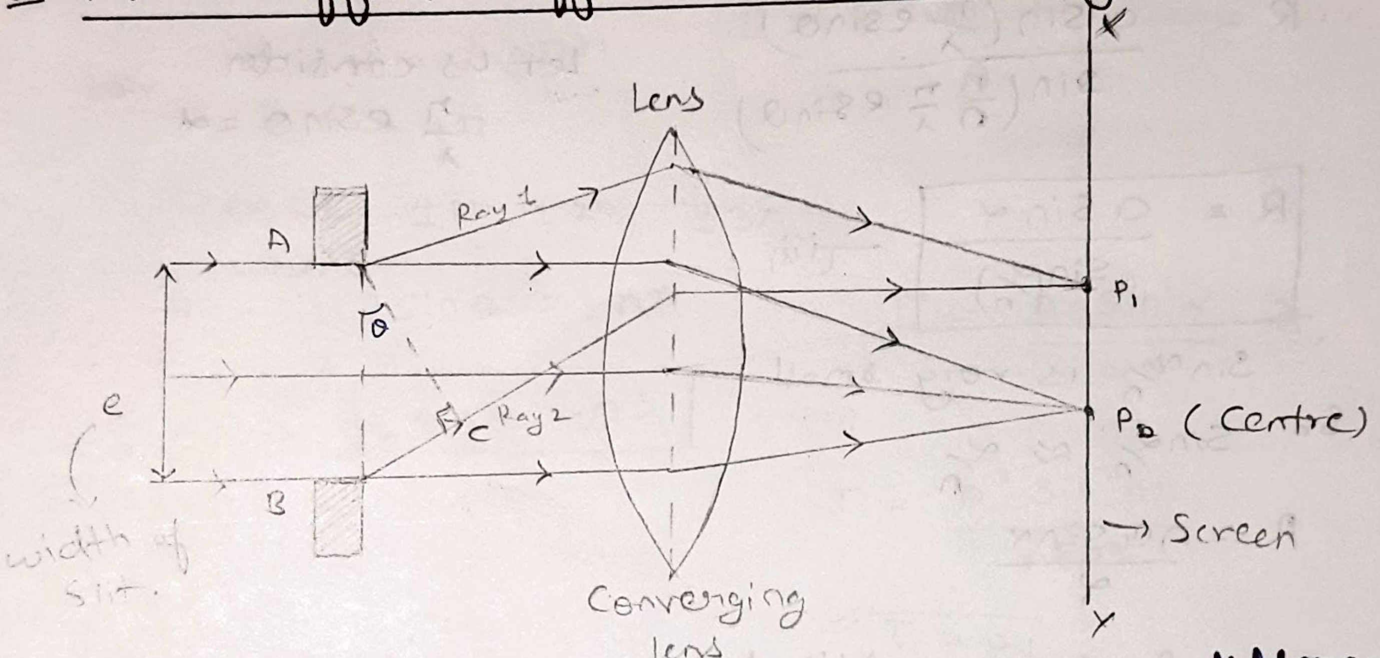

→ When a light ray bends from the sharp edges or corners of an obstracles & move towards the geometrical shadow of any obstracle then this phenomena is known as diffraction.

- **Diff. between frasnal and fronhoffer diffraction** (4)

| Augstine **Frasnal** | Joseph **Fronhoffer** |
| --- | --- |
| (i) Source, screen and diffraction device (opaqre obstracle) are at finite distance. | Source, screen & diffraction device are at infinite distance. |
|   |   |
| (ii) No lens and mirror are used | Lens is used (Convex) |
| (iii) Centre may be bright or dark. | Centre always bright. |

| | |
|---|---|
| 4. wavefront may be spherical or cylindrical. | Wavefront always plane. |
| 5. Diffraction devices used (obstacles) (zone plates, circular rings, Notchs) | Diffraction devices used [Single slit, double slit & N slit (Grating)] |

