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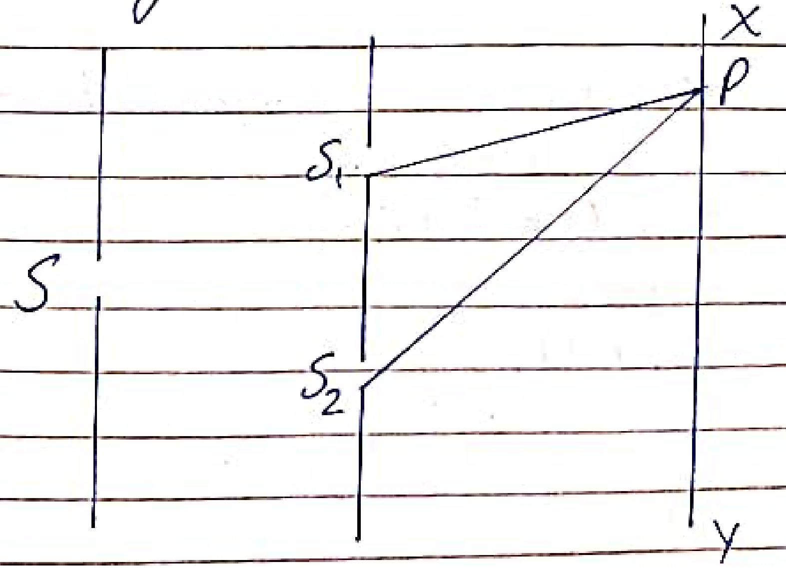
18 Nov

* Interference - Change in the Intensity of waves forming pattern on superposition.
⇒ Redistribution of energies of light waves when they superimpose and it results in formation of constructive and destructive pattern known as Interference pattern.

Constructive	Destructive
1) Intensity increase	Intensity decrease
2) In-phase superimposition of light waves.	Out of phase
3) Amplitude is more.	Amplitude is less.

* Interference Derivation:- Source of light S_0 is placed in front of a slit A which is placed ahead of two slits S_1 & S_2. Interference pattern can be observed at the screen xy.
Let a_1 & a_2 be the amplitude of the waves coming from S_1 & S_2. The equation of waves coming from S_1 & S_2 are given as.

$$y_1 = a_1 \sin(\omega t) \quad \text{--- (1)}$$
$$y_2 = a_1 \sin(\omega t + \delta) \quad \text{--- (2)}$$



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The waves y_1 & y_2 superimpose to form the interference pattern on the xy. The eq. of the resultant wave is given as $y = y_1 + y_2$

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

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

$$y = (a_1 + a_2 \cos\delta) \sin\omega t + a_2 \sin\delta \cos\omega t \quad \text{—— (3)}$$

Let $(a_1 + a_2 \cos\delta) = R\cos\theta$ — (4)

$(a_2 \sin\delta) = R\sin\theta$ — (5)

Lets substitute 4 + 5 into 3

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

$$* \boxed{y = R\sin(\omega t + \theta)}$$

sq. and adding 4 + 5

$$(a_2 \sin\delta)^2 + (a_1 + a_2 \cos\delta)^2 = R^2 \cos^2\theta + R^2 \sin^2\theta$$

$$* R^2 = a_1^2 + a_2^2 + 2a_1 a_2 \cos\delta \quad \text{—— (6)}$$

eq 6 in terms of intensity

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cos\delta \quad \text{—— (7)}$$

where $I_1 = a_1^2$ & $I_2 = a_2^2$

$\delta \rightarrow$ phase diff b/w two rays reaching from S_1 & S_2

path diff $= S_2P - S_1P$

Case I - $\cos\delta = 1$ [Bright Fringe]

$\delta = 2n\pi \quad (n = 0, 1, 2 \ldots)$

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

$$\boxed{I = (\sqrt{I_1} + \sqrt{I_2})^2}$$

$$\Rightarrow \delta = \frac{2\pi}{\lambda}(S_2P - S_1P)$$

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$$2n\pi = \frac{2\pi}{\lambda}(S_2P - S_1P)$$

$$\boxed{n\lambda = (S_2P - S_1P)}$$

path diff

Case II - $\cos\delta = -1$ [Dark Fringe]

$\delta = (2n+1)\pi$ $(n = 0, 1, 2 \ldots)$

$$\boxed{I = (\sqrt{I_1} - \sqrt{I_2})^2}$$

$$\boxed{S_2P - S_1P = (2n+1)\frac{\lambda}{2}}$$

Special cases

$I_1 = I_2$ or $a_1 = a_2$

$\cos\delta = 1$ | $\cos\delta = -1$

$I = 4I_1 = 4a_1^2$ | $I = 0$

20 Nov

* Coherent Sources - Two sources are coherent when they have same frequency and the constant phase diff b/w them.

Q How to obtain interference pattern.

Ans 1) Division of wavefront - A wavefront from a source is divided into two equal parts and are made to travel unequal distances.

2) Division of Amplitude - The amplitude of the beam is divided into two equal parts either by reflection or refraction.
Two parts travel different paths and interfere.
eg- Newton rings, Michelson interferometer.

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Q What are the condition for observing a sustained interference pattern?

Ans 1. The two sources should be coherent
2. Same amplitude
3. d should be as small as possible as it is in denominator.
4. D should be as large as possible as it is multiplied by λ (in nm).

⇒ Case II - Dark

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

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

$$\boxed{y_n = \frac{(2n+1)\lambda D}{4d} = \left(n+\frac{1}{2}\right)\frac{\lambda D}{2d}}$$

y gives the position of n^{th} dark fringe from center of screen.

Q Find the width of dark fringe in I P?

Ans
$$y_{n+1} - y_n = \left(n+\frac{3}{2} - n - \frac{1}{2}\right)\frac{\lambda D}{2d}$$

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

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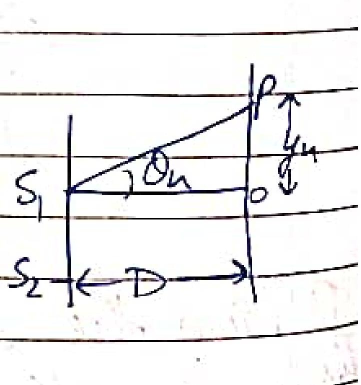
* Angular width of the fringe



Since θ is very small

$$\tan\theta_n \approx \theta_n = \frac{y_n}{D}$$

∴ angular fringe width, $\beta_n = \theta_{n+1} - \theta_n$

$$= \frac{y_{n+1}}{D} - \frac{y_n}{D} = \frac{1}{D}[y_{n+1} - y_n] = \frac{1}{D}\left(\frac{\lambda D}{2d}\right) = \frac{\lambda}{2d}$$ angular fringe width

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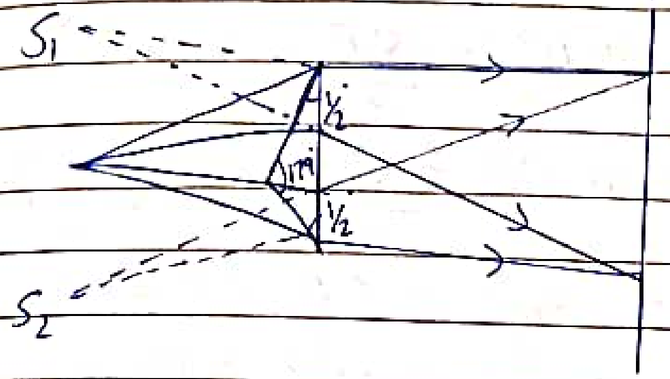
* Fresnel's Biprism

A Biprism is a single prism which has one angle obtuse. $\beta = \frac{\lambda D}{2d}$



Application:

1. Using this formula, wavelength of the light could be measured.

Q What will happen to the IP if white light is used in YDSE or fresnel's Biprism?

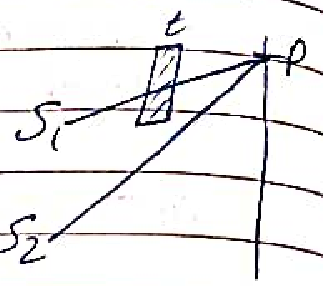
Ans White light would split in VIBGYOR pattern.

- Central fringe would be white as all the 7 colour would have their center of interference same. All rays would have maxima at center.
- Each wavelength will have its own ~~inf~~ interference P.
- Fringe width would depend upon λ.

Q What will happen to the fringe pattern and fringe width if a plate of thickness 't' and RI $=\mu$ is introduced in the path of one of the rays in the Young's double slit experiment?

Ans

Ans ⇒ The effective difference in time travelled by the rays S_1P & S_2P is



$$= \frac{(S_1P - t)}{c} + \frac{t}{v} - \frac{S_2P}{c}$$

$$= \left(\frac{S_1P - t}{c}\right) + \frac{\mu t}{v} - \frac{S_2P}{c}$$

$$= \frac{S_1P}{c} + \frac{(\mu-1)t}{c} - \frac{S_2P}{c} = \frac{S_1P - S_2P + (\mu+1)t}{c}$$

Path diff. b/w the rays $= S_1P - S_2P + (\mu-1)t$

$$= \frac{2dy_n}{D} + (\mu-1)t$$

[from YDSE]

