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unit-II

XXX ① Discuss conditions for interference of light and explain Biprism (fresnel) experiment for finding wavelength

XXX ②

\# ② Explain Fringes observed when wedge shaped film illuminated by monochromatic light.

\# ③ Describe arrangement to observe newton's rings by reflected light and find wavelength

** ④ Explain interference fringes in Lloyd's mirror arrangement

\# ⑤ Construction & working of michelson Interferometer

⑥ Determination of thickness of Transparent material using in Bi prism.

⑦ Determination of difference in wavelengths of sodium D1; D2 line / Spectral line

XXX Explain Cosine law

⑦ formation of colours of thin films

② Spatial coherence

⑤ Difference b/w Biprism & Lloyd's mirror fringes

④ Types of fringes

Introduction

Light → form of Energy

light Source →  eye

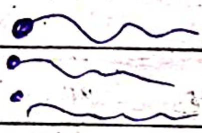
↓

Study → optics

Newton — [Corpuscular Theory]

Hugens's — [light & wave Theory]

Source → particles all direction



light waves

Source → Wavefront [Secondary source of light]

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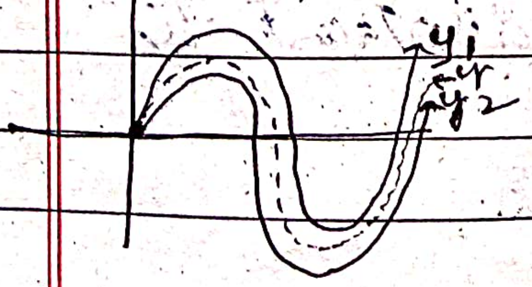
Interference concept from Superposition Theory

Principle of Superposition

When two or more waves travelling through a medium superimpose each other then a new wave is formed whose resultant displacement is algebraic sum of displacements of individual waves



$y = y_1 \pm y_2$ $\quad y = y_1 + y_2$ $[\phi = 2n\pi]$

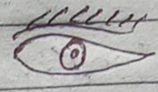
ϕ = phase difference $[\phi = (2n+1)\pi]$

$y = y_1 - y_2$

Introduction

form of

Light → Energy

light Source →  eye

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particles all direction

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[light & wave Theory]

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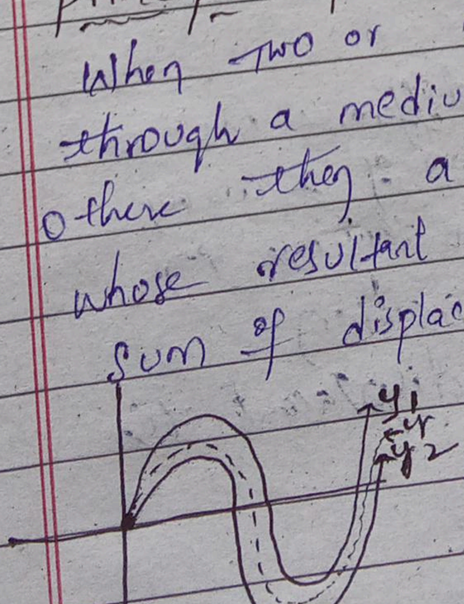

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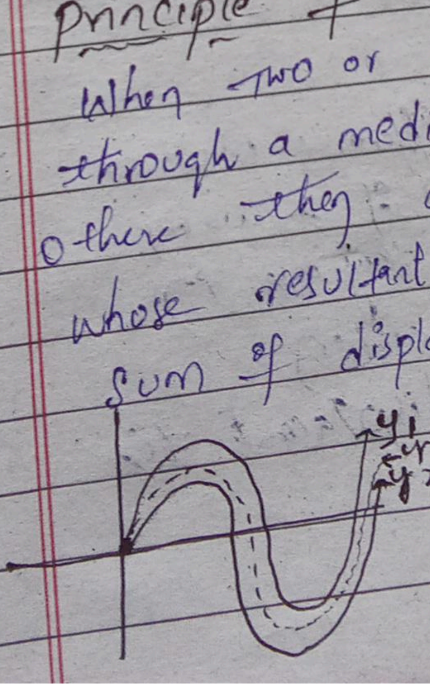

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ϕ = phase difference

$\phi = (2n+1)\pi$, $y = y_1 - y_2$

coherence = [Telugu script, illegible]

Coherence :-

→ When two wave sources have Zero or constant phase difference and same frequency & same wave form then ~~they~~ are called coherent sources.

This phenomenon is called coherence

→ it is simply a property of waves i.e ideal property which gives stationary inference.

Imp → Types of coherence

(i) Temporal coherence

(ii) spatial coherence

phase difference :- difference b/w position of 2 waves when they are in same direction

used to compare displacement etc

Interference is the phenomenon where the superposition of 2/more waves results in modification of resultant light intensity distribution

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(2) what is Interference & Conditions for interference of lights and types of Interference.

Interference:-
The phenomenon of modification of Redistribution of intensity of light in the region of superposition is called interference.
→ interference basically takes place based on superposition principle.

Conditions of interference of light:-
(i) The two interfering beams must originate from same source of light.
and the sources must be coherent sources i.e the initial ~~pathes~~ phase difference must be zero or constant.
(ii) Two interfering waves must propogates almost in the same direction or the wavefronts intersect at a very small angle
(iii) The original source of light must emit light of single wavelength i.e Monochromatic source of light.
(iv) The waves must have same period and wavelength also amplitudes must be equal (or) very nearly equal

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Types of interference

interference is of 2 types based on how it formed.

Division of Wave front	Division of Amplitude.
→ incident wave front is divided into 2 parts by reflection / refraction / diffraction	→ Amplitude of incoming beam is divided into two parts by parallel reflection / refraction
→ 2 parts travel some distance & produce interference.	→ 2 parts reunite after Traversing different paths & produces interference
Eg:- Fresnel's Biprism, Lloyd's mirror.	Eg:- Newton rin[gs], Michelson's Interf[erometer]

Types of interference

interference is of 2 types based on how it formed

Division of Wave front	Division of Amplitude
→ incident wave front is divided into 2 parts by reflection refraction / diffraction	→ Amplitude of incoming beam is divided into two parts by parellel reflection / refraction
→ 2 parts travel some distance & produce interference.	→ 2 parts reunit after Traversing different paths & produces interference.
Eg:- Fresnel's Biprism, Lloyd's mirror.	Eg:- Newton rings, Michelson's Inferometer

(1) Explain
and
find

Biprism
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(i) S
(ii)

(1) Explain Fresnals Bi prism experiment and derive an expression for finding wavelength.

Biprism :-

Biprism is a Combination of two acute prisms placed Base to Base. This combination is obtained from an optically plane glass plate by proper grinding and polishing. The obtuse angle of prism is about 179° and other angles are about 0.5° (30') each.

• Biprism Action :-

The biprism produce two coherent impages of given slit which are seperated by a certain distance and act as two coherent sources.

Experimental Setup :-

A optical bench carrying 4 stands, the first one for adjustable slit, Second one for biprism, third one for conevex lense and lastly 4 th one for eyepice i.e Screen.

Note :-

(i) Stands can be moved along bench

(ii) Slit & Biprism can be rotated in their own planes.

procedure :- or Formation of interference :-

A narrow slit S is illuminated with a monochromatic source of light of wavelength "λ" and is allowed to fall symmetrically on a Biprism. The intersection of two inclined faces forming obtuse angle must be adjusted accurately parellel to slit.

→ The edge B divides incident wave front into 2 parts.

→ 1st part passes through upper half ABE of prism is deviated through small angle towards lower half of diagram & appears to diverge from S_1.

→ 2nd part passes through lower half CBE deviated through lower half towards upper half & appears to diverge from S_2.

→ Hence S_1 and S_2 serve as coherent sources resulting in 2 wave fronts intersect and give interference pattern which is observed by eye piece.