## * Fraunhoffer Diffraction due to Single slit :-




in $\triangle ABC$

$e = AB$

(i) Path difference

$$\frac{BC}{AB} = \sin\theta$$

$$\Rightarrow \sin\theta = \frac{BC}{e}$$

$$\boxed{BC = e\sin\theta} \quad \text{— (i)}$$

$\hookrightarrow \Delta x$

(ii) Phase difference

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

$$\Delta\phi = \frac{2\pi}{\lambda} \times e\sin\theta$$

Let's consider there are n points between A & B

then Phase diff.

$$\boxed{\Delta\phi = \frac{1}{n} \cdot \frac{2\pi}{\lambda} e\sin\theta} \quad \text{— (ii)}$$

(iii) from the theory of n harmonic motions - resultent amplitude is given by

$(\Delta\phi = \delta)$

$$* \boxed{R = \frac{a\sin\frac{n\delta}{2}}{\sin\frac{\delta}{2}}} *$$

$$R = \frac{a \sin \frac{n\delta}{2}}{\sin \delta/2} \qquad \because \delta = \frac{1}{n} e \sin\theta \times \frac{2\pi}{\lambda}$$

$$R = \frac{a \sin\left(n \times \frac{1}{n} \frac{e \sin\theta}{2} \times \frac{2\pi}{\lambda}\right)}{\sin\left(\frac{1}{n} e \sin\theta \times \frac{2\pi}{\lambda}\right) \times \frac{1}{2}}$$

$$R = \frac{a \sin\left(\frac{\pi}{\lambda} e \sin\theta\right)}{\sin\left(\frac{1}{n} \frac{\pi}{\lambda} e \sin\theta\right)}$$

Let us consider $\frac{\pi}{\lambda} e \sin\theta = \alpha$

$$\boxed{R = \frac{a \sin\alpha}{\sin(\alpha/n)}} \quad \text{— (iii)}$$

$\sin \alpha/n$ is very small

So $\sin \alpha/n \approx \alpha/n$

$$R = \frac{n a \sin\alpha}{\alpha}$$

$na = A$ (new amplitude)

$$\boxed{R = \frac{A \sin\alpha}{\alpha} = \frac{\lambda A \sin\left(\frac{\pi}{\lambda} e \sin\theta\right)}{\pi e \sin\theta}}$$

(Resultent amplitude)

(iv) Resultent ~~amp~~ intensity –

$\because I \propto R^2$

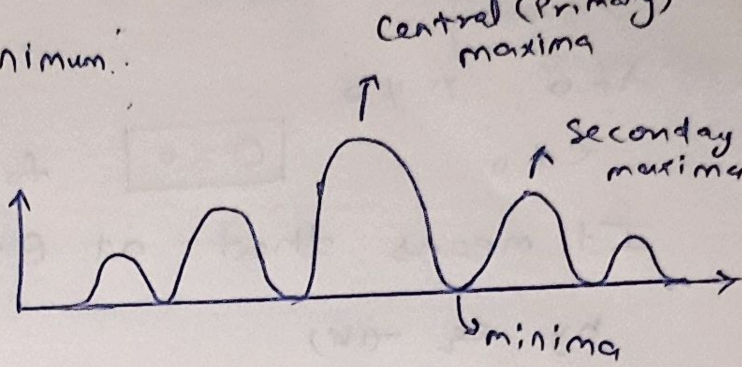
$= I = R^2$

$$\boxed{I = \frac{A^2 \sin^2\alpha}{\alpha^2}} \quad \text{— (iv)}$$

## (5.) Condition for minima :-

For I should be minimum.