① Position of Maxima

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

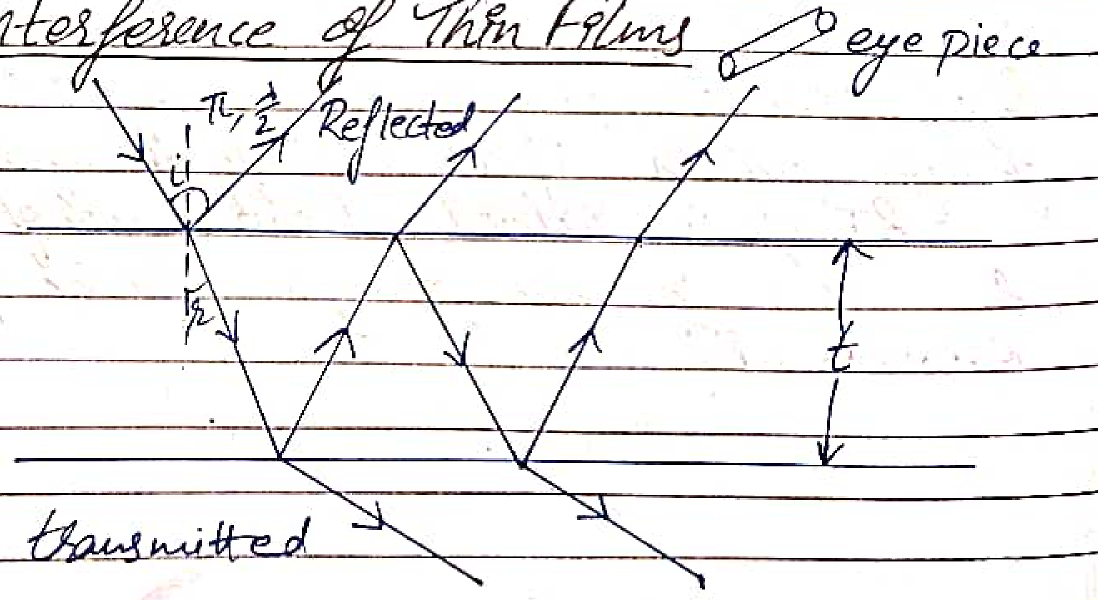
$$y_n = \frac{n\lambda D}{2d} + \frac{(\mu-1)tD}{2d}$$

② Fringe width $y_{n+1} - y_n = \frac{(n+1)\lambda D}{2d} + \cancel{\frac{(\mu-1)tD}{2d}} - \frac{n\lambda D}{2d} - \cancel{\frac{(\mu-1)tD}{2d}}$.

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

Introducing the plane will not change the fringe width it would change the fringe pattern

✱ <u>Interference of Thin Films</u>



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The thin film give rise to two Interference pattern.
1) Reflected IP 2) Transmitted IP

Reflected IP - This IP is Produced by the reflected light which is reflected from the top & bottom of the thin film.
In the reflected system the Stroke's treatment should be applied to the rays reflected from the top of the film, because they are reflected on a denser medium.

Stroke's Treatment - A path diff of $\lambda/2$ or phase diff of π is introduced in the reflected light if it got reflected on the denser medium.

Transmitted IP -
1. Interference pattern from the Transmitted light.
2. No stroke's treatment is required no reflection from denser medium.

* Because of stroke's treatment in reflecting system is complimentary to the transmitted system pattern.

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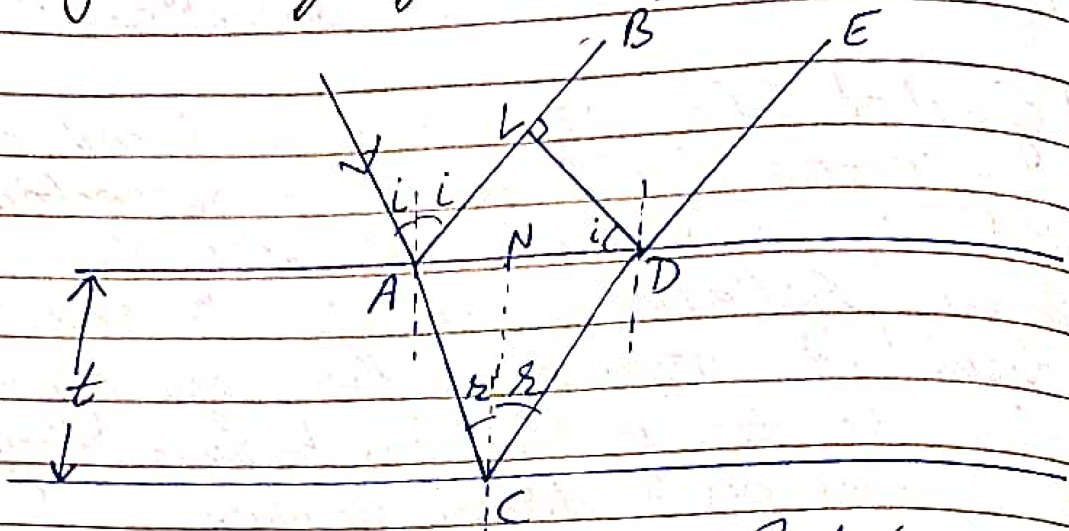
* Interference by Reflected light



Draw DL ⊥ on AD $\qquad 2\mu t\cos r = n\lambda$

The path diff b/w the rays AB and DE

Path diff = (AC+CD) in film − AL in air
$= \mu(AC+CD) - AL$

In ΔACN, $\cos r = \frac{t}{AC} \Rightarrow AC = \frac{t}{\cos r}$

Ily $CD = \frac{t}{\cos r}$

From ΔALD, $\frac{AL}{AD} = \sin i \Rightarrow AL = AD\sin i$
$= (AN+ND)\sin i$
$= (t\tan r + t\tan r)\sin i$
$= 2t\tan r\sin i$

Path diff $= \mu\left(\frac{2t}{\cos r}\right) - 2t\tan r\sin i$

$= \mu\left(\frac{2t}{\cos r}\right) - 2t\frac{\sin r\,\mu\sin r}{\cos r}$ $\qquad \left[\mu = \frac{\sin i}{\sin r}\right]$

$= \frac{2\mu t}{\cos r}(1-\sin^2 r)$

$= \frac{2\mu t}{\cos r}\cos^2 r = 2\mu t\cos r$

using Stroke's treatment on AB

$$\text{Path diff} = 2\mu t \cos r - \frac{\lambda}{2}$$

Maxima-

$$2\mu t \cos r - \frac{\lambda}{2} = n\lambda$$

$$2\mu t \cos r = (2n+1)\frac{\lambda}{2} \qquad n = 0, 1, 2 \ldots$$

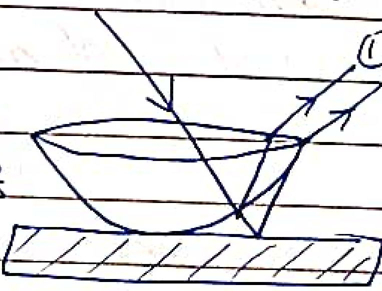
Minima-

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

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

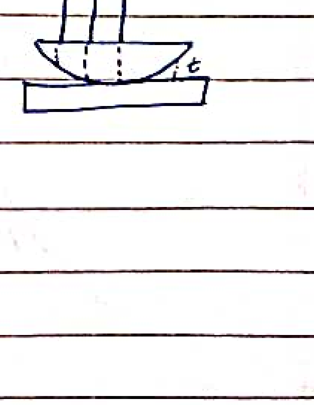
* Interference pattern by using Newton Rings Exp.

plano-convex lens is placed on a glass surface forming an air film in b/w them.
The locus of equal thickness in air film is circular ∴ Interference pattern is circular in nature.



Path difference b/w the rays ① & ②

$$\text{Path diff} = 2\mu t \cos r + \frac{\lambda}{2}$$



In newton rings exp. $r = 0$

$$\therefore \text{path diff} = 2\mu t + \frac{\lambda}{2}$$

for minima:

$$2\mu t + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$$

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

center fringe in reflected system is dark
" " " transmitted " is bright

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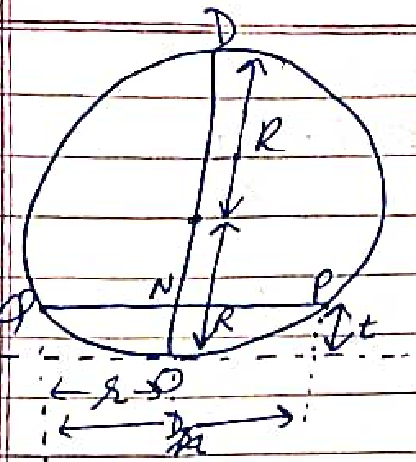
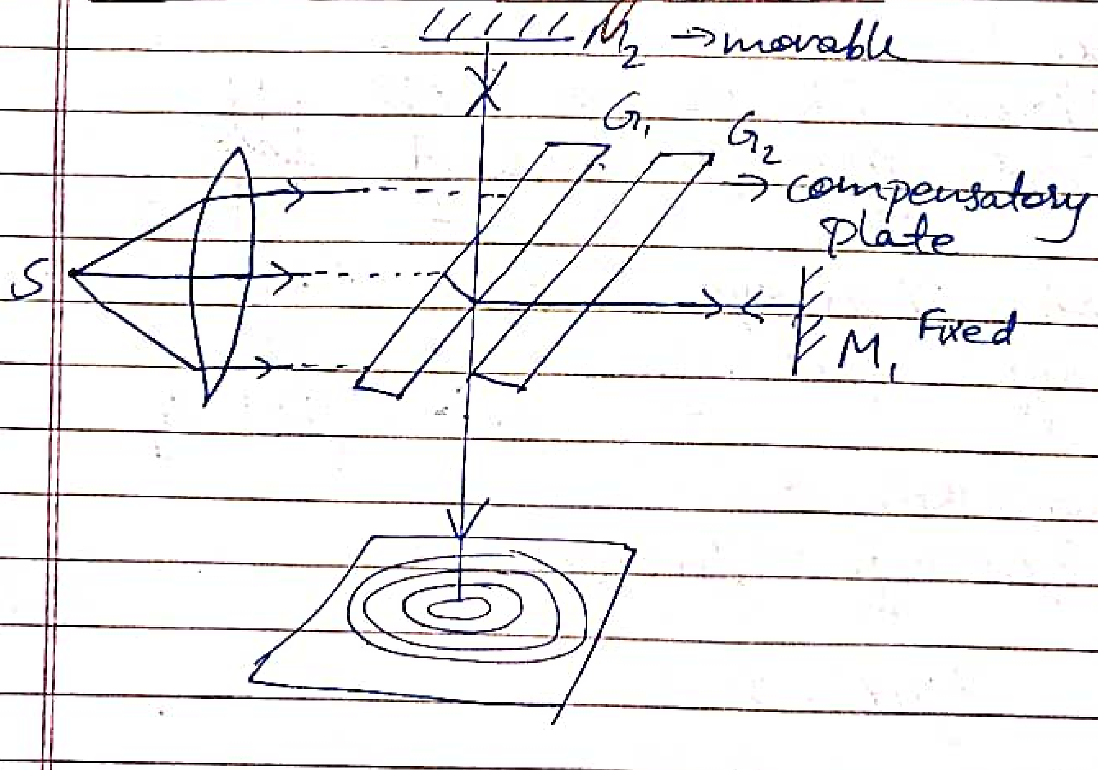


By prop. of circle
$ND \times ON = QN \times NP$
$(2R-t)(t) = r \times r$
$r^2 = 2Rt - t^2$
$r^2 \simeq 2Rt$ [as t is very small]
multiply both sides by 4
for minima rings
$r^2 = R(n\lambda)$ [μ is 1 for air]
$4r^2 = 4R(n\lambda)$
$\boxed{d_n^2 = 4nR\lambda}$

* For any liquid with RI μ $D_n^2 = \frac{4nR\lambda}{\mu}$.