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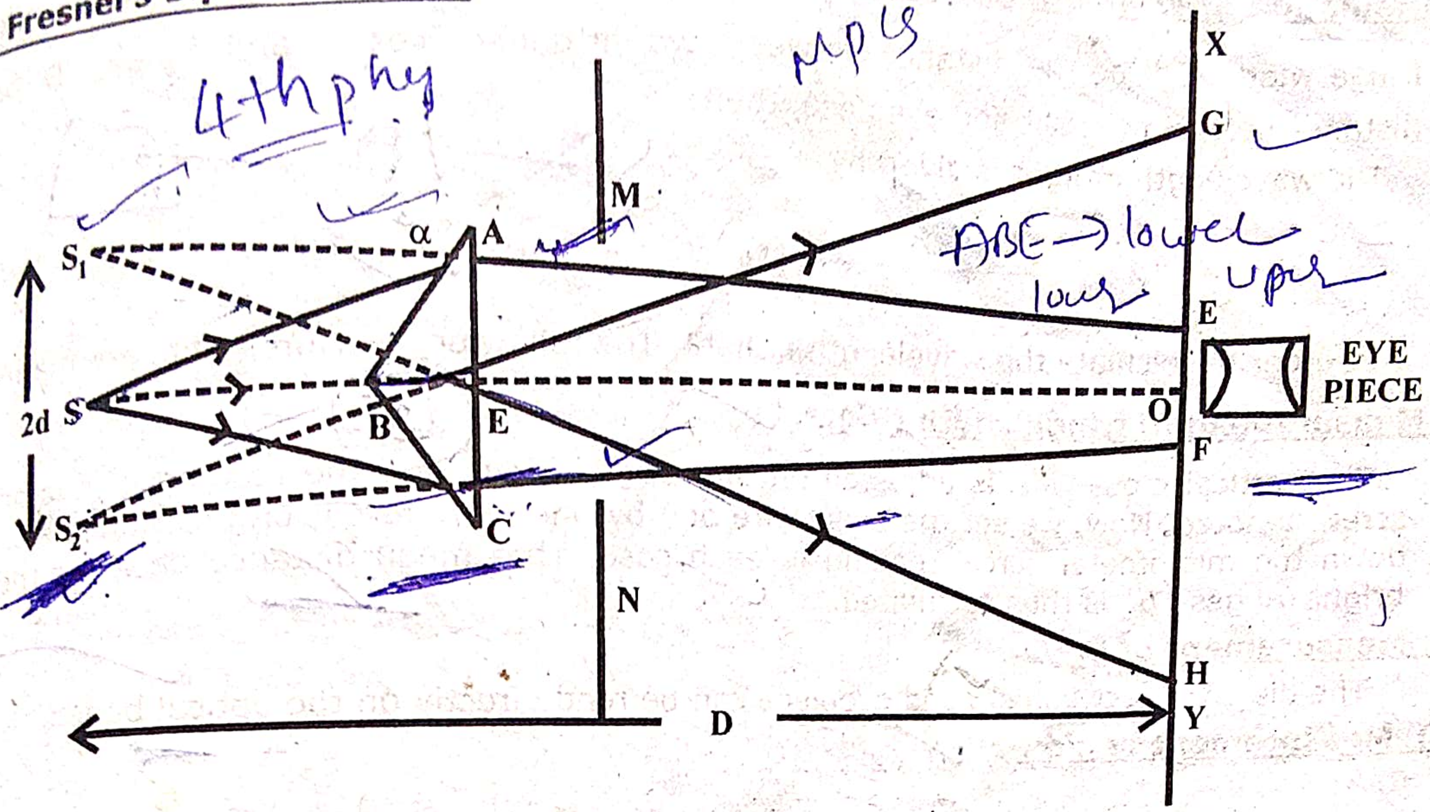
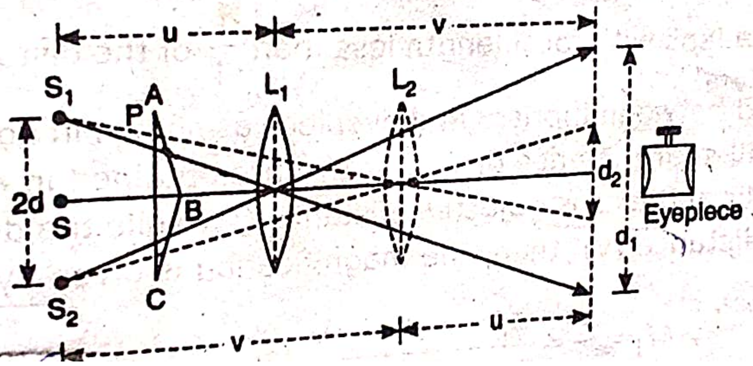
8) Fresnel's Biprism:- (IMP)

4th phy

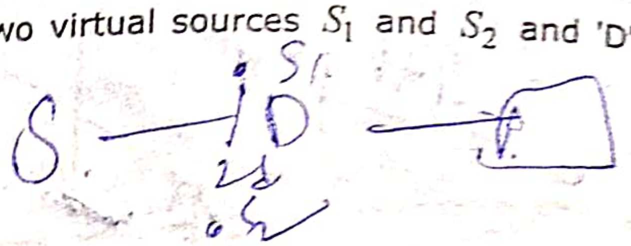
MPLS





Determination of wavelength of light:- If 'λ' be the wavelength of light used, 'β' be th fringe width, '2d' be the distance between two virtual sources S_1 and S_2 and 'D' be th distance between the slit and eyepiece, then

The wavelength of light is given by



$$\lambda = \frac{\beta.2d}{D} \text{ ———— } (1)$$

In order to calculate the wavelength of light, The following measurements are made.

(i) Measurement of fringe width (β):-

The vertical cross wire is adjusted on any bright fringe and the reading of micrometer screw is noted. Now, we set the cross wire one by one on different bright fringes and note down the micrometer screw reading in each case. That mean distance between the two bright fringes 'β' is thus calculated.

(ii) Measurement of D:-

The distance between slit and eyepiece can be read directly on the optical bench.

(iii) Measurement of '2d':-

For this purpose, a lens with focal length less than $\frac{1}{4}$ of the distance between biprism and eyepiece is mounted between biprism and eyepiece as shown in fig (ii). The lens is adjusted at a position 'L_1' till sharp images of S_1 and S_2 are obtained in eyepiece in this case, the distance between slit and lens is objective distance (u) while the distance between lens and eyepiece is image distance (v). then, the magnification is given by

$$M_1 = \frac{v}{u} = \frac{d_1}{2d} \text{ ———— } (1)$$

further, at the position (L_2) of lens, the sharp images of S_1 and S_2 are obtained in eyepiece. Then, the distance between Lens and eyepiece is objective distance (u) while the distance between slit and lens is image distance (v). then the magnification is given by

$$M_2 = \frac{u}{v} = \frac{d_2}{2d} \text{ ———— } (2)$$

$S_1 S_2$

on multiplying eq'ns (1) and (2), then

$$\frac{v}{u} X \frac{u}{v} = \frac{d_1}{2d} X \frac{d_2}{2d}$$

$$1 = \frac{d_1 d_2}{(2d)^2}$$

$(2d)^2 = d_1 d_2$

$(2d) = \sqrt{d_1 d_2}$

$$\boxed{2d = \sqrt{d_1 d_2}} \text{ ———— } (3)$$

Thus, wavelength λ can be determined by measuring the values $\beta, D \text{ and } 2d$.

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Lloyd's mirror Explanation :-

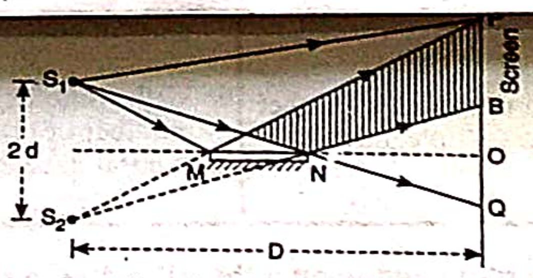
Apparatus :-
planemirror M.N and the Screen.
A narrow slit 'S_1' is illuminated by monochromatic Source of light.

Further light from slit 'S_1' is allowed to incident on mirror MN at grazing angle.