$\boxed{I = 0}$




for $I = 0$,

$A \neq 0$

for $I = 0$,

$A \neq 0$, $\alpha \neq 0$

(I ~~shou~~ will not zero due to A)

~~for~~ $\sin\alpha = \sin n\pi$

$\alpha = n\pi$

Hence $\pm 1\pi, \pm 2\pi, \pm 3\pi + \ldots$

where

$\alpha = \frac{\pi e \sin\theta}{\lambda} = \pm n\pi$

$\boxed{e \sin\theta = \pm n\lambda}$ —(V)

$I = \frac{A^2 \sin^2\alpha}{\alpha^2}$

$I = \frac{A^2 \sin^2 n\pi}{n^2\pi^2}$

$\boxed{I = 0}$

## (6.) Condition for central or Primary maxima :-

For central maxima I should be maximum

$\boxed{I \longrightarrow \infty}$

$\because I = \frac{A^2 \sin^2\alpha}{\alpha} = \infty$

$\boxed{\alpha = 0}$

$(A \neq 0)$ & $(\sin\alpha \neq 0)$

$\frac{\pi}{\lambda} e \sin\theta = 0$ ← ($\alpha = 0$)

$\lambda \neq 0$, $\pi \neq 0$

$e \neq 0$ $\boxed{\theta = 0}$ for central maxima :-

It means that at $\theta = 0$ we get central maxima.

by eq -(iv)

$$I = \frac{A^2 \sin^2\alpha}{\alpha^2} \qquad \left(\because \lim_{x \to 0} \frac{\sin x}{x} = 1\right)$$

$\alpha = 0$ put in this eq$^n$

$$\boxed{I_{max} = I_0 = A^2} \quad \text{—(vi)}$$

***

(7) Condition for secondary maxima :-

$$I = \frac{A^2 \sin^2\alpha}{\alpha^2} \qquad \left[\because \frac{d(N/D)}{d\alpha} = \frac{D \cdot \frac{dN}{d\alpha} - N \cdot \frac{dD}{d\alpha}}{D^2}\right]$$

~~for~~, for maxima

$$\boxed{\frac{dI}{d\alpha} = 0}$$

$$\frac{d}{dI}\left(\frac{A^2 \sin^2\alpha}{\alpha^2}\right) = \frac{\alpha^2 \cdot A^2 \, 2\sin\alpha \cos\alpha - A^2 \sin^2\alpha \cdot 2\alpha}{(\alpha)^4}$$

$$\frac{dI}{d\alpha} = \frac{2\alpha A^2 \sin\alpha \, [(\cos\alpha)\alpha - \sin\alpha)}{\alpha^4}$$

