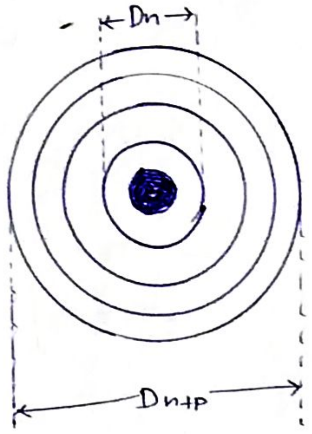
Newton's Rings

Kapil Gupta
D-1 Batch

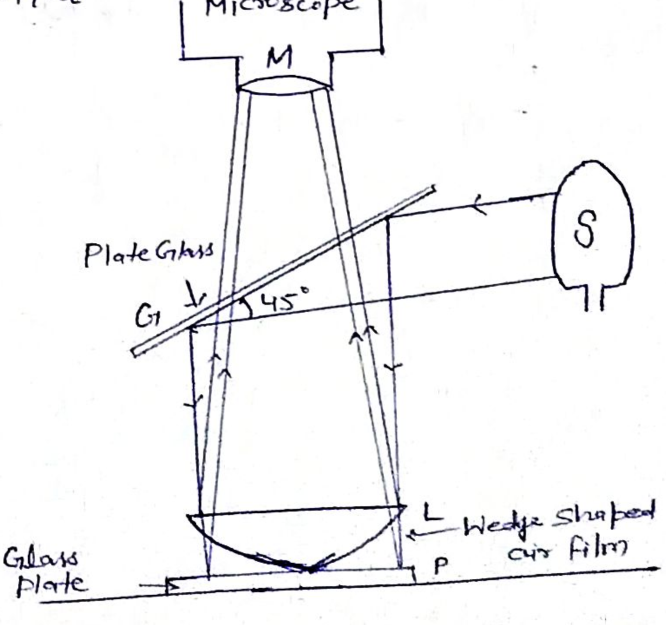
Newton ring is a special case of interference in an air film of variable thickness. When a plano convex lens of large focal length is placed in contact with a plane glass plate. We get a thin air film.

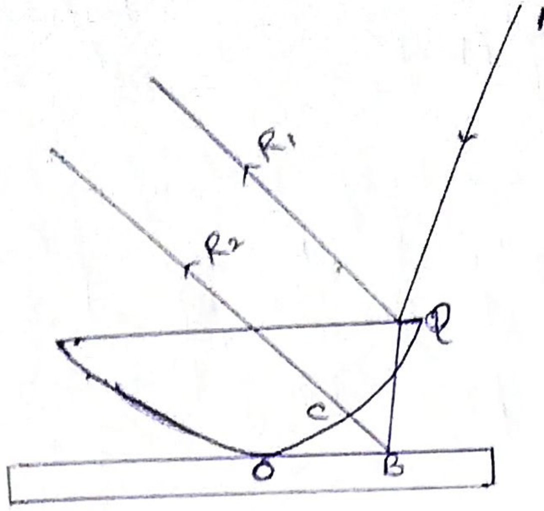
Thickness of this film increases when we proceed from point of contact. When monochromatic light falls normally on such a film. We get an inner dark spot surrounded by an alternatively bright & dark circular rings when seen by reflected light and vice-versa by transmitted light.



The air film is wedge shaped and ~~foci~~ loci of points of equal thickness are circle concentric with point of contact these rings are known as Newton rings.

This it the Experimental arrangement of Newton's Rings.