Application
1. To find λ of any unknown source.
2. Find the μ of unknown liquid.

* Michelson's Interfermeter -



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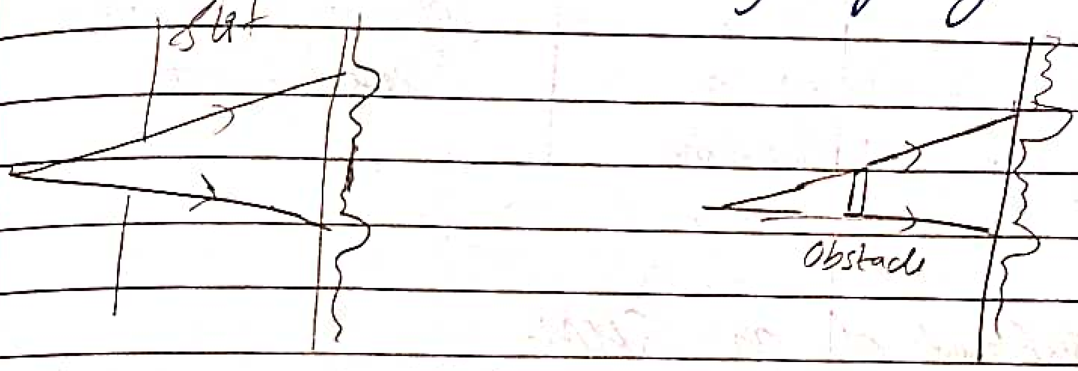
let us assume mirror M_2 is moved by dist. d
∴ path diff introduced will be 2t

IDP

Diffraction :

* The phenomenon of departure of light from its linear path is called as diffraction.
The necessary condition for diffraction around an obstacle or slit is that its size should be comparable to the wavelength of light.



It is observed that if the size of the obstacle or aperture is of the order of light there is a fringe pattern observed on the screen near the edges of shadow.

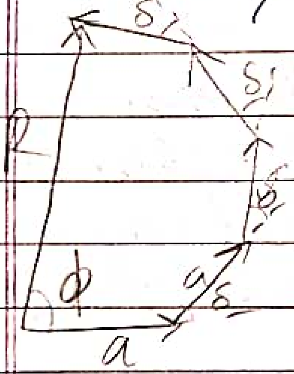
Difference b/w Interference & Diffraction

Diffraction	Interference
1. Occur b/w the secondary wavelets originating from diff. parts of exposed wavefront.	Occur b/w two seperate wavefront emerging from two coherent source
2. Maximas on both side of central Maxima dec. in intensity gradually.	Maxima are of equal intensity
3. Minimas are not perfectly dark.	Minimas are perfectly dark.
4. fringes are not equally spaced.	All the fringes are equally spaced

* Fraunhaufer	Fresnel
1. Incident wavefront is plane wavefront.	Incident wavefront is spherical or cylindrical.
2. Source is considered at infinity or convex lens is used in b/w source & diffracting device [source at F of lens]	Source is at finite dist. from the diffracting device.
3. The diffracting light is collected using a convex lens before the screen [screen is to be considered at infinite dist].	Screen is at finite dist. from the diffracting device.
4. Diffracting device is a single, double or a diffracting grating plate.	Diffracting device is Fresnel zone plate

* Resultant of n SHMs.

Let n SH vibration of equal amplitude a and equal phase diff. of δ act upon a particle simultaneously. Let R be the resultant amplitude and ϕ be the resultant phase.



$$R\cos\phi = a + a\cos\delta + a\cos2\delta \dots \quad (1)$$

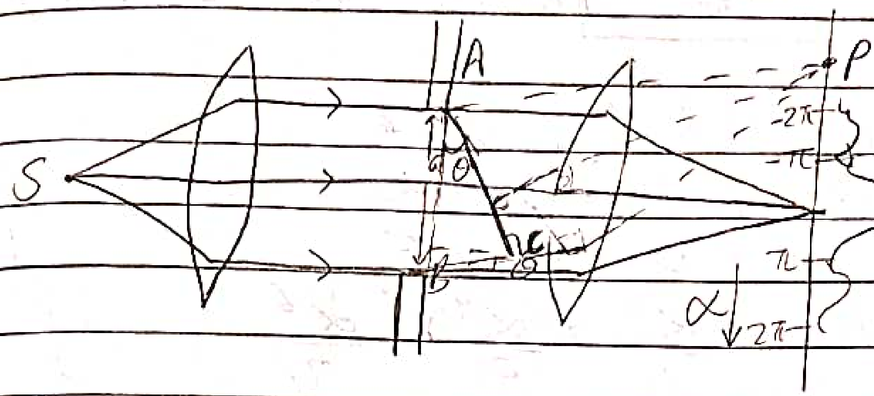
$$R\sin\phi = 0 + a\sin\delta + a\sin2\delta \dots \quad (2)$$

solving (1) & (2)

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

12 Dec

* Fraunhaufer Diffraction at a single slit
Consider a plane wavefront falling on a slit AB each pt. on the incident wavefront acts as a source of secondary disturbance / wavelets. Let the width of slit be 'a', which is comparable to the wavelength of light.



Consider a pt. P at an angle θ from the center of the slit. Draw AC ⊥ on BC
The path diff b/w extreme rays = BC
$= a \sin\theta$

$$\text{Phase diff} = \frac{2\pi}{\lambda}(a\sin\theta)$$

Let us divide slit AB in n secondary wavelets.
The phase diff b/w the 2 consecutive wavelets =

$$= \frac{2\pi}{n\lambda}(a\sin\theta) \Big\} \delta$$

The Resultant is given as

$$R = a' \frac{\sin n\delta/2}{\sin \delta/2}$$ [using relation from SHM]

(a' is given as α is already used)

$$R = a' \frac{\sin\left(\frac{\pi a}{\lambda}\sin\theta\right)}{\sin\left(\frac{\pi a}{n\lambda}\sin\theta\right)} \quad \text{--- (1)}$$

Let us assume $\alpha = \frac{\pi a}{\lambda}\sin\theta$

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$\therefore$ eq(1) becomes $R = \dfrac{a' \sin\alpha}{\sin\left(\frac{\alpha}{n}\right)}$

$\simeq \dfrac{a' \sin\alpha}{\alpha/n}$ [as n is very large, α/n is very small]

$\simeq \dfrac{n a' \sin\alpha}{\alpha}$

Amplitude

* $\boxed{R = A \dfrac{\sin\alpha}{\alpha}}$ —— (2) where $\alpha = \dfrac{\pi a}{\lambda} \sin\theta$ (slit width)

* Position of central maxima

$$R = \frac{A}{\alpha}\left[\alpha - \frac{\alpha^3}{3!} + \frac{\alpha^5}{5!} - \frac{\alpha^7}{7!} \ldots\right]$$

$$R = A\left[1 - \frac{\alpha^2}{3!} + \frac{\alpha^4}{5!} - \frac{\alpha^6}{7!} \ldots\right]$$

R is maximum when $\alpha = 0$

$R = A \Rightarrow I = R^2 = A^2$ for central/Principal maxima.

$\dfrac{\pi a}{\lambda} \sin\theta = 0 \quad \Rightarrow \sin\theta = 0$

$\theta = 0°$

* Position of minimum intensities

I is minimum when $\sin\alpha = 0$ & $\alpha \neq 0$

$\alpha = \pm n\pi \quad [n \neq 0]$

$\dfrac{\pi a}{\lambda} \sin\theta = \pm n\pi$

$$\boxed{a \sin\theta = \pm n\lambda}$$

* Position of Secondary Maxima

$$I = \frac{A^2 \sin^2\alpha}{\alpha^2} \quad \text{—— (3)}$$

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differentiating eq ③

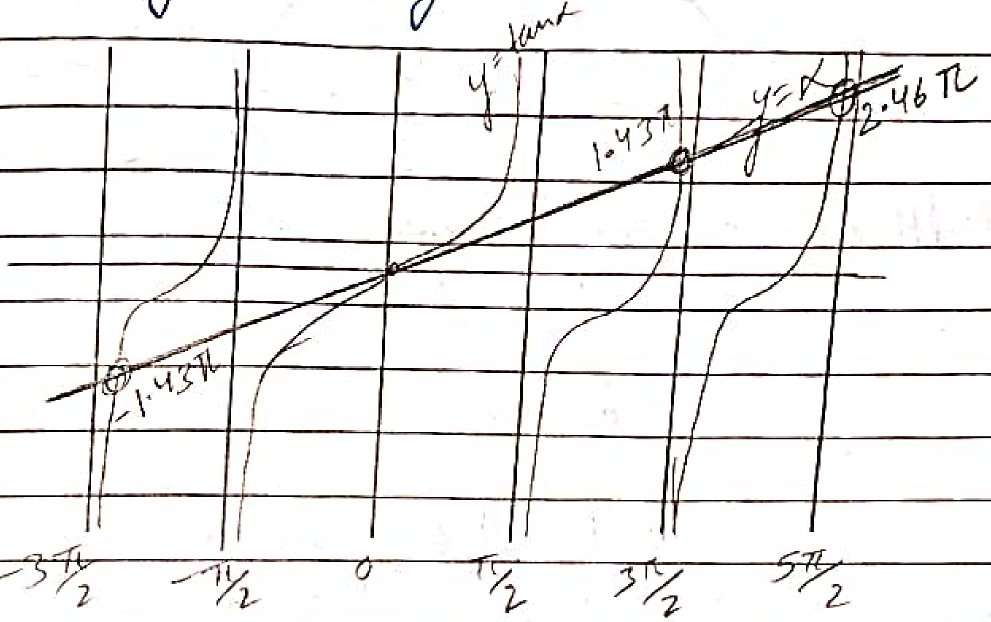
$$\frac{dI}{d\alpha} = A^2 \frac{d}{d\alpha}\left[\frac{\sin^2\alpha}{\alpha^2}\right] = 0$$

$$\Rightarrow A^2 \left[\frac{2\sin\alpha}{\alpha}\right]\left[\frac{\alpha\cos\alpha - \sin\alpha}{\alpha^2}\right] = 0$$

either $\sin\alpha = 0$ or $\alpha\cos\alpha = \sin\alpha$
these are minimas
or $\alpha = \tan\alpha$

∴ Position of secondary maxima is given by $\alpha = \tan\alpha$
using graphical method of find solⁿ of α.