$$\frac{dI}{d\alpha} = 0$$

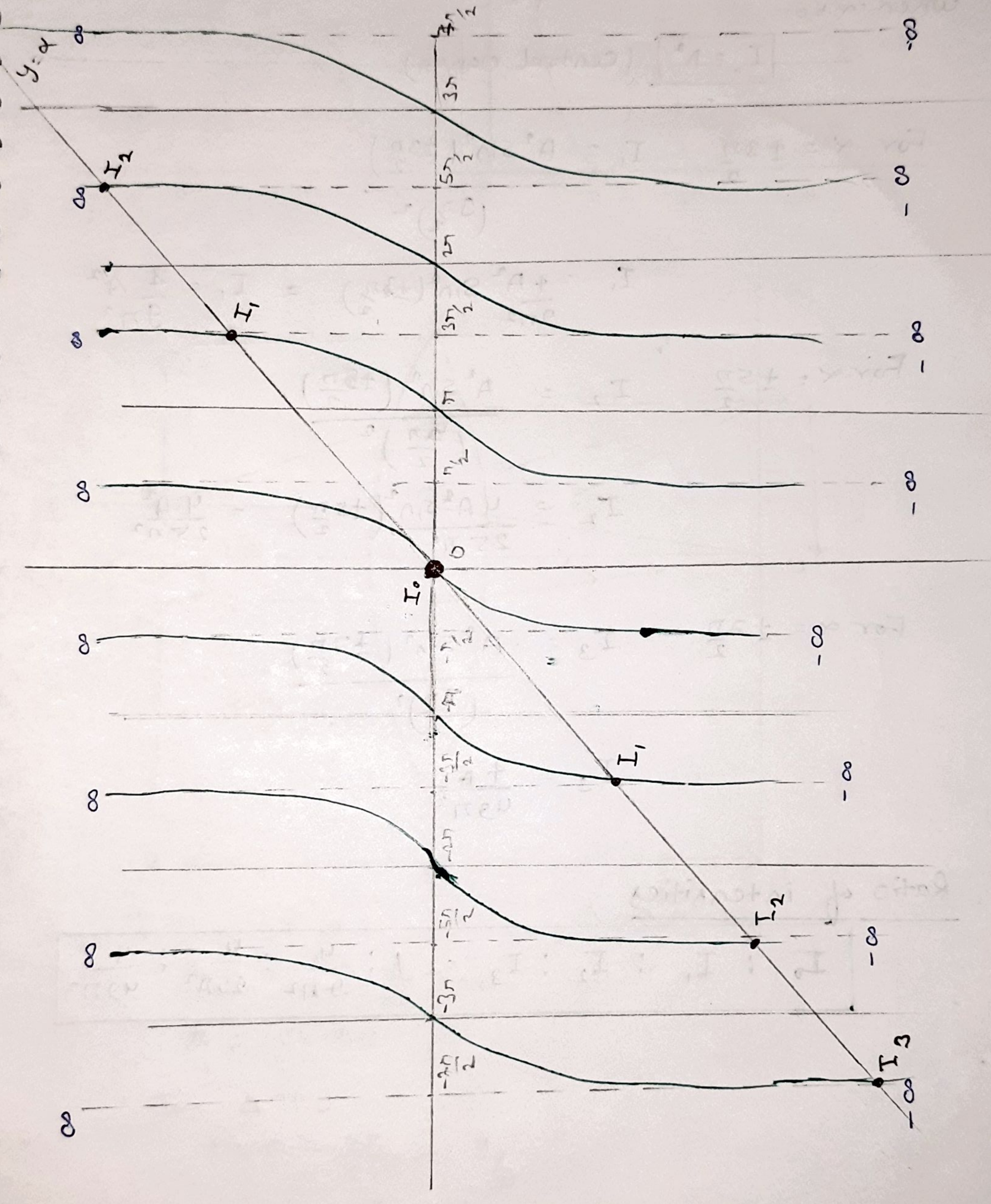
$$\frac{2\alpha A^2 \sin\alpha \, (\alpha \cos\alpha - \sin\alpha)}{\alpha^4} = 0$$

| | | |
|---|---|---|
| $\alpha = 0$ central (maxima) | $\sin\alpha = 0$ (minima) | $\alpha \cos\alpha - \sin\alpha = 0$ <br> $\boxed{\alpha = \tan\alpha}$ —(vii) |

$y = \alpha$ & $y = \tan\alpha$
will give the position of secondary maxima.

$y = mx + c$
$y = 1\alpha + 0$

$\left( \begin{array}{l} m = 1 \\ \tan\theta = 1 \\ \theta = 45 \text{ Slope} \end{array} \right)$



$\alpha = \pm\frac{3\pi}{2}, \pm\frac{5\pi}{2}, \pm\frac{7\pi}{2}, \pm\frac{9\pi}{2}, \pm\frac{\pi}{2} + \ldots$

From eq (i) $\quad I = \frac{A^2\sin^2\alpha}{\alpha^2}$

when $\alpha = 0$

$\boxed{I_0 = A^2}$ (central maxima)

For $\alpha = \pm\frac{3\pi}{2}$ $\quad I_1 = \frac{A^2\sin^2(\pm\frac{3\pi}{2})}{(\frac{3\pi}{2})^2}$

$I_1 = \frac{4A^2}{9\pi^2}\sin^2(\pm\frac{3\pi}{2}) = I_1 = \frac{4A^2}{9\pi^2}$

For $\alpha = \pm\frac{5\pi}{2}$ $\quad I_2 = \frac{A^2\sin^2(\pm\frac{5\pi}{2})}{(\frac{5\pi}{2})^2}$

$I_2 = \frac{4A^2}{25\pi^2}\sin^2(\pm\frac{5\pi}{2}) = \frac{4 \cdot A^2}{25\pi^2}$