As shown in fig. Reflected rays are QR_1 and BCR_2 and path difference btw them is.

$$\boxed{\Delta_1 = 2\mu t \cos(\theta + r)}$$

t = thickness of film
$\mu = 1$ (for air film)

Here 'θ' is very small so-

$$\cos(\theta + r) = 1$$

then $\boxed{\Delta_1 = 2\mu t}$

* The ray QR_1 is reflected from rarer medium and BCR_2 is reflected from denser medium, So an additional path different of '$\lambda/2$' is also created.

$$\boxed{\Delta_2 = \left(2\mu t - \lambda/2\right)}$$

$$\boxed{\Delta_{net} = (2n-1)\lambda/2}$$

⇒ Conditions for destructive interferance or (Dark fringes)

$$\Delta_1 = n\lambda$$

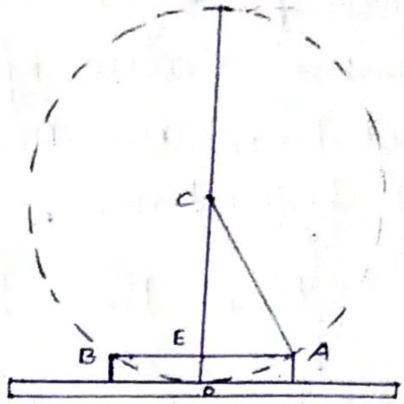
$$\boxed{2\mu t_n = n\lambda} \quad \therefore (n = 0, 1, 2, ---)$$

Similarly for constructive interferance or (Bright fringes)

$$\boxed{2\mu t_n = (2n-1)\lambda/2} \quad \therefore (n = 1, 2, ---)$$

Diameter of ~~Dark~~ fringes
Bright

let the centre of curvature is 'c' then-
thickness of film is t_n of point of incidence 'A' and radius is EA. (Assume a circle at Bottom with AB as a diameter)



$$CA^2 = AE^2 + CE^2$$

$$R^2 = r_n^2 + (R - t_n)^2$$

$$r_n^2 = 2Rt_n - t_n^2 \qquad (R >>> t_n)$$

$$r_n^2 = 2Rt_n$$

$$\boxed{r_n = \sqrt{2Rt_n}}$$

Diameter of n^{th} Ring $\quad D_n = 2r_n$

$$\boxed{D_n = \sqrt{8Rt_n}}$$

For diameter of dark fringe put $t_n = \frac{n\lambda}{2\mu}$

$$\boxed{D_n = 2\sqrt{\frac{n\lambda R}{\mu}}}$$

Similiarly for Bright fringe put t_n and then get.
Here clearly we can see that :-
diameter is directly proportional to
(i) Natural Number
(ii) Wave length
(iii) Radius of Curvature
(iv) $\frac{1}{\mu}$

In the experimental arrangement a photo convex lens L of large radius of curvature 'R' is placed on a plane glass plate 'p' and Newton Ring's are observed in an air film btw the lens and the glass. plates with help of a travelling microscope diameter btw n^{th} & $(n+p)^{th}$ of rings are:-