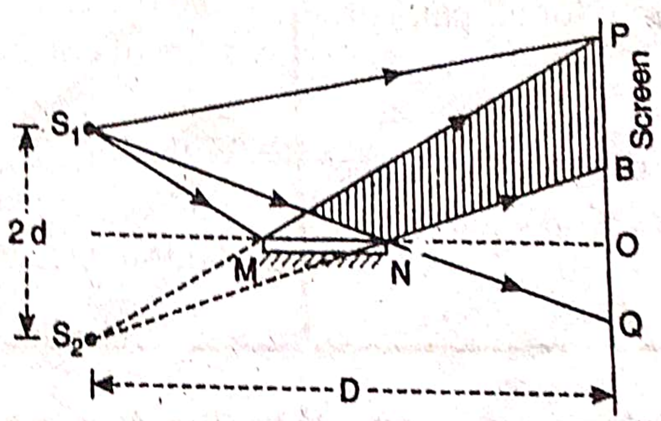
→ The reflected beam appears to diverge from S_2 which is virtual Image of S_1.

→ So hence S_1 and S_2 act as 2 coherent Sources. here.

→ The direct cone of light PS_1Q and reflected cone of light PS_2B Super imposed over each other and produces interference fringes in overlapping region PB of Screen.



Lloyd's mirror Experiment: (VIMP)



Central Fringe (Zero order fringe)

In the case of biprism we saw it has central fringe or zero order fringe is bright but here in Lloyd's mirror experiment central fringe or zero order fringe is dark.

why because the reflected light has suffered a phase change of π

So as a result of which the condition $(2n\pi)$ for maxima in Biprism is converted into condition for minima in Lloyd's mirror.

So Hence The central fringe is dark in Lloyd's mirror.

Determination of Wavelength :-

To find wavelength, Lloyd's mirror is mounted vertically on an upright of an optical bench and placed along upright = [illegible]

the length of bench.

→ on another upright a narrow vertical slit is mounted which is

illuminated by a monochromatic Source of light.

→ At last the mirror is rotated about an axis parellel to the length of bench untill fringes are obsened in micrometer eyepiece,

If λ be the wavelength of light used, 'β' the fringe width, '2d' be the distance between S_1 and S_2 and D be the distance b/w slit & eyepiece,

⇒ wavelength of light can be found by the following formula.

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

~~Of~~ points Seperate ~~n Bi~~
or Lloyd's mirror Question ~~e~~ ~~B)~~ ~~3 5 0~~ ~~రాయలేదు~~

Difference between Biprism and Lloyd's mirror frings.

Bi prism fringes	Lloyd's mirror fringes
The central fringe is Bright	The central fringe is dark.
The complete pattern of interference fringes is obtained	A few fringes are invisible here
The fringe width is same for all pairs of coherent sources.	Fringe width is different for different pairs of coherent sources.
Condition for max intensity is, $\phi = \pm 2n\pi, n=0,1,2,\ldots$	$\phi = (2n\pm1)\pi, n=0,1,2$
Minimum intensity condition is $\phi = (2n\pm1)\pi$ $n=0,1,2$	$\Rightarrow \phi = \pm 2n\pi$ $n=0,1,2,3$
with white light biprism produces limited coloured fringes with central white	with white light Lloyd's mirror produces number of black & white fringes ... central dark

Interference by a film with 2 non-parallel reflecting surfaces.

or

① What is wedge-shaped film. describe fringes observed when a wedge shaped film is illuminated by monochromatic light.

Wedge shaped film :-

Consider 2 plane surfaces AB and CD inclined at an angle 'θ' and enclosing a non-uniform thickness air film (wedge shaped film). The thickness of air film is increasing from C to D.

→ Let μ be refractive index of film material.

→ when we pass monochromatic source of light i.e Na light through wedge shaped film material the interference pattern is observed

→ Consider a light wave PQ incident on surface AB of wedge film at an angle of incidence (i)

→ As a result the ray is partly reflected as QR₁ & rest is refracted as QR

Q.R later the refracted light wave again reflected from lower Surface CD as RT, and refracted from Surface AB, as TR_2.

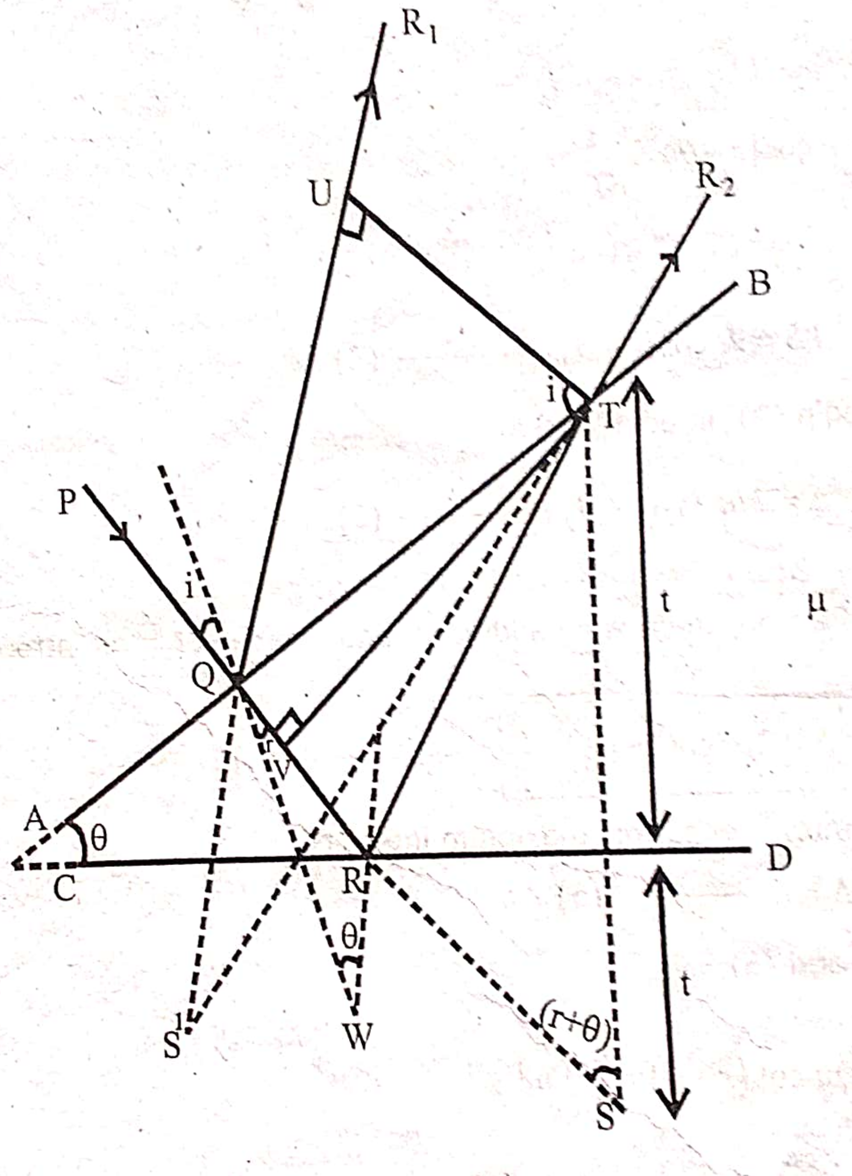
→ The waves QR_1 & TR_2 give the interference pattern.

→ To calculate optical path difference between waves QR_2 and QR_1 we draw 2 normals TU & TV on QR_1 and QR Respectively.

→ later we can extend QR as QS as show in fig.

The optical path difference b/w waves QR_2 and QR_1 i.e interfering waves is given by,.