$y = \alpha$ & $y = \tan\alpha$



Therefore position of secondary maxima are

$= \pm 1.43\pi, \pm 2.46\pi \ldots\ldots$

$\simeq \pm 1.5\pi, \pm 2.5\pi \simeq \pm \frac{3}{2}\pi, \pm\frac{5}{2}\pi$

$\alpha \simeq \pm(2n+1)\frac{\pi}{2}$

* Ratio of Intensities → $I = A^2 \frac{\sin^2\alpha}{\alpha^2}$

Intensity of principle maxima, $\boxed{I = A^2}$

" " 1st secon. " $I_1 = A^2 \frac{\sin^2 \frac{3\pi}{2}}{\left(\frac{3\pi}{2}\right)^2} = \cancel{\frac{4A^2 \sin^2\left(\frac{3\pi}{2}\right)}{9\pi^2}}$

$= \frac{4A^2}{9\pi^2}$

Intensity of II maxima, $I_2 = \frac{A^2 \sin^2\left(\frac{5\pi}{4}\right)}{\left(\frac{5\pi}{4}\right)^2} = \frac{16A^2 \sin^2\left(\frac{5\pi}{4}\right)}{25\pi^2}$

$= \frac{4A^2}{25\pi^2}$

$\frac{I_1}{I_0} = \frac{4}{9\pi^2} = 4.5\%$

$\frac{I_2}{I_0} = \frac{4}{25\pi^2} = 1.61\%$

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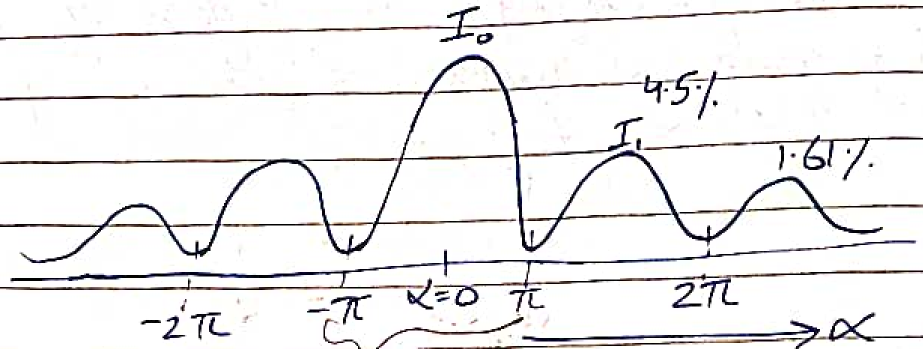
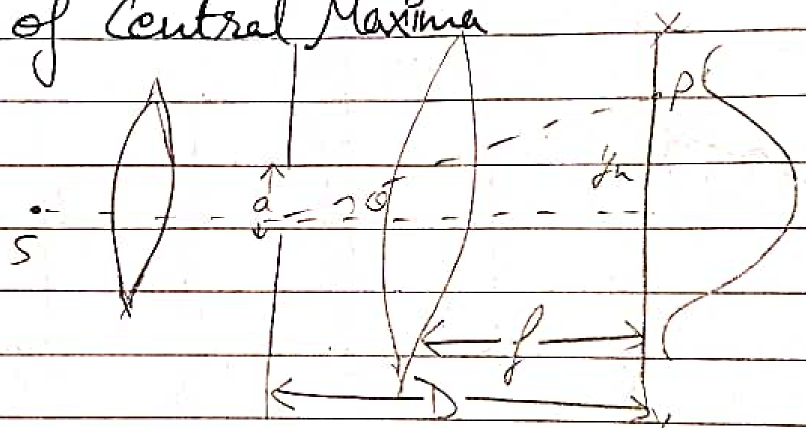


* Width of Central Maxima



For the first minima : $\alpha = \pm\pi$

$\frac{\pi a}{\lambda} \sin\theta = \pm\pi$

$\boxed{\sin\theta = \pm\frac{\lambda}{a}}$ — (1)

$\sin\theta = \frac{y_n}{D} \approx \frac{y_n}{f}$

$\frac{y_n}{f} = \frac{\lambda}{a} \Rightarrow \boxed{y_n = \frac{\lambda f}{a}}$

$\Rightarrow$ thickness central maxima $= \boxed{\frac{2\lambda f}{a}}$

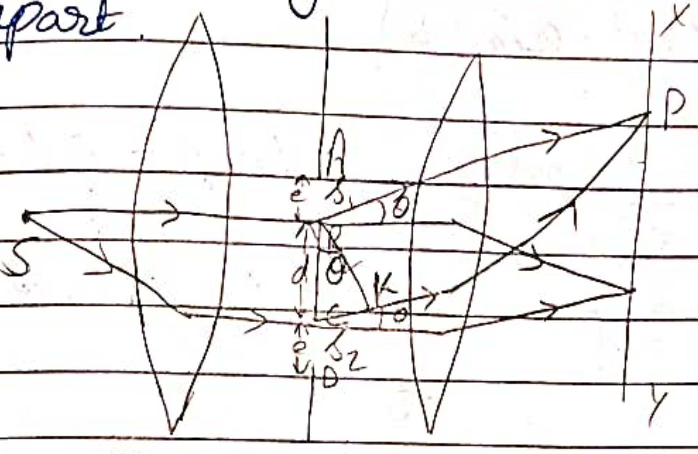
Q) Discuss the effect of λ and slit width on the central maxima?

Ans $\quad$ thickness $\propto \frac{1}{a}$

thickness $\propto \lambda$

* Diffraction from double Slit

Let S be the source and AB & CD be two slits of width 'e' and dist 'd' apart.



A parallel beam of monochromatic light of wavelength 'λ' fall on the slit and the pattern is observed on the screen XY.

The pattern is combination of diffraction and interference pattern.

The amplitude of the wave from one of the slits at an angle θ on the screen is given as

$$R = \frac{A \sin\alpha}{\alpha} \quad \text{where } \alpha = \frac{\pi e \sin\theta}{\lambda}$$

draw $BK \perp S_2K$

The path diff b/w two rays from slit S_1 & S_2 is

$= S_2K$

$= (e+d)\sin\theta$

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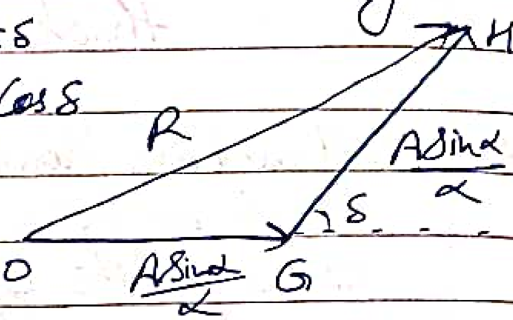
Phase diff, $\delta = \frac{2\pi}{\lambda}(e+d)\sin\theta$

The resultant amplitude are at P is given as

$$R^2 = OG^2 + OH^2 + 2\,OG\cdot OH\cos\delta$$



$$R^2 = \left(\frac{A\sin\alpha}{\alpha}\right)^2 + \left(\frac{A\sin\alpha}{\alpha}\right)^2 + 2\left(\frac{A\sin\alpha}{\alpha}\right)\cos\delta$$

$$R^2 = 2\left(\frac{A\sin\alpha}{\alpha}\right)^2(1+\cos\delta)$$

$$R^2 = 4\left(\frac{A\sin\alpha}{\alpha}\right)^2\left(\cancel{2}\cos^2\frac{\delta}{2}\right)$$

$$\boxed{R^2 = \underbrace{\frac{4A^2\sin^2\alpha}{\alpha^2}}\underbrace{\cos^2\beta}}$$ where $\beta = \frac{\pi}{\lambda}(e+d)\sin\theta$