$$\boxed{(D_{n+p}^2 - D_n^2) = 4p\lambda R}$$

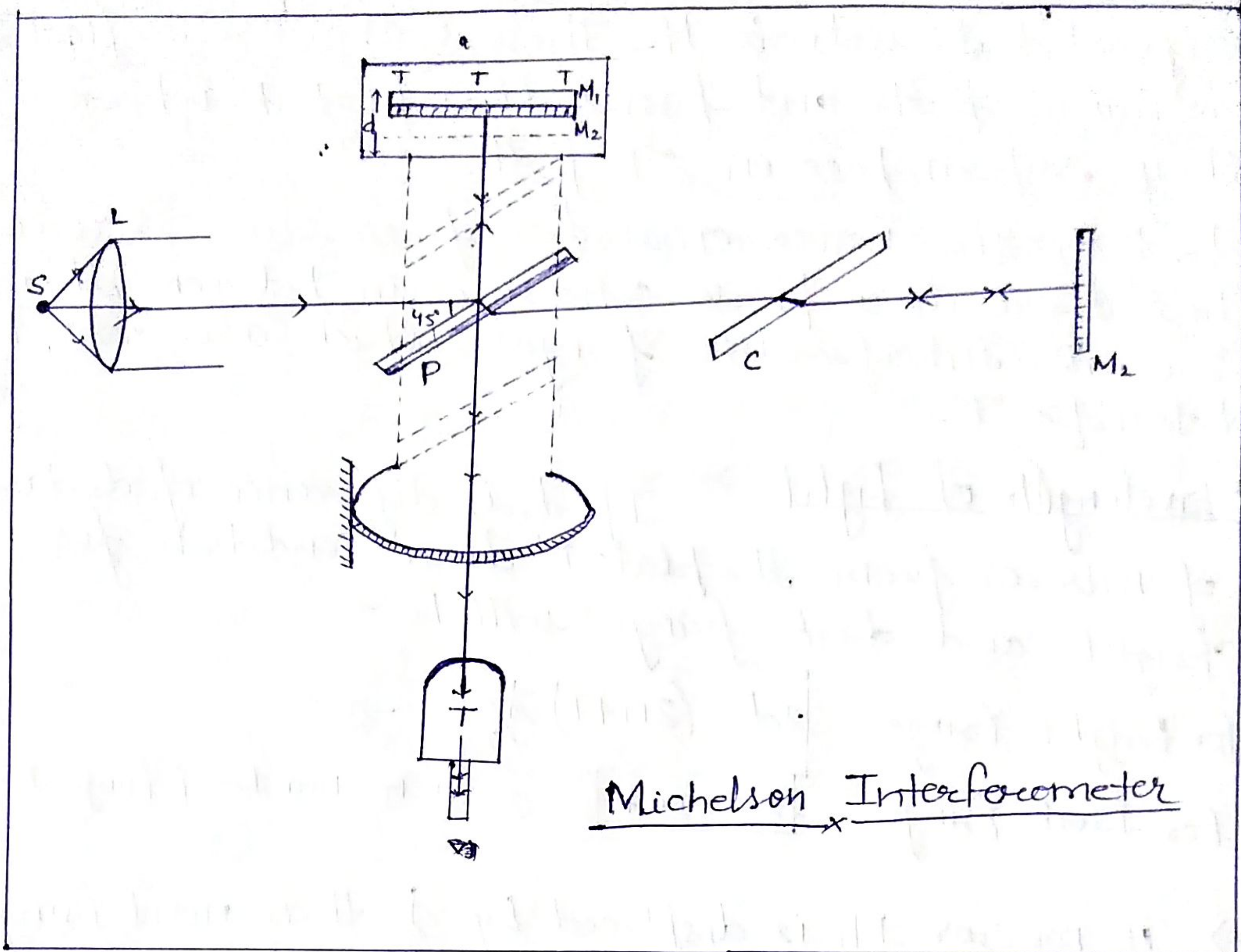
Now a few drops of transparent liquid whose refractive index is to be determined is placed btw the lens 'L' and glass plate 'P' of Newton rings arrangement for the same value of 'p' the diameter of two rings D'_n and D'_{n+p} are measured hence refractive index 'μ' of liquid are.

$$\boxed{D'^2_{n+p} - D'^2_n = \frac{4p\lambda R}{\mu}}$$

By dividing above two eqⁿs.

$$\boxed{\mu = \frac{D^2_{n+p} - D^2_n}{D'^2_{n+p} - D'^2_n}}$$

Michelson's Interferometer



Michelson Interferometer

Construction :-

In above fig. 's' is extended light source. Light from the source 's' passes threw the lens. Then incident on two parallel plane glasses 'P' and 'c'. both inclined at 45° angle.

Plate 'c' is known as compensating plate. And the Half portion of 'p' which is towards plate 'c' is half silvered. The reflected and ~~refracted~~ transmitted rays from two perpendicular mirrors M_1 and M_2 respectively. Both the mirrors are adjusted with screws. The fringes are seen through the telescope 'T.'

Working :-

When parallel beam of light coming from the lens is incident on plate 'P', then it's half part is reflected and remaining half is refracted by amplitude division process.

Then reflected wave travels to mirror M_1 and refracted travels to M_2. These waves are reflected on same path and passes the plate 'P' where they superimpose on OT path.
As both the waves emanates from same source, thus there is a phase coherence in between them. So creates interferance fringes. which are seen by telescope T.