18. Interference by a film with two non- parallel reflecting surfaces (or) (WEDGE SHAPED FILM):- (VVIMP)



$\therefore$ The optical path difference between (waves QR_2 [illegible] waves is given by

$$\Delta = \mu(QR + RT) - QU$$

$$= \mu(QV + VR + RT) - QU$$

$$= \mu(QV) + \mu(VS) - QU \qquad [\because RT = RS \ \& \ VR + RS = VS].$$

$$\Delta = \mu(VS) \text{———————} (1) \quad [\because QU = \mu(QV)]$$

from Δ^{le}, $TVS \Rightarrow$

$$\cos(r+\theta) = \frac{VS}{ST}$$

$$VS = ST \ Cos(r+\theta)$$

$$VS = 2t\cos(r+\theta) \text{———————} (2)$$

sub'' eq'n (2), in eq'n (1) $\Rightarrow$

$$\Delta = 2\mu t\cos(r+\theta) \text{———————} (3)$$

but, due to reflection, there is an additional path change of $\frac{\lambda}{2}$ is introduced. then

$$\boxed{\Delta = 2\mu t\cos(r+\theta) \pm \frac{\lambda}{2}} \text{———————} (4)$$

- For constructive interference (or) maximum intensity,

$$\Delta = n\lambda \text{———————} (5)$$

From eq'ns (4) and (5) $\Rightarrow$

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

$$\Rightarrow \boxed{2\mu t\cos(r+\theta) = (2n \pm 1)\frac{\lambda}{2}} \text{———————} (6)$$

- For destructive Interference (or) Minimum Intensity

$$\Delta = (2n \pm 1)\frac{\lambda}{2} \quad \text{———} (7)$$

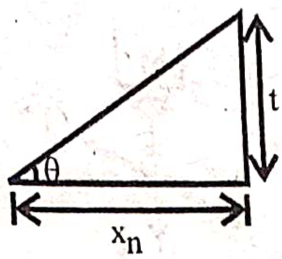
from eq'ns (4) and (7) $\Rightarrow$

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

$$\Rightarrow \boxed{2\mu t \cos(r+\theta) = \pm n\lambda} \quad \text{———} (8)$$

- In the case of wedge shaped film, t remains constant only in direction parallel to the thin edge of wedge, hence the straight fringes parallel to the edge of the wedge are obtained.

Fringe width (Spacing between two consecutive bright fringes):-



For n^{th} maxima,

$$2\mu t \cos(r+\theta) = (2n+1)\frac{\lambda}{2} \quad \text{———} (9)$$

for normal incidence and air film,

$r = 0$ & $\mu = 1$

from eq'n (9) $\Rightarrow$

$$2t \cos\theta = (2n+1)\frac{\lambda}{2} \quad \text{———} (10)$$

from, the fig.

$$Tan\theta = \frac{t}{x_n}$$

$$\Rightarrow t = x_n \, Tan\theta \quad \text{———} (11)$$

Sub" eq'n (11), in equation (10) $\Rightarrow$

$$2x_n Tan\theta \, . \cos\theta = (2n+1)\frac{\lambda}{2}$$

$$2x_n \sin\theta = (2n+1)\frac{\lambda}{2} \quad \text{———} (12)$$

If the $(n+1)^{th}$ maximum is obtained at a distance x_{n+1} from thin edge, then

$$2x_{n+1} \sin\theta = \left[2(n+1)+1\right]\frac{\lambda}{2}$$

$$\Delta = (2n \pm 1)\frac{\lambda}{2} \text{———} (7)$$

from eq'ns (4) and (7) $\Rightarrow$

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

$$\Rightarrow \boxed{2\mu t \cos(r+\theta) = \pm n\lambda} \text{———} (8)$$

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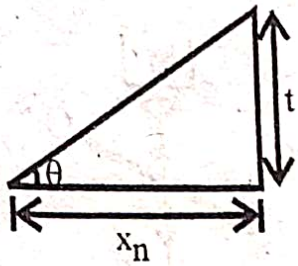

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$$2x_{n+1} \sin\theta = [2(n+1)+1]\frac{\lambda}{2}$$

$$2x_{n+1}\sin\theta = (2n+3)\frac{\lambda}{2} \text{———} (13)$$

on subtracting eq'n (12) from eq'n (13) $\Rightarrow$

$$2x_{n+1}\sin\theta - 2x_n\sin\theta = (2n+3)\frac{\lambda}{2} - (2n+1)\frac{\lambda}{2}$$

$$2(x_{n+1} - x_n)\sin\theta = (2n+3-2n-1)\frac{\lambda}{2}$$

$$2\beta\sin\theta = \lambda$$

$$\Rightarrow \beta = \frac{\lambda}{2\sin\theta} \qquad [\because x_{n+1} - x_n = \beta]$$

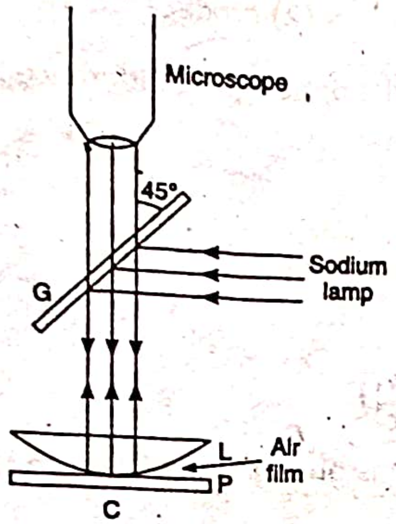
$$\boxed{\beta = \frac{\lambda}{2\theta}} \text{———} (14) \quad [\therefore \theta \text{ is very small} \Rightarrow \sin\theta \approx \theta]$$

of wire:

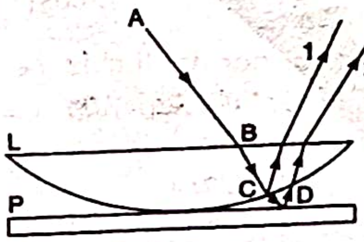
19) Newton's Rings: (Reflected light):- (VVIMP)

When a plano-convex lens with its convex surface is placed on a plane glass plate, an air film of gradually increasing thickness is formed between convex lens and plane glass plate. The thickness of the film at the point of contact is zero. If monochromatic light is allowed to fall normally, and the film is viewed in reflected light, alternate dark and bright rings concentric around the point of contact between the lens and glass plate are observed are known as Newton's rings.

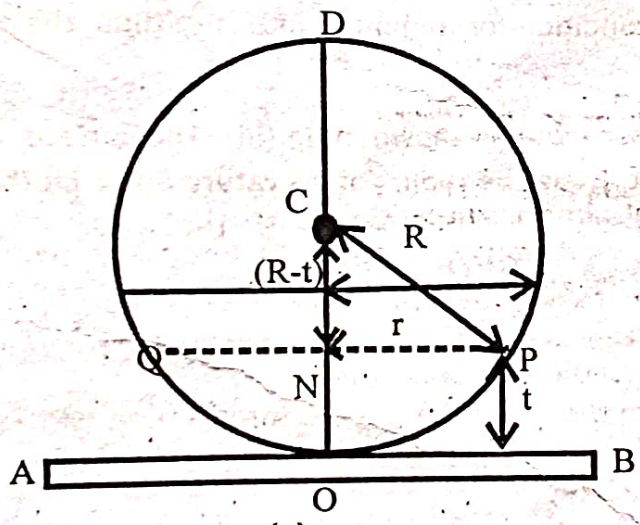
Experimental arrangement:-



(a)



(b)



(c)

(d)

The Newton's rings experimental arrangement is shown in fig. It consists of mainly three parts namely sodium vapour lamp with a plane glass plate (G) at an angle 45^0 with the vertical travelling MICROSCOPE (M) and the combination of plano-convex lens 'L' and plane glass plate(P).

A parallel beam of monochromatic light from an extended source is made incident on a inclined glass plate (G), which reflects it in vertically downword direction. Each ray of light suffers reflections from upper and lower surfaces of thin air film formed between plano- convex lens and plane glass plate. These reflected rays of light superimpose and produce an interference pattern consisting of alternate dark and bright rings as shown in fig.

- As locus of all the points of air film of same thickness, is a circle. So Interference fringes due to all the rays of incident light at points corresponding to a particular thickness of air film, merge to appear as a circular ring.

- Central ring is dark and the thickness of rings goes on decreasing as we move away fro[m] central ring. because the thickness of air film goes on increasing as we move away from poi[nt] of contact of plano-convex lens with plane glass plate.
- Newton's rings are Localised fringes.

Theory:

AB is a monochromatic ray of light which falls on the system as shown in fig (ii). A part reflected at C which goes out in the form of ray (1) without any phase change.