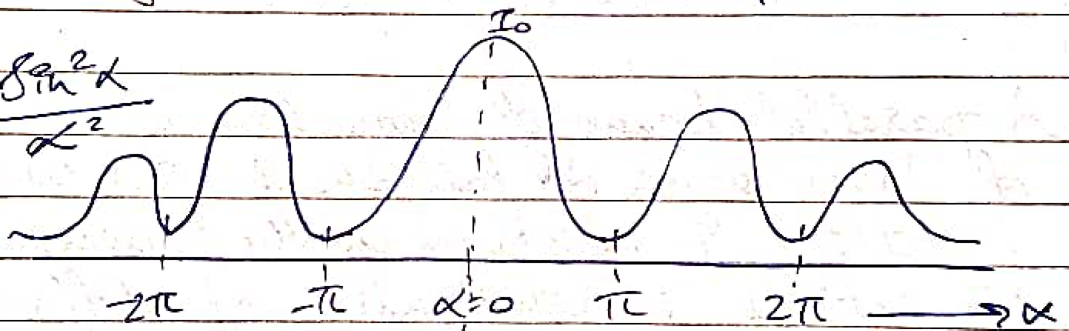
This term governs diffraction pattern

$I = R^2$ intensity at pt. P

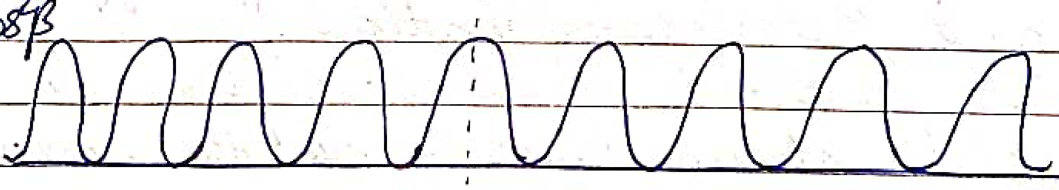
Interference pattern

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

① $\frac{\sin^2\alpha}{\alpha^2}$



② $\cos^2\beta$



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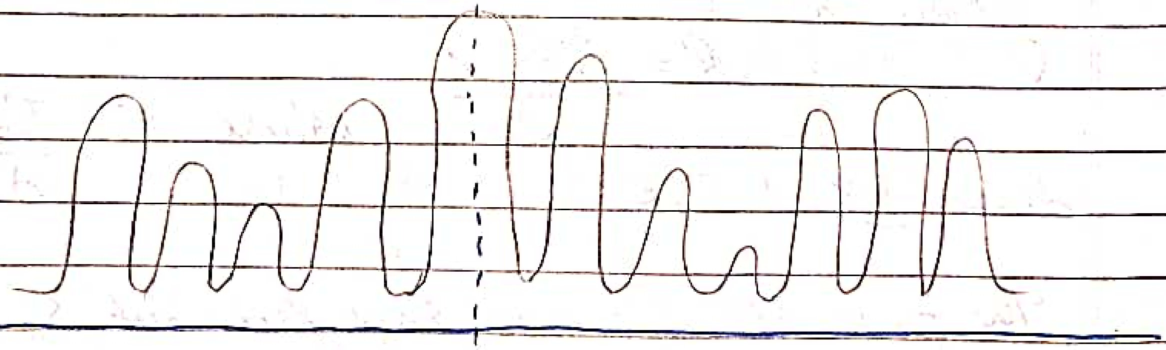

Position of diffraction Minima:- $\sin\alpha = \pm n\pi$

$$\frac{\pi e}{\lambda}\sin\theta = \pm n\pi \quad \text{—(1)}$$

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Order of Interference maxima being absent in the pattern.

position of Interference maxima

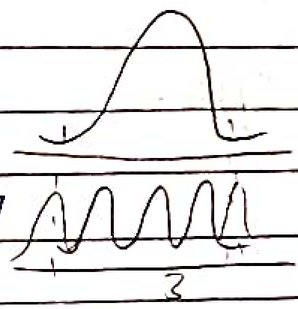
$$\cos\beta = 1$$

$$\beta = \pm m\pi$$

$$\frac{\pi(e+d)\sin\theta}{\lambda} = \pm m\pi \quad \text{—— (2)}$$

Divide (2) by (1)

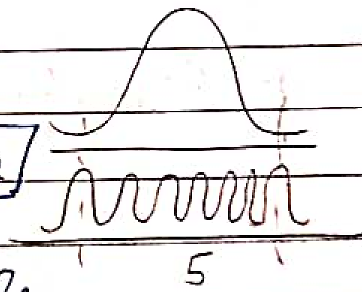
$$\boxed{\frac{e+d}{e} = \frac{m}{n}}$$



Case I: $e = d$

$$\frac{e+e}{e} = \frac{m}{n} \quad \text{or} \quad \boxed{m = 2n}$$

Second maxima band in interference pattern will fall on the first minima of envelope.
therefore 3 interference band will be present inside the central envelope.



Case II $2e = d$

$$\frac{e+2e}{e} = \frac{m}{n} \quad \text{or} \quad \boxed{m = 3n}$$

5 Interference band are present inside central envelope.

Q Discuss the effect of increasing slit width 'e' on the ~~central~~ diffraction pattern.

width of central maxima $= \frac{2\lambda f}{e}$

(1) So the central envelope width would decrease.

(2) No. of band depend on interference pattern.
↳ dec. in envelope

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Q. Discuss the effect of increasing d ?
Solⁿ 1) Interference pattern shrinks and
2) diffraction pattern remain same.

Q. Discuss the effect of increasing λ on pattern?
Solⁿ 1) fringe width inc.
2) envelope size inc
whole diffraction pattern is expand.

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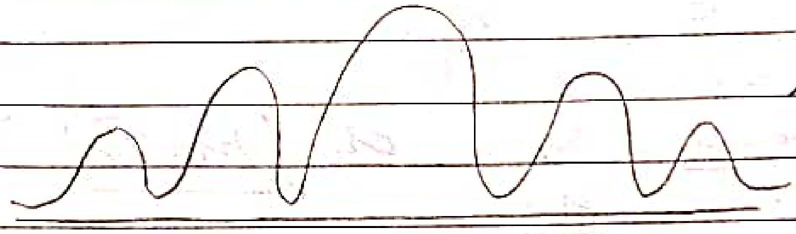
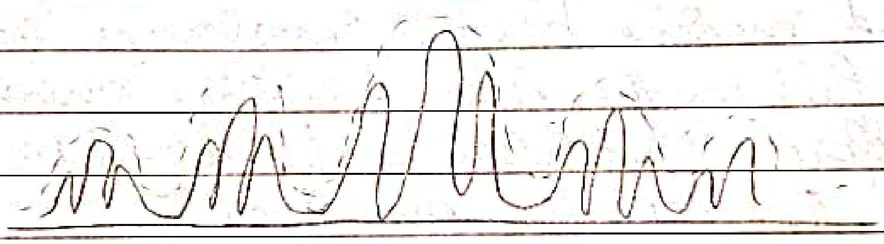
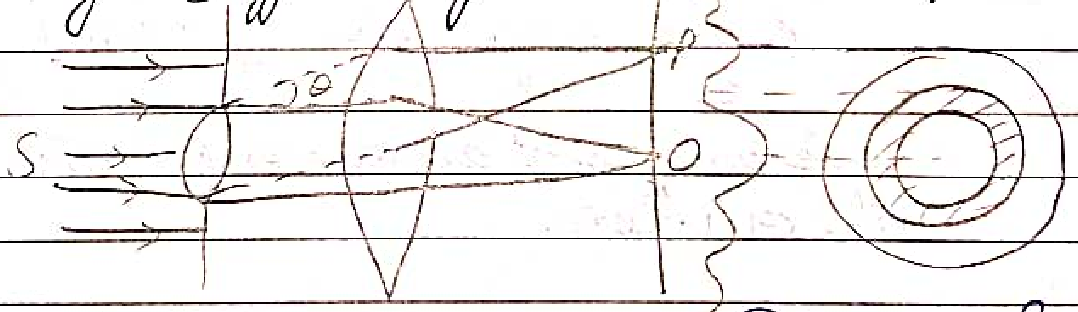




* Fraunhaufer Diffraction from a circular Aperture -



Disc are formed

* Fraunhaufer Diffraction from Diffraction grating element.
An arrangement consisting of large no. of parallel slits of equal width and seperated from each other by equal opague Spaces, is called as diffraction grating

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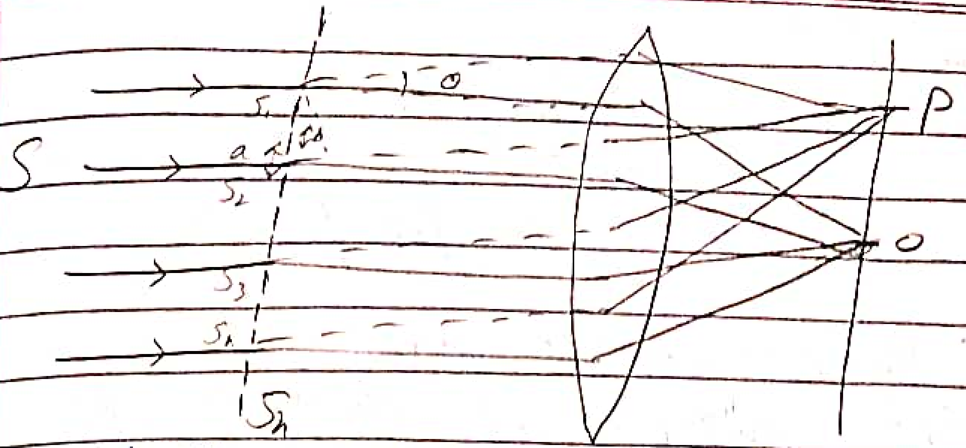


Let the width of the slit be a and opaque dist. be b

The amplitude of wavelets coming from any one to the slit is given as

$$\alpha = \frac{\pi a}{\lambda} \sin\theta$$

Path diff of waves coming from any two consecutive slits is equals to $(a+b)\sin\theta$

$\therefore$ phase diff $= \frac{2\pi}{\lambda}(a+b)\sin\theta$

$$\text{let } 2\beta = \frac{2\pi}{\lambda}(a+b)\sin\theta$$

This is similar to an arrangement of n SHM with phase diff 2β, and amplitude R, therefore resultant amplitude at pt P

$$R' = R\frac{\sin N\beta}{\sin\beta}$$

$$R' = \frac{A\sin\alpha}{\alpha}\frac{\sin N\beta}{\sin\beta} \quad \text{where } \beta = \frac{\pi(a+b)\sin\theta}{\lambda}$$

Therefore intensity at pt P is given as

$$I = \frac{A^2\sin^2\alpha}{\alpha^2}\frac{\sin^2 N\beta}{\sin^2\beta} \quad \text{——— } (3)$$

Maxima of I

I is maximum $\sin\beta \to 0$

$\beta \to n\pi$

But $\sin N\beta \to 0$ for $\beta = n\pi$

$\therefore$ By L'Hospital Rule

$$\lim_{\beta \to n\pi} \frac{\sin N\beta}{\sin\beta} = \lim_{\beta \to n\pi} \frac{\frac{d}{d\beta}(\sin N\beta)}{\frac{d}{d\beta}(\sin\beta)} = \lim_{\beta \to n\pi} \frac{N\cos N\beta}{\cos\beta} = N$$