→ **Wavelength of Light** :→ If 'd' is difference of distances of mirror from the plate 'P' then condition for bright and dark fringes will be:-

For Bright fringe $\boxed{2d = (2n+1)\lambda/2}$ -①

For Dark fringe $\boxed{2d = n\lambda}$ -② (∵ n = number of fringes.)

⇒ if mirror M_1 is displaced by $\lambda/2$ then next fringe is observed i.e. n to $(n+1)$. Let mirror M_2 is displaced by distance x, then N fringes are shifted. Thus-

$$\boxed{2(d+x) = (n+N)\lambda} \quad -③$$

from ② & ③

$$2x = \lambda N$$

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

Here :- N = No. of fringes
x = x is determined by micrometer screen

→ **Refractive index of thin film** :→ Michelson interferometer is adjusted to produce straight white light fringe and telescope is focused with it's the cross wire is set on the a chromatic fringe with is perfectly straight.

The given plate is now inserted in path of the interfering beams. This increases the optical path of that beam by $(\mu-1)t$.
Where 'μ' is refractive index and 't' is thickness of the plate. Since the beam transverse the plate twice the two interfering beams. The fringes are therefore shifted. The moveable mirror M_2 is moved full the fringes are brought back to their initial position so that a chromatic fringe again coinsides with the cross-wire if the displacement of M_1 is x.

then:-

$$2(\mu-1)t = 2x$$

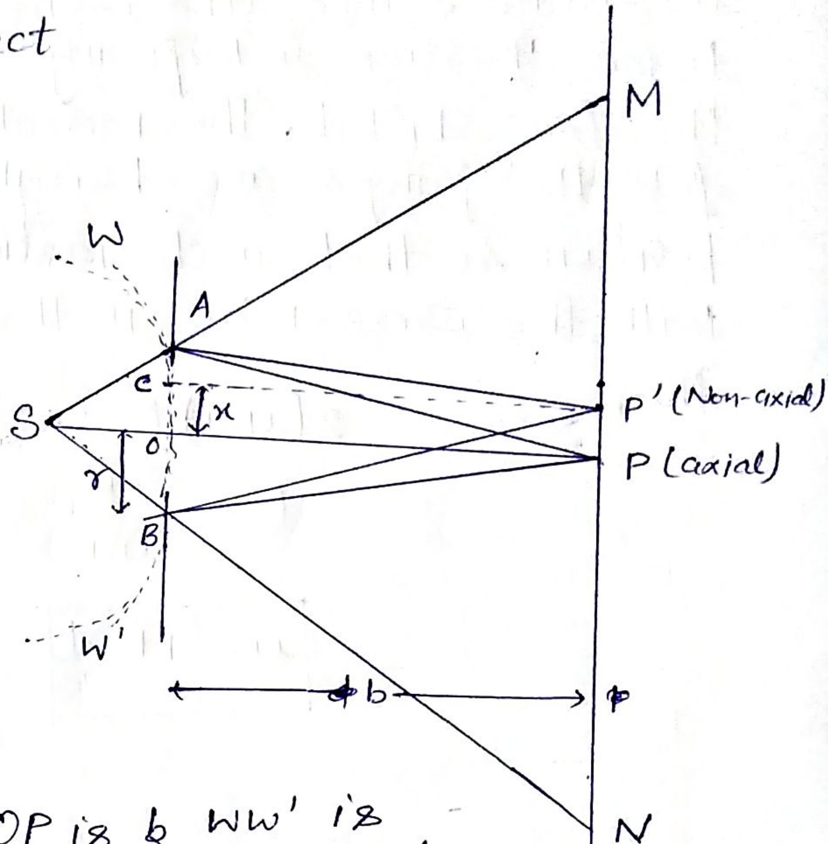
$$t = \frac{x}{(\mu-1)}$$

$$\boxed{\mu = 1 + \frac{x}{t}}$$

Fresnel's Diffraction

Fresnel's diffraction is used to calculate the diffraction pattern created by waves passing through an aperture or around an object when viewed closely to object

Let us consider a point light source 'S' of wavelength λ emits a spherical wavelet WW' and illuminate a circular appertuire AB of radius r.