The rest part is refracted along CD. at point 'D' it is again reflected and goes out in the form of ray (2) with a phase change of π. These rays (1) & (2) produce Interference pattern consistin[g] of alternate dark and Bright rings.

If 't' be the thickness of the air film, then the optical path difference between rays (1) & (2) is given by

$$\Delta = 2\mu t\cos(r) + \frac{\lambda}{2}$$

for normal incidence and an air film

$$r = 0 \ \ and \ \ \mu = 1$$

$$\therefore \ \Delta = 2t + \frac{\lambda}{2} \text{------------} (1)$$

at the point of contact of plano- convex lens and plane glass plate, $t = 0$, *then*

$$from\ eq'n\ (1) \Rightarrow$$

$\Delta = \frac{\lambda}{2}$, which is the condition for minimum intensity thus, the central spot is dark.

Let LOL^1 be the lens placed on a glass plate as shown in fig (iii). The surface LOL^1 is the part of spherical surface with centre 'C'. Let 'R' be the radius of curvature and r be the radius of Newton's ring corresponding to the constant film thickness 't'.

$$from\ \Delta^{le}\ Triangle,\ CNP \Rightarrow [from\ fig\ (iii)]$$

$$CP^2 = CN^2 + NP^2$$

$$R^2 = (R-t)^2 + r^2$$

$$\cancel{R^2} = \cancel{R^2} + t^2 - 2Rt + r^2$$

$$\Rightarrow r^2 = 2Rt - t^2 \approx 2Rt \quad \left[\because t << R \Rightarrow t^2\ can\ be\ Neglected\ comparable\ to\ 2Rt\right]$$

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

sub" eq'n (2), in eq'n (1) $\Rightarrow$

$$\Delta = \frac{2r^2}{2R} + \frac{\lambda}{2}$$

$$\Rightarrow \boxed{\Delta = \frac{r^2}{R} + \frac{\lambda}{2}} \text{------------} (3)$$

Diameter of Bright ring:-

for the Bright ring/ maximum intensity

$$\Delta = n\lambda \text{ ———— } (4)$$

from eq'ns (3) & (4) $\Rightarrow$

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

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

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

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

$$\left(\frac{D_b}{2}\right)^2 = \frac{(2n-1)\lambda R}{2} \qquad [\because D_b = 2r]$$

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

$$D_b^2 = 2(2n-1)\lambda R$$

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

$$\boxed{D_b \propto \sqrt{(2n-1)}} \text{ ———— } (5)$$

Thus, the diameters of the bright rings are proportional to the square roots of odd natural numbers.

Diameter of dark ring:-

For the dark ring / Minimum Intensity

$$\Delta = (2n+1)\frac{\lambda}{2} \text{ ———— } (6)$$

from eq'ns (3) & (6) $\Rightarrow$

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

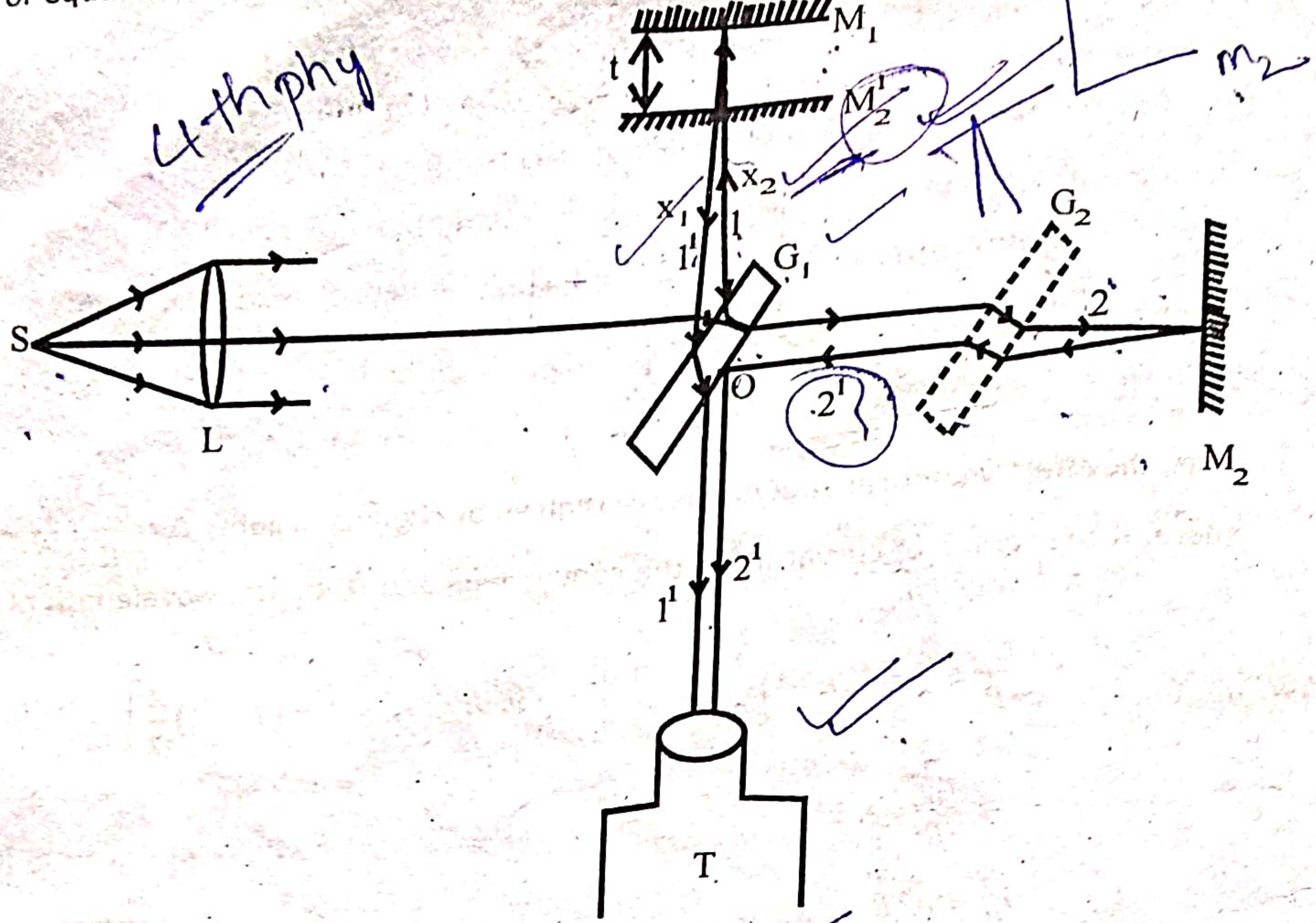
$$\frac{r^2}{R} + \frac{\lambda}{2} = n\lambda + \frac{\lambda}{2}$$

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

$$r^2 = n\lambda R$$

23) Michelson's Interferometer:- (IMP)

This is an instrument, which can produce both types of interference fringes such as circular fringes of equal inclination of '∞' and localised fringes of equal thickness.



M_1 & M_2 → *Plane mirrors*

G_1 & G_2 → *Plane Glass plates*

T → *Telescope*

S → *Monochromatic extended source*

L → *Convex lens*

M_2^1 → Virtual Image *of* M_2

Construction:-

The Michelson's interferometer is shown in fig. It consists of two plane mirrors M_1 and M_2 which are at right angles to each other. M_1 can be moved such that its new postion is parallel to its previous position while M_2 is Fixed M_1 and M_2 are provided with three levelling screws at their backs. with the help of these screws the mirror can be tilted about horizontal and vertical axes so that they can be made exactly perpendicular to each other. There are two plane Glass plates G_1 and G_2 of same thickness and of the same material placed parallel to each other.

These plates are also inclined at an angle 45^0 with the mirror M_1 and M_2.

The face of G_1 towards G_2 is semi-silvered. T is a Telescope which receives the reflected lights from M_1 and M_2.