Substitution in (3)

$$I_{max} = \frac{A^2 \sin^2\alpha}{\alpha^2} N^2$$

Position of maxima $\beta = n\pi$

$$\frac{\pi(a+b)\sin\theta}{\lambda} = \pm n\pi$$

or $\boxed{(a+b)\sin\theta = \pm n\lambda}$

Position of Minima

for minima $\sin N\beta \to 0$

$N\beta = \pm m\pi$

m can take any value except ~~n=0, N, 2N ... nN~~

$m = 0, N, 2N \ldots nN$

$I = 0$

Position of Secondary Maxima

for maxima $\frac{dI}{d\beta} = 0$

$$\Rightarrow \frac{d}{d\beta}\left(\frac{\sin N\beta}{\sin\beta}\right)^2 = 0$$

$$2\frac{\sin N\beta}{\sin\beta}\left(\frac{N\cos N\beta}{\sin^2\beta}\right) = 0$$

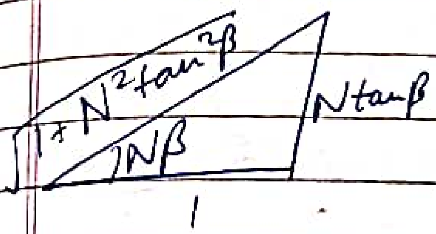
$$N\cos N\beta \sin\beta = \sin N\beta \cos\beta$$

either $\dfrac{\sin N\beta}{\sin\beta} = 0 \rightarrow$ Minima

or $\dfrac{d}{d\beta}\left(\dfrac{\sin N\beta}{\sin\beta}\right) = 0$

$$\boxed{\tan N\beta = N\tan\beta}$$

To determine the solution draw a triangle as shown



$$\sin^2 N\beta = \frac{N^2\tan^2\beta}{\left(\sqrt{1+N^2\tan^2\beta}\right)^2}$$

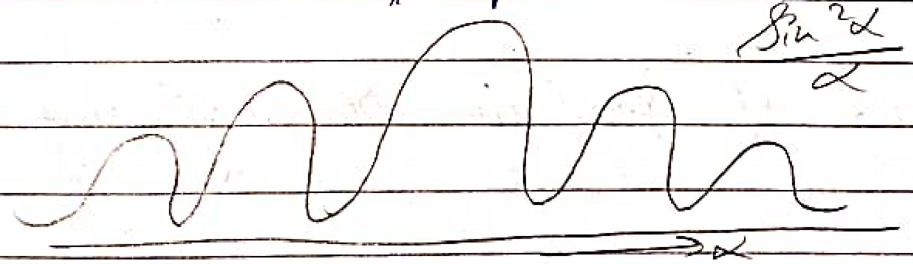
$$\sin^2 N\beta = \frac{N^2}{\cot^2\beta + N^2}$$

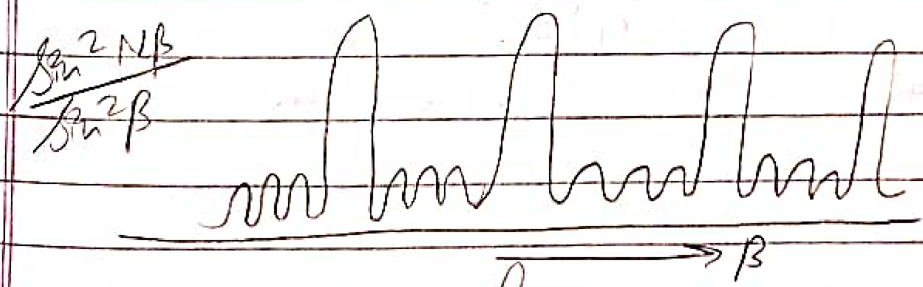
$$\therefore \frac{\sin^2 N\beta}{\sin^2\beta} = \frac{N^2}{(\cot^2\beta + N^2)\sin^2\beta} = \frac{N^2}{\cos^2\beta + N^2\sin^2\beta}$$

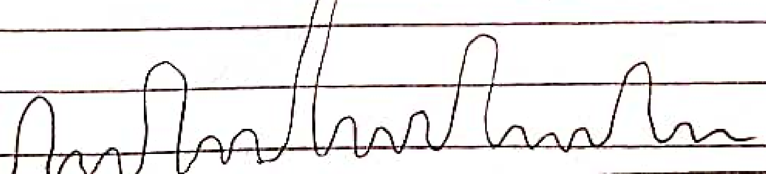
$$= \frac{N^2}{1+(N^2-1)\sin^2\beta}$$

The Ratio of Intensity of secondary Maxima to Principle Maxima.

$$\frac{I}{I_0} = \frac{1}{1+(N^2-1)\sin^2\beta}$$







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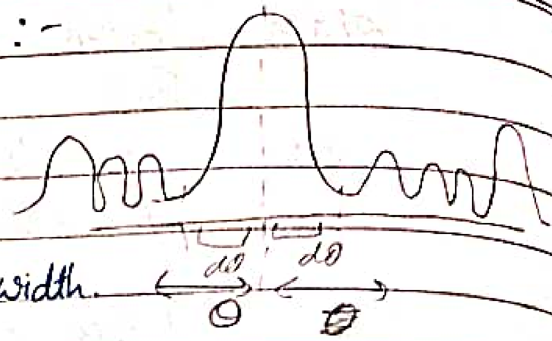
* Width of Principal Maxima :-



For n^{th} order principal maxima

$$(a+b)\sin\theta = n\lambda$$

If $\theta \pm d\theta$ represent position of next minimas, $2d\theta$ will be its width.

$(nN+1)^{th}$

The minima at $\theta + d\theta$ is given as

$$N(a+b)\sin(\theta + d\theta) = (nN+1)\lambda$$

$$N(a+b)(\sin\theta\cos d\theta + \cos\theta\sin d\theta) = (nN+1)\lambda$$

when $d\theta$ is small, $\cos d\theta = 1$, $\sin d\theta \sim d\theta$

$$N(a+b)(\sin\theta + \cos\theta\, d\theta) = nN\lambda + \lambda$$

$$\underline{N(a+b)\sin\theta} + N(a+b)\cos\theta\, d\theta = \underline{nN\lambda} + \lambda$$

$$\Rightarrow \quad N(a+b)\cos\theta\, d\theta = \lambda$$

or $$\boxed{2d\theta = \frac{2\lambda}{N(a+b)\cos\theta}}$$

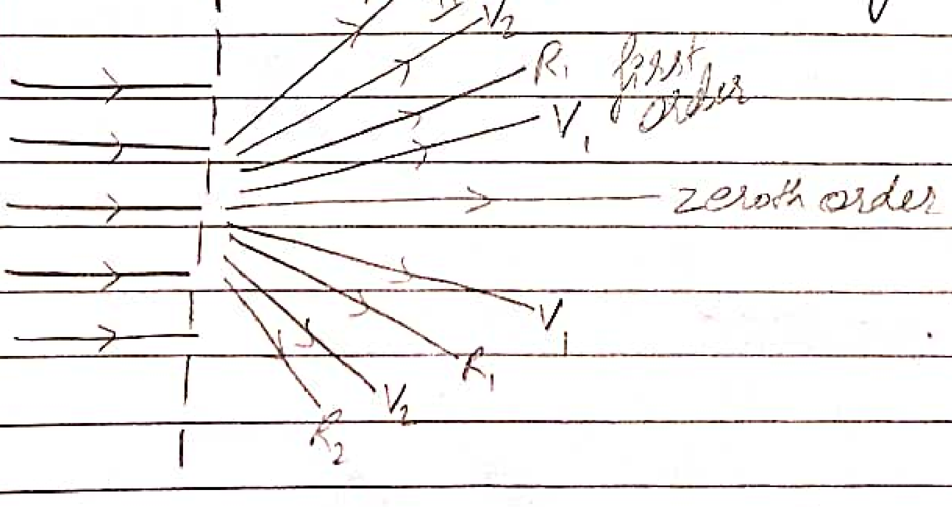
width $\propto \lambda$

$\propto \frac{1}{N}$

$\propto \frac{1}{a+b}$

$\propto \frac{1}{\cos\theta}$

* Formation of Spectrum on a grating



* Order of Absent Spectra in a diffraction grating

The condition of maxima of n^{th} order is

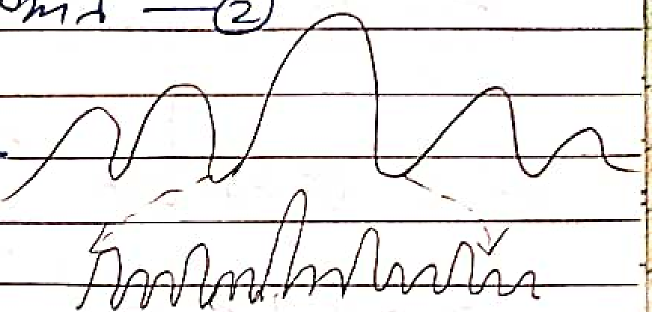
n^{th} maxima $\rightarrow (a+b)\sin\theta = n\lambda$ — ①

Condition of minima for single slit is

$$a\sin\theta = m\lambda \quad \text{— ②}$$

Dividing ① by ②

$$\frac{a+b}{a} = \frac{n}{m}$$



Case I - $a = b$

$n = 2m$

Note - 3 principle maximas will be inside central envelope.

Case II - $b = 2a$

$$\frac{a+2a}{a} = \frac{n}{m}$$

$$n = 3m$$

* Dispersive power of diffraction grating

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

dispersive power is defined as the ratio of change in the angle of diffraction per unit change in wavelength of the incident light.

for n^{th} maxima $(a+b)\sin\theta = n\lambda$ — ①

differentiating wrt λ on both side

$$(a+b)\cos\theta \frac{d\theta}{d\lambda} = n$$

or $$\frac{d\theta}{d\lambda} = \frac{n}{(a+b)\cos\theta} = \omega$$

$\omega \propto n$

$\propto \frac{1}{a+b}$

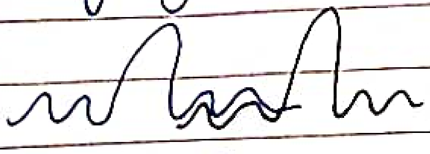
$\propto \frac{1}{\cos\theta}$

* Resolving power of Grating:-

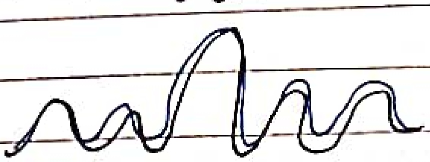
resolution of human eye is 1 minute.