① Intensity @ Axial Point P :→

let the distance btw OP is b WW' is spherical wavefront which is incident on AB. To consider the intensity at P, half period zones are constructed.

If the distance 'b' is such that only one half period zone can be visible then intensity at point P is given by :-

$$\boxed{I = E_0^2}$$

For this value maximum intensity is obtained at point 'P'.

If 'b' is deacreased in such a way that aperture faces two half period zones than resultant amplitude.

$$\boxed{E_0 = E_{01} - E_{02}}$$

Thus by altering value of 'b' the point 'P' becomes alternatively bright and dark depending on whether odd or even number of zones are exposed by the apareture.

② **Intensity @ Non-axial Point (P') :→**

As shown in above figure Path difference will given by :-

$\Delta = SBP' - SAP'$

$\Delta = (SB + BP') - (SA + AP')$ $\quad$ $(\because SB = SA)$

$\Delta = BP' - AP'$

Now in $\Delta BCP'$

$(BP')^2 = (BC)^2 + (CP')^2$

$(BP')^2 = (r+x)^2 + b^2$

$BP' = \sqrt{b^2 + (x+r)^2}$

$BP' = b\left(1 + \left(\frac{x+r}{b}\right)^2\right)^{1/2}$

Now using Bionomial Expansion

Since $b >> (x+r)$

$$\boxed{BP' = \left[b + \left(\frac{(x+r)^2}{2b}\right)\right]} \quad -①$$

Similarly $AP' = [b^2 + (x-r)^2]^{1/2}$

$$\boxed{AP' = \left[b + \frac{(x-r)^2}{2b}\right]} \quad -②$$

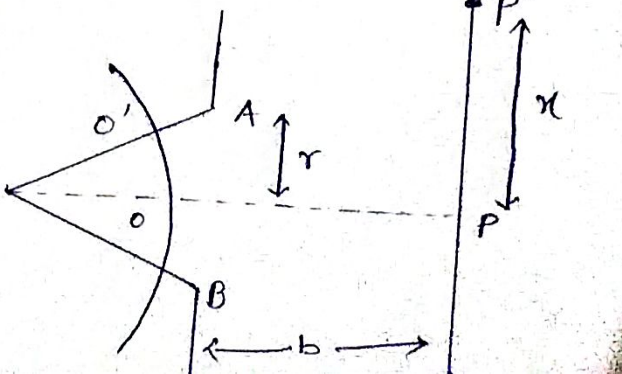
for $\Delta = BP' - AP'$ we ① - ②

$$\Delta = \cancel{b} + \left(\frac{(x+r)^2}{2b}\right) - \cancel{b} - \frac{(x-r)^2}{2b}$$

$$\boxed{\Delta = \frac{2xr}{b}}$$

For Bright fringes (n = odd)

For P' if n is odd then intensity of light will be maximum i.e. P' illuminated.



let for this maximum condⁿ state

if $x = x_m$ then

$$\boxed{\Delta = \frac{2x_m r}{b} = \frac{(2m+1)\lambda}{2}}$$

$$\boxed{x_m = \frac{nb\lambda}{4r} = \frac{(2m+1)b\lambda}{4r}} \qquad m = 0, 1, 2, \ldots$$

The radius of illuminated ring of order 'm' given by :-

$$x_m = \frac{(2m+1)b\lambda}{4r}$$

② <u>For Dark Fringe :-</u> $(n = \text{even})$

if 'n' is even then intensity of light will be minimum at point P'. will be dark than radius of m^{th} order is given as.

$$\boxed{x_m = \frac{2mb\lambda}{4r}}$$

Thus dark & bright concentric rings are observed on the screen.

K.K