Working:-

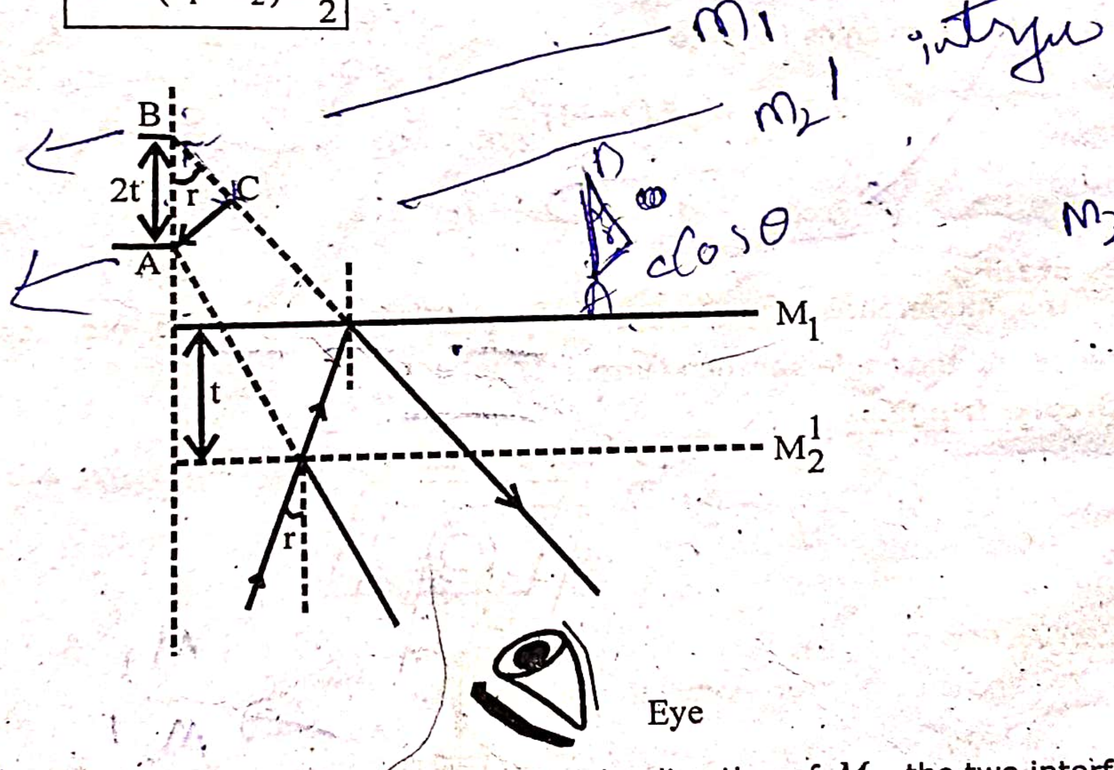
Light from a monochromatic extended source 'S' after being rended by a collimating lens 'L' falls on the semisilvered glass plate G_1. at G_1 incident light splits into two parts. One being reflected as ray (1) and which travels towards Mirror M_1 and again reflected as ray '1^1' and again reaches the glass plate G; the second being refracted as ray (2) and which travels towards Mirror M_2 and again reflected as ray 2^1 and again reaches the glass plate G_1. ray 2 and 2^1 passes through compensating plate G_2. Thus, the paths Travelled by two rays (1&2) are equal. These two rays 1^1 & 2^1 gives the Interference pattern. It can be observed in the Telescope 'T'.

If we see in the direction of M_1, one observes M_1 and also a virtual Image M_2^1 of M_2. Thus, the two interfering beams come by reflection from Mirror M_1 and M_2^1.

If the distance $OM_1 = x_1$ and $OM_2^1 = x_2$, then
The path difference between interfering rays (waves) is given by

$$\boxed{\Delta = 2(x_1 - x_2) \pm \frac{\lambda}{2}}$$

Theory:-



When you are observing interference pattern, in the direction of M_1, the two interfearing beams come from points A and B as shown in fig. hence the optical path difference between two beams is 'BC'.

from Δ^{le} $BAC \Rightarrow$

$$\cos r = \frac{BC}{AB}$$

$$\Rightarrow BC = AB \cos r$$

$$BC = 2t \cos r \text{ and}$$

but, due to reflection, there is an additional path difference of $\frac{'\lambda'}{2}$ is introduced. Then the effective path difference is given by

$$\Delta = 2t\cos r + \frac{\lambda}{2} \text{ ——— (1)}$$

for maximum intensity,

$$\Delta = n\lambda \text{ ——— (2)}$$

from eq'ns (1) & (2) ⇒

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

$$2t\cos r = (2n-1)\frac{\lambda}{2} \text{ ——— (3)}$$

for minumum Intensity

$$\Delta = (2n+1)\frac{\lambda}{2} \text{ ——— (4)}$$

from eq'ns (1) & (4) ⇒

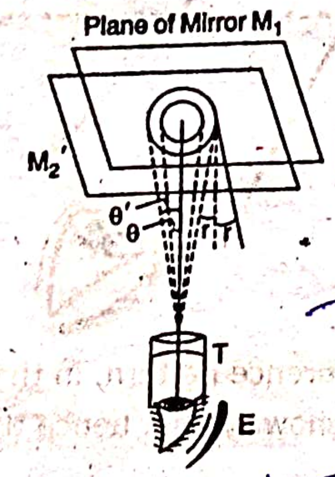
$$2t\cos r + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$$

$$2t\cos r = n\lambda \text{ ——— (5)}$$

Types of frings:-

The interference fringes may be straight, circular, parabolic, etc. depending upon path difference and the angle between Mirrors M_1 and M_2^1.

1) Circular fringes:-



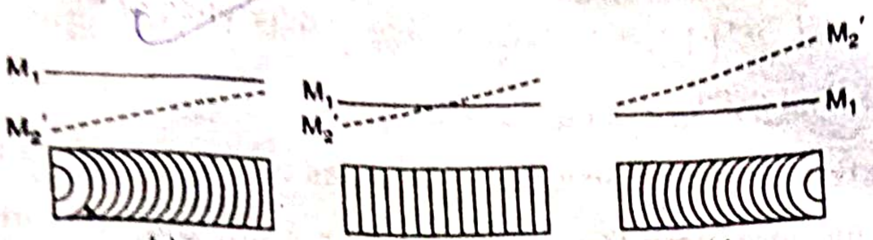
M1

→ M2'

m2

When mirror M_2 is exactly perpendicular to mirror M_1 (or) Mirror M_1 and M_2^1 are parallel an air film of constant thickness is enclosed between them. It can be seen from fig. that the path differences are different for different values of 'θ'. Hence, the path rings while the path difference which satisfies the condition of maxima appears bright rings while the path difference which satisfies the condition of minima appears dark rings. These are formed at infinity hence they are observed through a Telescope focused at infinity.

2) Localised fringes:-



(a) (b) (c)

When the mirror M_2 is not exactly perpendicular to Mirror M_1 (or) the mirror M_1 and the virtual Image M_2^1 are inclined, the air film, enclosed between them is wedge-shaped. The shape of fringes depends on the thickness of the film and the angle of incidence.

When the two mirrors M_1 and M_2^1 intersect in the middle, straight fringes are observed. When the two mirrors are inclined, curved fringes with convexity towards the thin edge of the wedge are observed as shown in fig.

3) Localised white light fringes:-

When monochromatic light source is replaced by a white source, then coloured and curved localised fringes are obtained. The fringes of zero thickness being again perfectly dark and straight. Other fringes are coloured due to overlapping of various colours. If the film is thick, uniform illumination is observed.