Resolving power is the ability of an instrument to see too closely lined object asseperate.

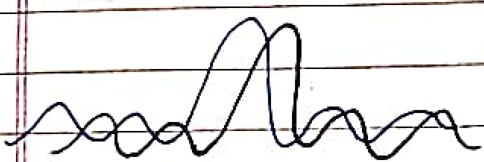
Rayleigh's Criterion of Resolution-



crearly resolved



not resolved



just resolved

According to the Rayleigh's criterion, two wavelengths are said to be just resolved when the central maxima of first wavelength falls on the first minima of the other wavelength.

Let two wavelength be λ, $\lambda + d\lambda$

n^{th} maxima of wavelength $\lambda + d\lambda$

$$(a+b)\sin\theta = n(\lambda + d\lambda) \quad \text{---} ①$$

Adjacent minima of wavelength λ

$$N(a+b)\sin\theta = (nN+1)\lambda \quad \text{---} ②$$

from ① + ②

$$n(\lambda + d\lambda) = \frac{(nN+1)\lambda}{N}$$

$$n\lambda + nd\lambda = \frac{n\cancel{N}\lambda}{\cancel{N}} + \frac{\lambda}{N}$$

$$nd\lambda = \frac{\lambda}{N} \qquad \boxed{\frac{\lambda}{d\lambda} = nN}$$

Resolving power is $\propto N$
$\propto n$

16 Dec
* Polarization of light :-

wave

Longitudinal

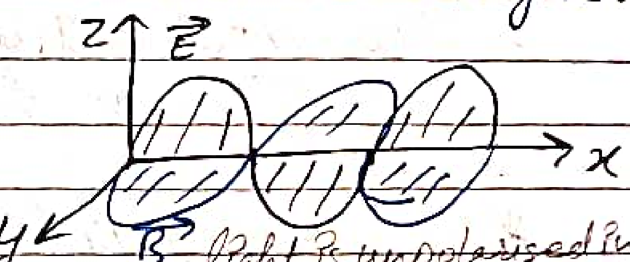
vibrations in medium are in the direction of propagation of wave

Transverse

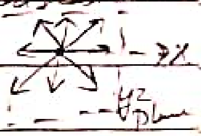
Vibrations are $\perp$ to the direction of propagation of wave

light
↓
EM wave

∴ vibration in E & M fields

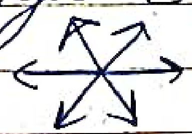


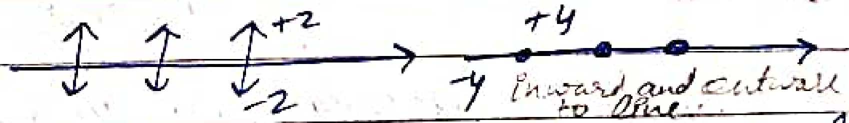
light is unpolarised in yz-plane.



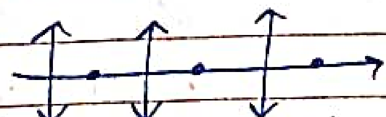
* Unpolarized light - light having vibrations along all possible straight line $\perp$ to the propagation of light is said to be unpolarised.

representation :



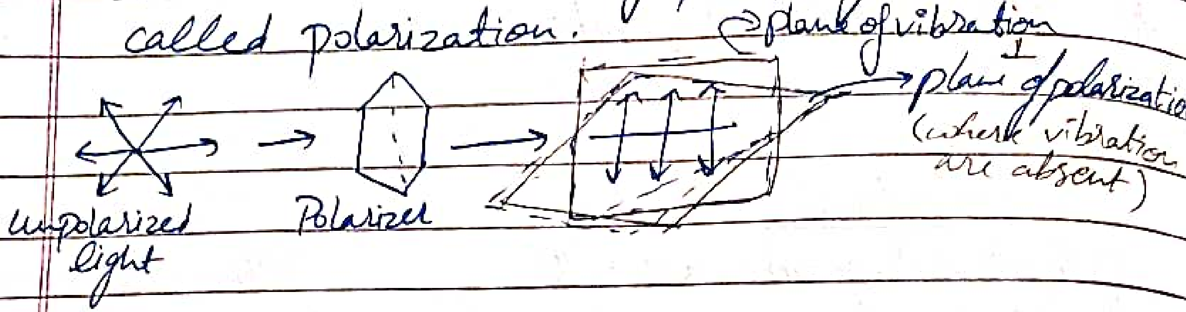


* Polarized light -
The light having vibrations only along a single straight line $\perp$ to the direction of propagation of light, is said to be polarised.



partial polarized.

* Polarization – The phenomenon of constraining the vibration of light in a single direction ⊥ to the direction of propagation, is called polarization.

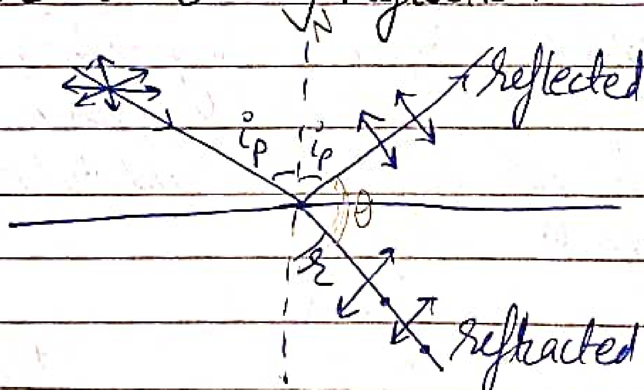


- Plane of vibration – The plane containing the vibration of a polarised light.

- Plane of polarisation – The plane ⊥ to the plane of vibration, having no vibration.

* Method of polarization of light :-

① Polarisation by Reflection –



for glass $i_p = 57°$

When unpolarized light is incident on the surface of any transparent material, the reflected and refracted ray are partially polarised.
For the angle of incident equal to polarizing angle, the reflected light become completely plane polarised while refracted is partially polarised.

According to Brewster's law, the RI of medium is related to polarising angle.

$$\mu = \tan i_p$$

The outcome of brewster's law is that the reflected and refracted rays are ⊥ to each other.

Proof-
To prove = $\theta = 90°$

Given- $\mu = \tan i_p$

$$\mu = \frac{\sin i_p}{\cos i_p} \quad \text{—①}$$

also $$\mu = \frac{\sin i_p}{\sin r} \quad \text{—②}$$

from eq ① + ②

$$\frac{\sin i_p}{\cos i_p} = \frac{\sin i_p}{\sin r}$$

$$\cos i_p = \sin r$$

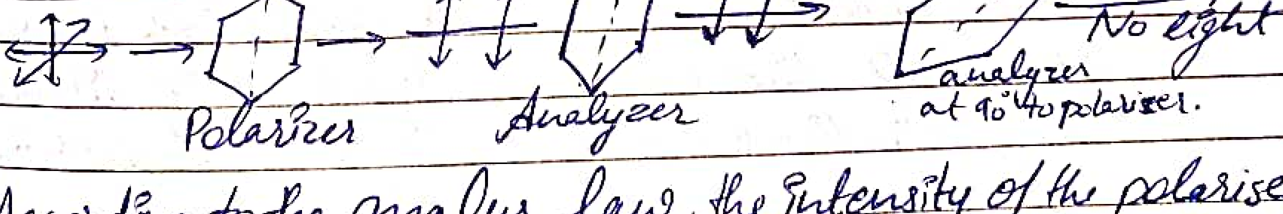
$$\sin(90 - i_p) = \sin r$$

$$r = 90 - i_p \quad \text{or} \quad r + i_p = 90°$$

also, $i_p + \theta + r = 180°$ [at normal]

$$\boxed{\theta = 90°}$$

* Malus law -



According to the malus law, the intensity of the polarised light comming out of the analyzer which is placed after the polarizer at an ∠ θ is given as $I = I_0 \cos^2\theta$

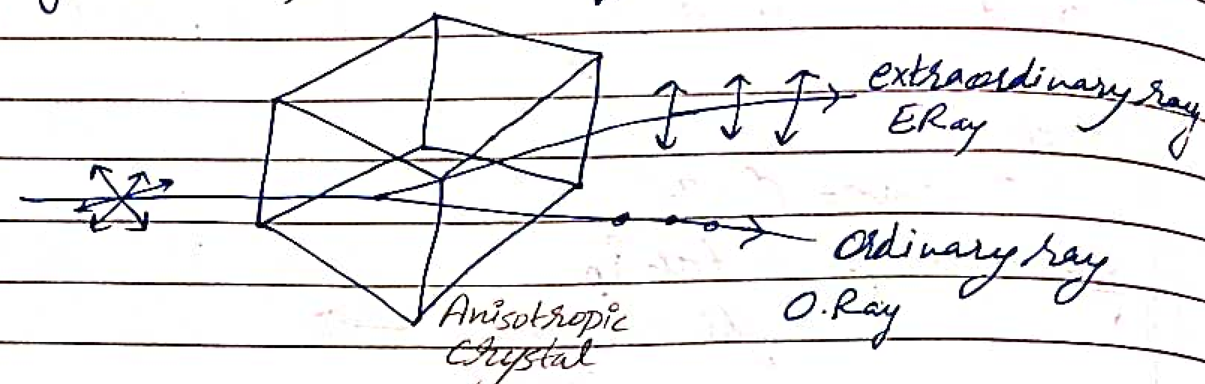
I_0 is the amplitude of polarised light.

θ is the ∠ b/w polarizer and Analyzer.

28 Dec

* Double Refraction :- method of polarization

Anisotropic crystals → velocity of light diff. in diff. directions
(eg- calcite)

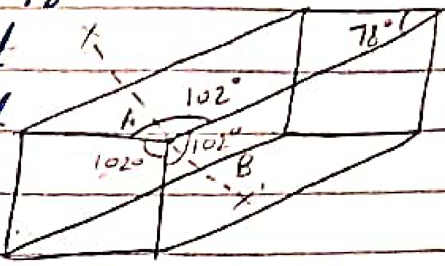


Crystals in which velocity of light is not same in all direction, these crystals show the phenomenon of double refraction the two rays emerging out are called ordinary rays and extraordinary ray.