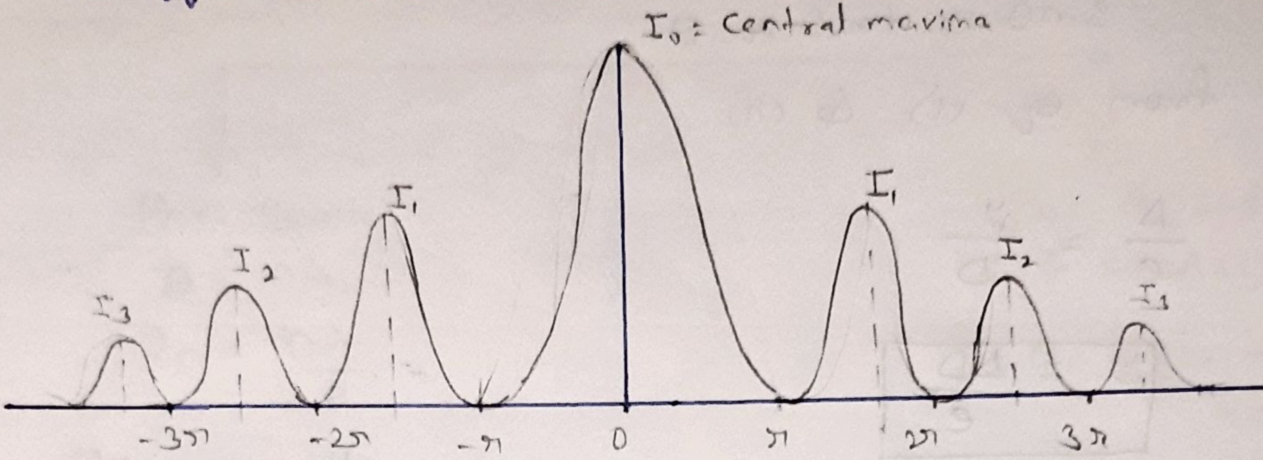
For $\alpha = \pm\frac{7\pi}{2}$ $\quad I_3 = \frac{A^2\sin^2(\pm\frac{7\pi}{2})}{(\frac{7\pi}{2})^2}$