24) Uses of Michelson's Interferometer:-

i) Determination of wavelength of monochromatic source of Light:-

Initially the michelson interferometer is set for circular fringes with central bright spot. If 't' be the thickness of the air film between two mirrors and 'n' be the order of the spot obtained, then for the normal incidence $(r=0)$, $2t+\frac{\lambda}{2}=n\lambda$ ——— (1) Types use

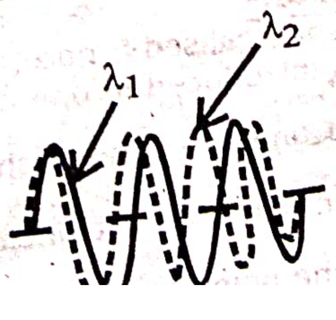
If, now M_1 is moved $\frac{\lambda}{2}$ away from M_2^1, then $(n+1)^{th}$ bright spot appears at the centre of the field. Let N be the number of fringes that cross the centre of field when the mirror M_1 is moved from initial position x_1 to a final position x_2, then

$$N\frac{\lambda}{2}=x_2-x_1$$

$$\Rightarrow N\lambda=2(x_2-x_1)$$

$$\boxed{\lambda=\frac{2(x_2-x_1)}{N}}$$

ii) Determination of difference in wavelength of sodium D_1, D_2 lines (or) Determination of difference in wavelengths of spectral lines :- (V IMP)



$n \rightarrow 3 \rightarrow \lambda_1$ $(\lambda_1 > \lambda_2)$

$(n+1) \rightarrow 4 \rightarrow \lambda_2$

Initially michelson interferometer is set for circular fringes. Let the source have wavelengths say λ_1 and λ_2 $(\lambda_1 > \lambda_2)$ which are very close to each other. The two waveleng form their separate fringe patterns but as λ_1 and λ_2 are very close to each other and thicknes air film is small, the two patterns practically coincide. as the mirror M_1 is moved slowly, the patterns separated. further mirror M_1 is moved in such a way that, maximum intensity (brig corresponds to λ_1 is coincides with the maximum intensity (bright) corresponds to λ_2. The posit mirror M_1 is noted as x_1. Further Mirror M_1 is moved in such a way that n^{th} bright of λ_1 coincides with $(n+1)^{th}$ bright of λ_2.

now, the position of mirror M_1 is noted as x_2. Let $x[x_2 - x_1]$ be the effective distan between mirrors M_1 & M_2^1. Then

$$2x = n\lambda_1 \quad \text{——————} (1) \quad \&$$

$$2x = (n+1)\lambda_2 \quad \text{——————} (2)$$

from eq'n (1) $\Rightarrow$

$$n = \frac{2x}{\lambda_1} \quad \text{——————} (3)$$

from eq'n (2) $\Rightarrow$

$$(n+1) = \frac{2x}{\lambda_2} \quad \text{——————} (4)$$

$(4)-(3) \Rightarrow$

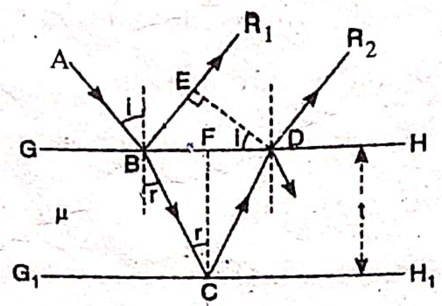
$$(n+1) - n = \frac{2x}{\lambda_2} - \frac{2x}{\lambda_1}$$

$$1 = \frac{2x\lambda_1 - 2x\lambda_2}{\lambda_1\lambda_2}$$

$$\Rightarrow 2x(\lambda_1 - \lambda_2) = \lambda_1\lambda_2$$

$$\boxed{\lambda_1 - \lambda_2 = \frac{\lambda_1\lambda_2}{2x} = \frac{\lambda_{avg}^2}{2x}} \qquad \left[\because \lambda_{avg} = \frac{\lambda_1 + \lambda_2}{2}\right]$$

13). Oblique incidence of a plane wave on a thin film due to refleced light:- (Cosine Law)



Let GH and G_1H_1 be the two surfaces of Transparent film of uniform thickness 't' and Refractive index 'μ' as shown in fig. Suppose a ray AB of monochromatic light is incident on its upper surface. This ray is partly reflected along BR_1 and refracted along BC. After one reflection at 'C', we obtain the ray CD. After refraction at D, the ray finally emerges out along DR_2 in air. Obviously DR_2 is parallel to BR_1 inorder to calculate the path difference between the rays, we draw a normal DE on BR_1.

The path difference between the rays is given by

$$\Delta = \mu(BC + CD) - BE \text{ ——— } (1)$$

From the Δ^{le} $BCF \Rightarrow$

$$Cos\, r = \frac{CF}{BC}$$

$$Cos\, r = \frac{t}{BC}$$

$$\Rightarrow BC = CD = \frac{t}{Cos\, r} \text{ ——— } (2)$$

from the $\Delta^{le} BCF \Rightarrow$

$$Tan\, r = \frac{BF}{FC}$$

$$\Rightarrow BF = FC\, Tan\, r$$

$$BF = t\, Tan\, r \quad \&$$

$$BD = BF + FD$$

$$BD = 2BF = 2t\, Tan\, r$$

from the Δ^{le} $BED \Rightarrow$

$$\sin i = \frac{BE}{BD}$$

$$\Rightarrow BE = BD \sin i$$

$$BE = 2t \tan r \sin i \text{ ——— } (3)$$

we know that,

$$\mu = \frac{\sin i}{\sin r}$$

$$\Rightarrow \sin i = \mu \sin r \text{ ——— } (4)$$

sub|| eq'n (4) in eq'n (3) $\Rightarrow$

$$BE = 2t \tan r(\mu \sin r)$$

$$BE = 2\mu t \tan r \sin r \text{ ——— } (5)$$

sub|| eq'ns (2) & (5), in eq'n (1) $\Rightarrow$

$$\Delta = \mu\left(\frac{t}{\cos r}+\frac{t}{\cos r}\right)-2\mu t \tan r \ \sin r$$

$$\Delta = \frac{2\mu t}{\cos r}\left[1-\sin^2 r\right]$$

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

$$\boxed{\Delta = 2\mu t \cos r} \text{———} (6)$$

This is known as cosine law.

14) Oblique incidence of a plane wave on a thin film due to transmitted light (cosine law):-

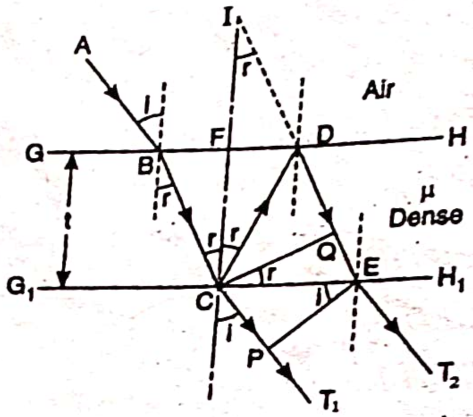


Fig. shows the geometry of the transmitted light to produce interference pattern. Due to simultaneous reflection and refraction we obtain two transmitted rays CT_1 and ET_2. These rays have a constant phase difference. inorder to calulate the path difference between the two transmitted rays, we draw normal CQ on DE and EP on CT_1 and we also produce ED in the backward direction which meets produced CF at I.

The path difference between two transmitted rays is given by

$$\Delta = \mu(CD+DE)-CP \text{———} (1)$$

from Δ^{le} *CPE* $\Rightarrow$

$$\sin i = \frac{CP}{CE} \ \&$$

from Δ^{le} *CQE* $\Rightarrow$

$$\sin r = \frac{QE}{CE}$$

We know that

$$\therefore \ \mu = \frac{\sin i}{\sin r}$$

$$\mu = \frac{\frac{CP}{CE}}{\frac{QE}{CE}} = \frac{CP}{QE}$$

$$\Rightarrow CP = \mu(QE) \text{ ——— } (2)$$

Sub" eq'(2), in eq'n (1) $\Rightarrow$

$$\Delta = \mu(CD + DE) - \mu(QE)$$

$$= \mu(CD + DQ + QE) - \mu(QE)$$

$$= \mu(CD + DQ)$$

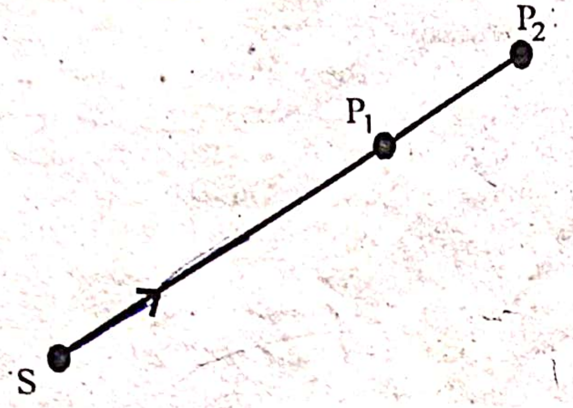
$$= \mu CI$$

$$\boxed{\Delta = 2\mu t \cos \gamma} \text{ ——— } (3)$$

4) Temporal Coherence :- (VIMP)

Temporal coherence is the measure of the average correlation between the value of a wave and it self delayed by (coherence time) " τ " at any pair of times. i.e. it characterizes how well a wave can interfere with itself at different time.