- The extraordinary ray forms an image which rotates with the rotation of crystal. The image formed by the ordinary ray does not rotate.

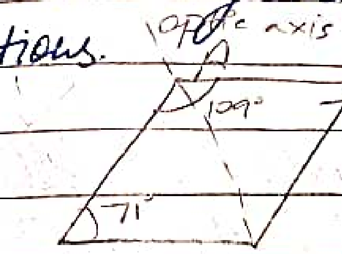
	O-ray	e-ray
1.	Obey's Snells law	does not obey snell's law
2.	It travels with same speed in all direction.	It travels with different speed in diff. direction.
3.	Single refractive index μ_0.	Its refractive index changes with direction.

Calcite crystal - It is a colourless, transparent, anisotropic crystal. Chemically it is crystallised $CaCO_3$. The 6 faces are ||gm with angles 102° & 78°. There are two edges called as blunt edges where all 3 ∠s are 102° & 78° are equal



Optic axis - A line passing through any one of the blunt corners and making equal ∠s with each of the three edges is called optic axis. Any line || to optic axis is also called as optic axis.

Principle Section - A plane containing the optic axis and ⊥ to the opposite faces of the crystal is called as principle section.
As the crystal has 6 faces there are 3 principle sections.



Nicol Prism - Is an optical device for producing and analysing plane polarised light.
principle - The ordinary ray is eleminated by the method of total internal reflection only the extra-ordinary ray emerges out.

construction - It is made up of calcite crystal whose length is 3 times its width. The end-faces of the crystal are cut such that they make ∠s of 68° & ~~10~~ 112° in the principle section.

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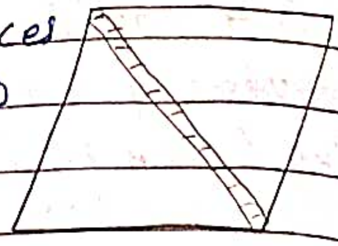
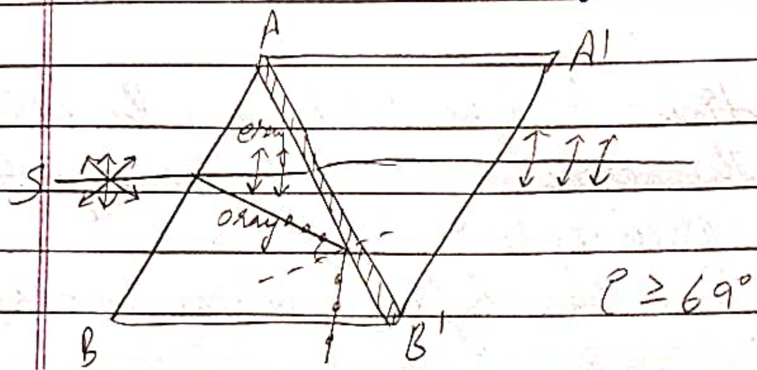
The crystal is cut into two pieces from of one blunt corner to other along a plane ⊥ to the principle Section.



The cut surfaces are polished optically flat and cemented together with a layer of Canada Balsam.

- The RI of Canada Balsam is μ 1.55, which lies in b/w ordinary and extraordinary rays.
  $\mu_o(1.66)$ $\mu_e(1.49)$



<u>Working</u>- When a ray of light falls on the side AB of the prism it is doubly refracted. The O-ray when falls on the canada Balsam layer it travels from the denser medium to the rarer medium. The critical angle can be calculated as

$$\sin\theta = \frac{1.55}{1.66} = 0.933 \quad \Rightarrow \theta = 69°$$

Therefore the ordinary ray will totaly internaly reflected if it falls on the balsam layer with angle of incidence greater or equal to 69°.

So only the e-ray emerges out of the nikol prism from the side A'B'. Hence it is plane polarised in the plane of principle section

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Quarter Wave Plate-

A plate of doubly refracting crystal whos length is such that it introduces a path diff of $\lambda/4$ b/w the ordinary & extraordinary rays. Therefore phase diff $= \pi/2$ is introduced. Its thickness can be calculated as follows

$$(\mu_0 - \mu_E)t = \frac{\lambda}{4}$$

$$\Rightarrow \boxed{t = \frac{\lambda}{4(\mu_0 - \mu_e)}} \quad \text{for } \mu_0 > \mu_E$$

$$t = \frac{\lambda}{4(\mu_e - \mu_0)} \quad \text{for } \mu_e > \mu_0$$

Half wave Plate-

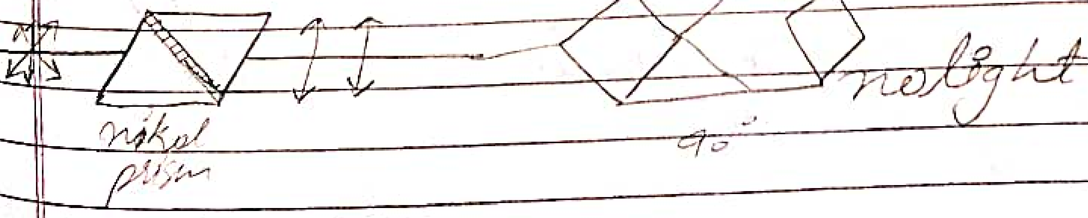
Path diff of $\frac{\lambda}{2}$ is introduced b/w o ray & e ray.
phase diff $= \pi$.

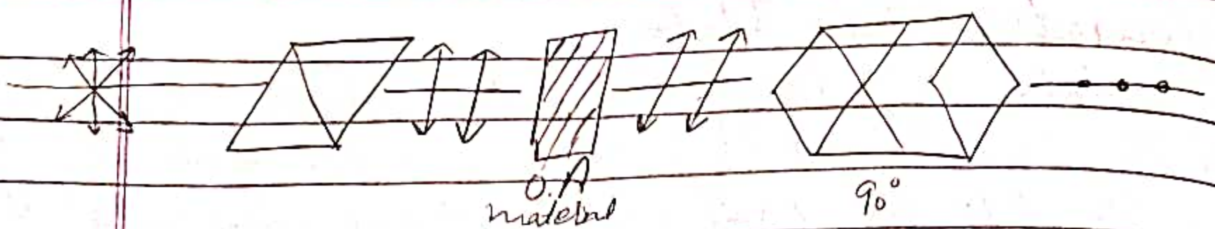
$$(\mu_0 - \mu_E)t = \lambda/2$$

$$\boxed{t = \frac{\lambda}{2(\mu_0 - \mu_E)}} \quad \text{for } \mu_0 > \mu_E$$

$$t = \frac{\lambda}{2(\mu_E - \mu_0)} \quad \text{for } \mu_E > \mu_0$$

Optical Activity- Some substance like quartz, Sugar crystal, rotate the plane of vibration of light passing through them.





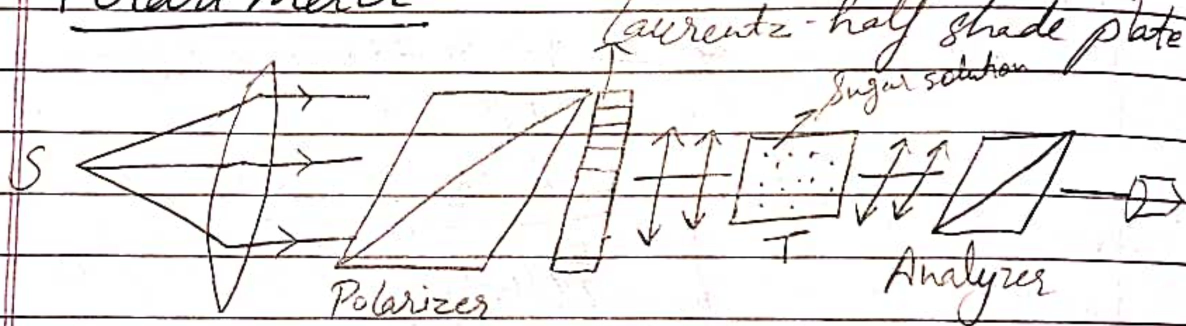
specific rotation is given as the rotation produced by 1 decimeter (10cm) length of the solution when its concentration is 1g per cubic cm.

$$\alpha = \frac{\theta}{lc}$$

It depend upon the temperature of the solution and wavelength of the light.

2 Jan/2023

* Polarimeter



Action of Laurentz Half Shade Plate:—
Half Shade plate is a combination of two Semi-circular plates XBY and XDY. The plate XBY is of Quartz and XDY is made of glass. The thickness of quartz plate is that it introduces a path diff of $\frac{\lambda}{2}$ and thickness of glass plate is such that it absorbs same amount of light as quartz plate.

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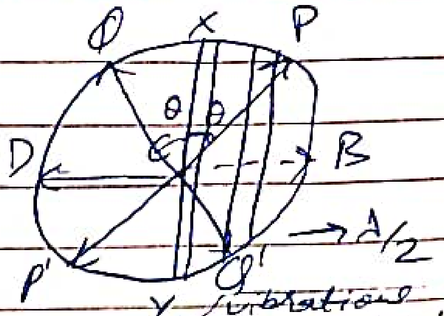

Let CP be the direction of vibration in the plane polarized light. The light passing through glass has vibration along CP but the quartz crystal has vibration along QQ'.

Vibrations
Glass → PP'
Quartz → QQ'

Reason - In quartz crystal e-ray is along CX and o-ray along CB. Quartz rotates CB to CD (as it is introduces $\lambda/2$ path difference. Therefore effective direction of vibration is CQ.

⇒ Working :-

If plane of analyzer:-

1) is ∥ to QCQ' ⟶ Quartz side will be brighter

2) is ∥ to PCP' ⟶ Glass side will be brighter

3) is ∥ to XCY ⟶ Both side will be equally bright.

⇒ Procedure-

1) The tube T is filled with water and analyzer is adjusted to obtain a position of equal illumination on both sides of field of view. Take one reading here.

2) Fill the sugar solution in tube T. Rotate the analyzer again to obtain position of equal illumination. The difference is angle θ.

$$\underset{\text{(specific rotation)}}{\alpha} = \frac{\theta}{lc}$$