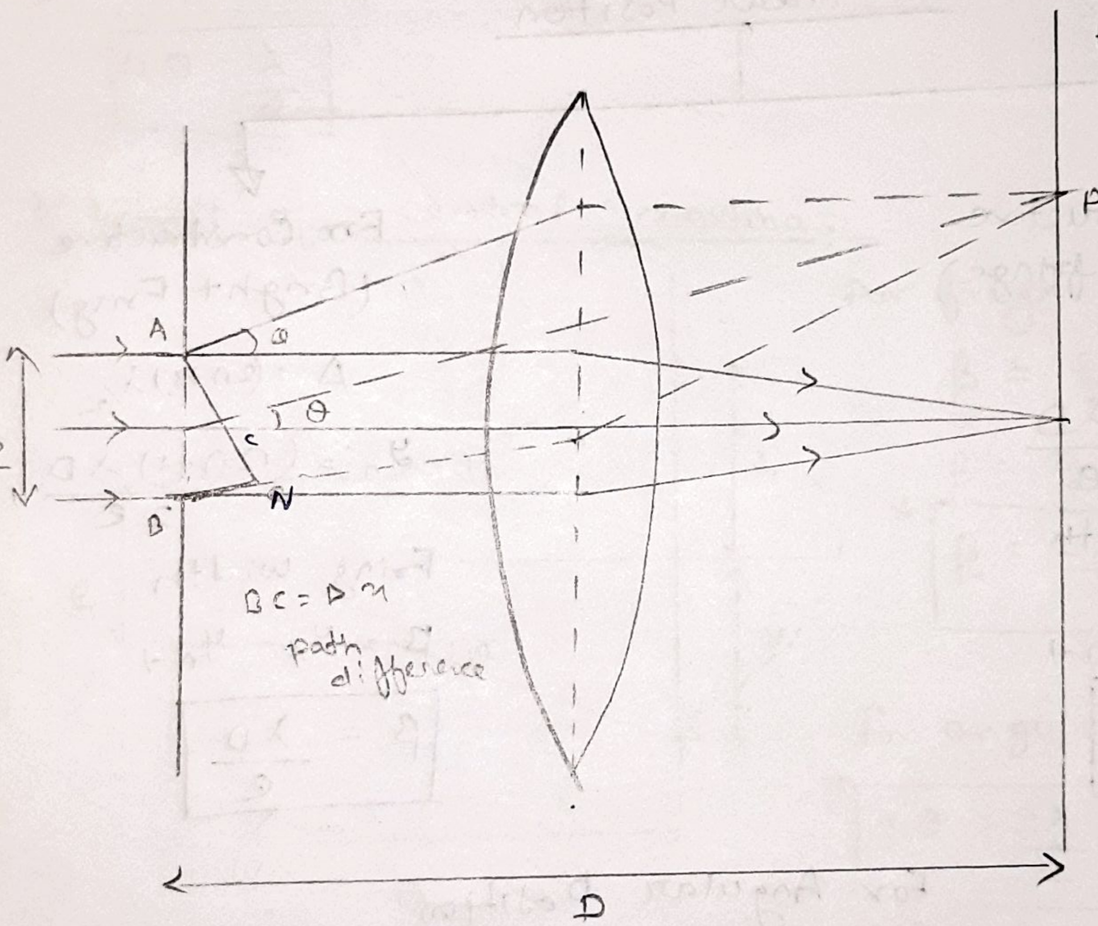
$I_3 = \frac{4A^2}{49\pi^2}$

Ratio of intensities

$$\boxed{I_0 : I_1 : I_2 : I_3 = 1 : \frac{4}{9\pi^2} : \frac{4}{25\pi^2} : \frac{4}{49\pi^2}}$$

## ★ Diffraction Pattern :-




Δ = Path diff.

In $\triangle ABN$

$$\theta = \sin\theta = \frac{\Delta}{e} \quad \text{---(i)}$$

$$\Delta = e\sin\theta$$

In $\triangle CPO$

$$\tan\theta = \frac{OP}{CO} = y/D$$

$$\tan\theta = y/D \quad \text{---(ii)}$$

When angle is very small

$\sin\theta \approx \tan\theta \approx \theta$

from eq (i) & (ii)