- It describes the correlation between waves observed at different moments in time.



S - Source of light

P_1, P_2 - Two points on the same wave at different moments of time

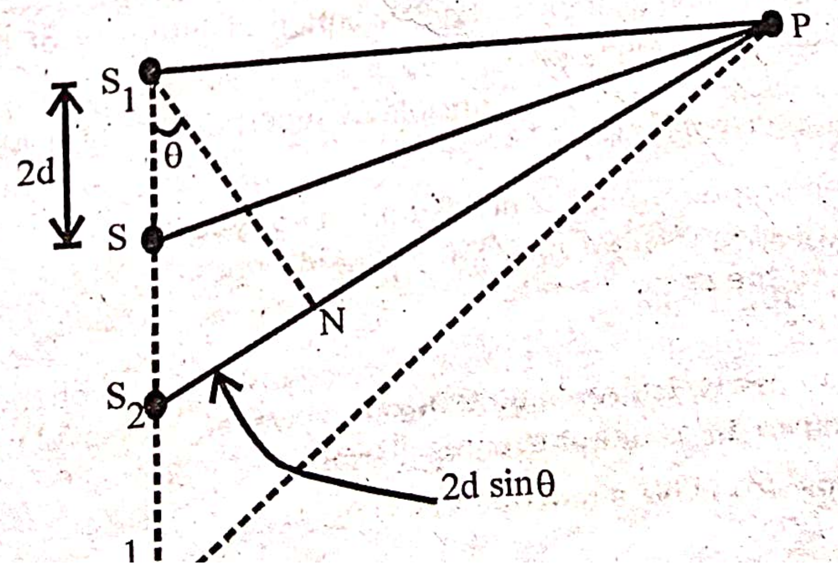
consider a monochromatic source of light 'S' and Two points P_1 & P_2 on the same wave as shown in fig. consider the situation in which the path of wave is extended. hence, the phase difference between P_1 and P_2 will depend on distance between points P_1 and P_2 and coherence length.

- If the distance between P_1 & P_2 is less than coherence length, then the wave maintains constant phase difference between P_1 and P_2 and takes place interference pattern.
- If the distance between P_1 & P_2 is greater than coherence length, then there is no phase relation as a result interference fringes lose sharpness or contrast.

5) Spatial coherence :- (IMP)

If the phase difference for any two fixed points in a plane normal to the wave propagation does not vary with time, then the wave is said to exhibit spatial coherence.

- Spatial coherence describes the correlation between waves at differernt points in space.
- In general, it is the condition for path difference between waves to produce interference pattern.



Let S_1 and S_2 be two sources (atomic emitters) and P be a point of observation as shown in fig. Then the path difference between the waves is given by

$$S_2P - S_1P = 2d \sin\theta$$

in general, the emission time of an atom is 10^{-9} sec. hence the corresponding length is $C\,X\,10^{-9}$.

- To produce interference pattern, the path difference should be less than that $C\,X\,10^{-9}$.

$$\therefore\ S_2P - S_1P = 2d \sin\theta \le C\,X\,10^{-9} \quad \begin{bmatrix} \text{in our consideration} \\ \text{it is valid for } S_1\ \&\ S_2 \end{bmatrix}$$

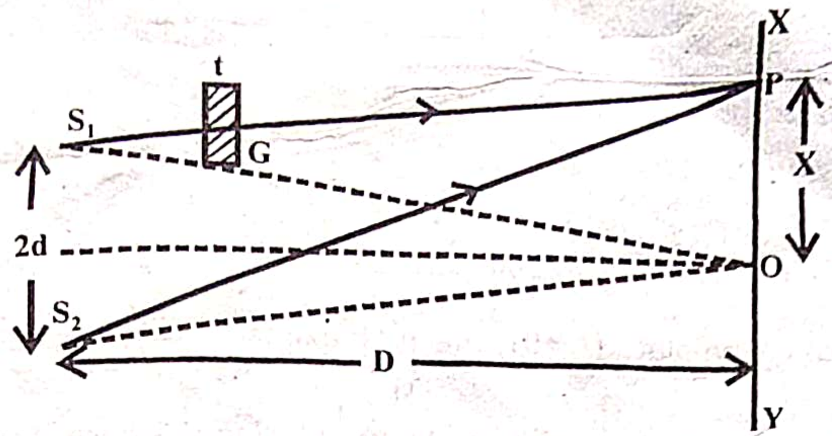
Now, the source S_2 be drawn a part to a position S_2^1.

Then, the path difference becomes $\left(S_2^1P - S_1P\right)$ and the spatial coherence becomes poorer.

i.e. If the path difference b/w two waves is greater than '$C\,X\,10^{-9}$', the interference fringes lose sharpness or contrast.

Interference of light:- (V. IMP)

9) Determination of thickness of a Transparent material using Biprism:- (VVIMP)



The Biprism experiment can be used to determine the thickness of a thin sheet of transparent material such as glass, mica etc. When a thin Transparent sheet of thickness 't' and refractive index 'μ' is introduced in the path of one of the interfering beams as shown in fig, The entire fringe system is displaced through a constant distance towards the path of the beam in which the plate is introduced. Now, we consider the path S_1P. The length (S_1P-t) of this path is travelled in air with the velocity of light C, while the length 't' is travelled in mica with velocity C_g.

$\therefore$ The time taken by a wave to travel from S_1 to $p = \dfrac{(S_1P-t)}{C} + \dfrac{t}{C_g}$

" " $= \dfrac{S_1P-t}{C} + \dfrac{\mu t}{C} \quad \left[\because \mu = \dfrac{C}{Cg} \Rightarrow C_g = \dfrac{C}{\mu}\right]$

" " $= \dfrac{S_1P-t+\mu t}{C}$

" " $= \dfrac{S_1P+(\mu-1)t}{C}$

$\therefore$ The path S_1 to P is equivalent to an air path $= S_1P+(\mu-1)t$

$\therefore$ The path difference at $P = S_2P - S_1P - (\mu-1)t$

$\therefore$ The path difference at $P = \dfrac{2xd}{D} - (\mu-1)t$ ——— (1) $\left[\because S_2P - S_1P = \dfrac{2xd}{D}\right]$

But, we know that, for n^{th} maxima

The path difference at $P = n\lambda$ ——— (2)

from eq'ns (1) & (2) $\Rightarrow$

$$\frac{2x_n d}{D} - (\mu - 1)t = n\lambda \qquad \left[\because \text{ for } n^{th} \text{ fringe } \frac{2xd}{D} = \frac{2x_n d}{D}\right]$$

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

$$\Rightarrow x_n = \frac{D}{2d}\left[n\lambda + (\mu - 1)t\right] \text{———} (3)$$

In the absence of the plate $(t = 0)$, the n^{th} maxima $= \dfrac{Dn\lambda}{2d}$

If 'S' is the displacement of n^{th} maxima by introducing the mica, then

$$S = \frac{D}{2d}\left[n\lambda + (\mu - 1)t\right] - \frac{Dn\lambda}{2d}$$

$$\Rightarrow S = \frac{Dn\lambda}{2d} + \frac{D}{2d}(\mu - 1)t - \frac{Dn\lambda}{2d}$$

$$S = \frac{D}{2d}(\mu - 1)t$$

$$\Rightarrow \boxed{t = \frac{S\,X\,2d}{(\mu - 1)D}} \text{———} (4)$$

Speed = $\frac{\text{dis}}{\text{Time}}$

use [illegible]

$S_1 \to P$

[illegible]

$\Rightarrow S_2 P - S_1 \to P$

$\Rightarrow$ [illegible]

nth fringe x_n

$t = 0 \to$ [illegible]

$S = x_n - x_0$