$$\frac{\Delta}{e} = \frac{y}{D}$$

$$\boxed{y = \frac{\Delta D}{e}}$$

<u>for linear Position</u>

**For Destructive (Dark fringe)**

$\Delta = n\lambda$

$$y_n = \frac{n\lambda D}{e}$$

Fringe width

$\beta = y_n - y_{n-1}$

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

**For Constructive (Bright Fring)**

$\Delta = (2n+1)\lambda/2$

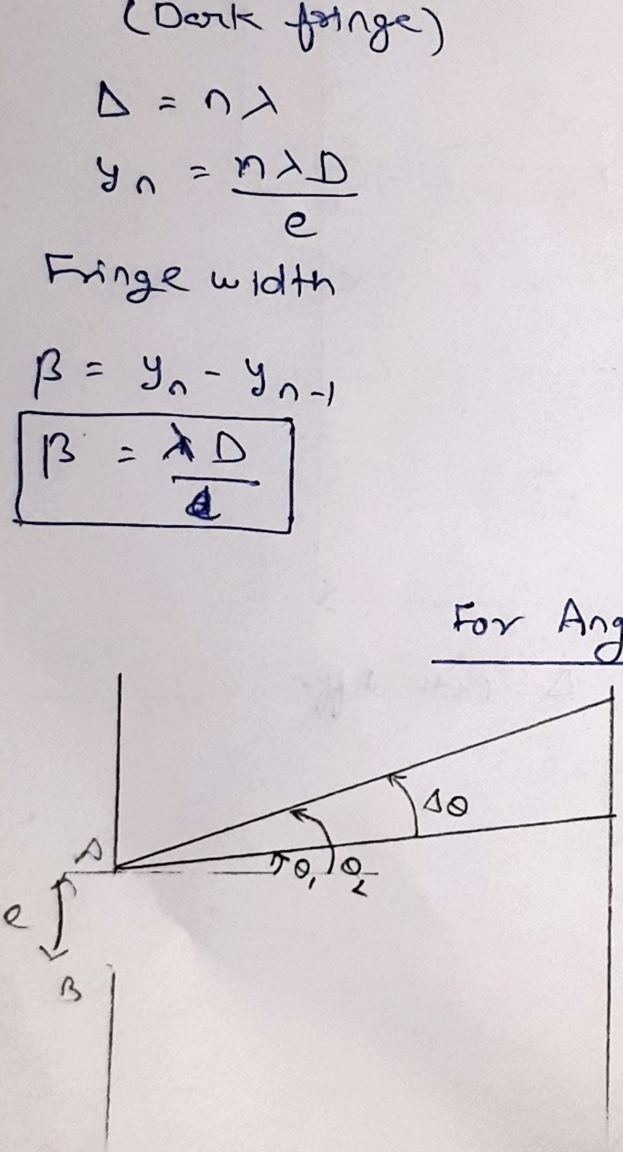
$$y_n = \frac{(2n+1)\lambda D}{2e}$$

Fring width

$\beta = y_n - y_{n-1}$

$$\boxed{\beta = \frac{\lambda D}{e}}$$

<u>For Angular Position</u>




From eq (i)

$\Delta = e\sin\theta$

$$\sin\theta = \frac{\Delta}{e}$$

When angle is very small

$$\boxed{\theta = \frac{\Delta}{e}}$$ Path diff

# Angular Position

**For Dark**

$\Delta = n\lambda$

$\theta_n = \dfrac{n\lambda}{e}$

Angular width

$\Delta\theta = \theta_n - \theta_{n-1}$

$$\boxed{\Delta\theta = \frac{\lambda}{e}}$$

**For Bright**

$\Delta = (2n+1)\lambda/2$

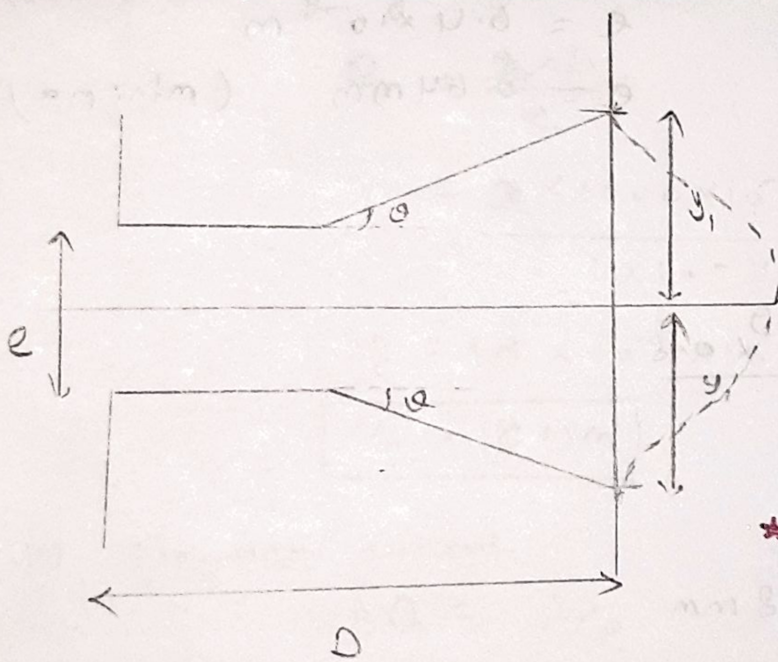
$\theta_n = \dfrac{(2n+1)\lambda}{2e}$

Angular width

$\Delta\theta = \theta_n - \theta_{n-1}$

$$\boxed{\Delta\theta = \lambda/e}$$

## * Width of central maxima :-




for fringe width

$\beta = y_1 + y_2$

$\beta = 2y_1$

$$\boxed{\beta_c = \frac{2\lambda D}{e}}$$

for angular width

$$\boxed{\Delta\theta = \frac{2\lambda}{e}}$$

Q 1 A parallel beam of light of wavelength 6000 nm is incident normally on a slit of width 'e'. If the distance between slit and screen is 0.8 m and the distance of second order maxima for the centre of the screen is ~~which~~ 15 mm, calculate the width of slit.

Sol$^n$

Given

$D = 0.8\,m$

$\lambda = 6000\,nm$

$y_2 = 15\,mm$

$$\because y = \frac{n\lambda D}{e}$$

$$15\times10^{-3} = \frac{2\times 6000\times10^{-9}\times 0.8}{e}$$

$$e = \frac{96}{15}\times10^{-4}$$

$$e = 6.4\times10^{-4}\,m$$

$$e = 0.64\,mm.$$ (minima) ✗

$$y_n = \frac{(2n+1)\lambda D}{2e}$$

$$\cancel{15}^{5}\times10^{-3} = \frac{5\times \cancel{6000}^{2}\times10^{-9}\times 0.8}{2\;e}$$

$$e = \frac{1.6}{2}\times10^{-3}$$

$$e = 0.8\times10^{-3} = 0.8\,mm$$

Q Yellow light ($\lambda = 6000 \mathring{A}$) illuminates a single slit of width $1 \times 10^{-4}$ m. Calculate -

(i) The distance between the two dark lines on either side of the central maxima, when the diffraction pattern is viewed on a screen kept 1.5 m away from the slit.

(ii) The angular spread of the first diffraction minima.

Sol^n Given $D = 1.5$ m
$\lambda = 6000 \mathring{A}$
$e = 1 \times 10^{-4}$ m

(i) dark fringe width

$$\beta_c = \frac{2\lambda D}{e}$$

$$Y_c = \frac{2 \times 6000 \times 10^{-10} \times 1.5}{1 \times 10^{-4}}$$

$$Y_c = 18 \times 10^{-7} \times 10^{+4}$$

$$\boxed{Y_c = 18 \text{ mm}}$$

(ii) Angular width

$$\Delta\theta = \lambda / e$$

$$\Delta\theta = \frac{6000 \times 10^{-10}}{1 \times 10^{-4}}$$

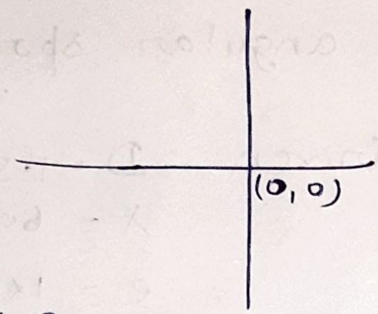
$$\Delta\theta = 6 \text{ m(Rad)Ans}$$

Q3 Monochromatic light of wavelength 5890 Å is incident Normally on a slit of width 0.003 mm. Find the ~~the~~ angular position of first and second minima in diffraction Pattern of a slit.

Solⁿ Given -

$\lambda = 5890$ Å $\qquad \Delta\theta_1 = ? \qquad \Delta\theta_2 = ?$

$e = 0.003 mm$



let

$$\sin\theta_1 = \frac{n\lambda}{e} \qquad \theta_2 = \frac{2\lambda}{e}$$

$$\sin\theta_1 = \frac{5890\times10^{-10}}{3\times10^{-6}} \qquad \sin\theta_2 = 2\times\theta_1$$

$$\sin\theta_2 = 0.392\ \cancel{rad}$$

$$\sin\theta_1 = 1963.3\times10^{-4}$$

~~Sin θ.~~

$$\sin\theta_1 = 0.196\ \cancel{rad}.$$

$$\theta_2 = \sin^{-1}(0.392)$$

$$\theta_1 = \sin^{-1}(0.196) \qquad \theta_2 = 23.07\ rad$$

$$\theta_1 = 11.303\ rad$$