$\left(\frac{\partial n}{\partial n} - \frac{\partial m}{\partial y}\right)$

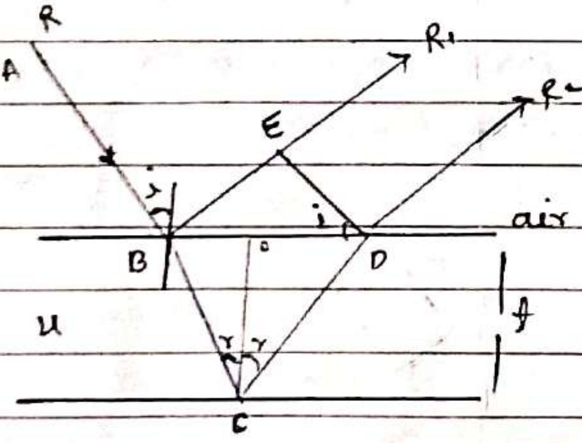
UNIT III
(Interference & Diffraction)

Interference: Special redistribution of intensity due to superposition of two waves with constant phase difference.

Coherent Source: The two source of light said to be coherent if they emit light which have always constant phase difference.

+ Coherent source are obtained
(a) Division of wave front (Eg slit method)
b) Division of amplitude (by thin film)

Interference in thin film due to Reflected ray:



Path diff b/w two rays (R_1 & R_2)

$\Delta = \mu(BC + CD) - BE$ —— ①

$\because \angle BED$

$\sin i = BD \sin i$

$\Delta = \mu(BC + CD) - BD\sin i$

$\Delta = \mu(BC + CD) - (OB + OD)\sin i$ —— ②

In ΔBOC & ΔDOC

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

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

$$\left[BC = \frac{t}{\cos r} \right]$$

Similary

$$\left[CD = \frac{t}{\cos r} \right]$$

$$\tan r = \frac{OB}{OC}$$

$$OB = OC \tan r$$

$$[OB = t \tan r]$$

Similarly

$$[OD = t \tan r]$$

Therefore eqn ② becomes.

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

$$\Delta = \frac{2\mu t}{\cos r} - 2t \tan r \, \mu \sin r$$

$$\Delta = \frac{2\mu t}{\cos r} - 2t \frac{\sin r}{\cos r} \mu \sin r \quad \left(\because \mu = \frac{\sin i}{\sin r} \right)$$

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

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

$$\left[\Delta = 2\mu t \cos r \right]$$

According stoken Law'

$\therefore$ The total P.D $= \Delta \pm \frac{\lambda}{2}$

$$\left[\Delta eff = 2\mu t \cos r \pm \frac{\lambda}{2} \right]$$

Condition:- Constructive interference

$$\Delta eff = \frac{2n\lambda}{2}$$

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

$$\left[2\mu t \cos r = (2n-1)\lambda/2 \right] \quad n = 1, 2, 3, \ldots$$

⊙ Destructive Interference:

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

<u>for Dark</u>

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

$$\left[2\mu t \cos r = n\lambda \right] \quad n = 0, 1, 2,$$

Note: When $t=0$ the path difference is $\lambda/2$ so condition of minimum intensity is satisfied.

Q. A parallel beam of sodium light of wavelength 5880 A° is incident on a ~~thom latt~~ thin glass plate of reflective index 1.5 such that the angle of refraction in the plate is 60°. Claculate the mallest thikness of the plate which will made it appear dark by reflection.

$\lambda = 5880 A°$ $\quad t = ?$

$\mu = 1.5$

$r = 60°$

for dark fringe $n=1$

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

$$t = \frac{n\lambda}{2\mu\cos r} = \frac{1\times 5880\times10^{-8}}{2\times1.5\times\cos 60}$$

$$\boxed{t = 3920\times10^{-8}\,cm}$$

Q. Calculate the thikness of thennearst film ($\mu = 1.4$) in which interference of violet component $\lambda = 4000Å$ of Normal incidence of light can take place by reflection.

$\mu = 1.4$ $\quad \lambda = 4000Å = 4000\times10^{-10}m = 4000\times10^{-8}cm$

$t = ?$ $\quad r = 0$

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

$$\cancel{t = \frac{n\lambda}{2\mu\cos r} = \frac{1\times4000\times10^{-8}}{2\times1.4\cos 0}} =$$

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

$$t = \frac{(2n-1)\frac{\lambda}{2}}{2\times1.4\cos r}$$

$$= \frac{1\times4000\times10^{-8}}{4\times1.4\cos 0}$$

$$\boxed{t = 714.28\times10^{-8}\,m}$$

stryke

A parallel beam of sodium light $\lambda = 5890 A^\circ$ ~~strike~~ a film of oil floating on water. when viewd and angle of 30° from the normal 8th dark band is seen. determine the thikness of the film. Effectiv index of oil = 1.5

Sol.

$$\lambda = 5890\,A^\circ = 5890 \times 10^{-8}\,cm \qquad i = 30^\circ$$

$$n = 8$$

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

$$t = \frac{n\lambda}{2\mu \cos 30} = \frac{8 \times 5890 \times 10^{-8} \times 2}{2 \times 1.5 \times \sqrt{3}}$$

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

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

$$\cos r = \sqrt{1 - \sin^2 r}$$

$$= \sqrt{1 - \left(\frac{\sin i}{\mu}\right)^2}$$

$$= \sqrt{1 - \left(\frac{\sin 30}{\mu}\right)^2}$$

$$\cos r = 0.94$$

$$t = \frac{8 \times 5890 \times 10^{-8}}{2 \times 1.5 \times 0.943}$$

$$\boxed{t = 1.665 \times 10^{-4}\ cm}$$

A soap film of reflective index 1.43 is illumented by white light incedent at angle of 30° the reflected light is examin by spectroscopy in which drak-band crossponding to the wavelength 6×10^{-7}m is obserbed. Calculate the thickness of the film.

Sol

$\mu = 1.43$ $\lambda = 6\times10^{-7}$m $= 6\times10^{-5}$cm

$i = 30$

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

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

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

$t = \frac{1\times6\times10^{-5}}{2\times1.43\times\cos 30}$

$\cos r = \sqrt{1-\left(\frac{\sin 30}{\mu}\right)^2}$

$t = \frac{1\times6\times10^{-5}}{2\times1.43\times0.86}$

$= \sqrt{1-\left(\frac{\sin 30}{1.143}\right)^2}$

$[\, t = 2.60\times10^{-5}\text{cm} \,]$

$\cos r = 0.80$

Q. Light of wavelenght 5893 Å is reflected at nearly normal incident from a soap film of reflective index $\mu = 1.42$. What is the least theakness of the film that will apear first ① Dark ② bright

$\mu = 1.42$

$\lambda = 5893\times10^{-8}$ cm

$r = 0$

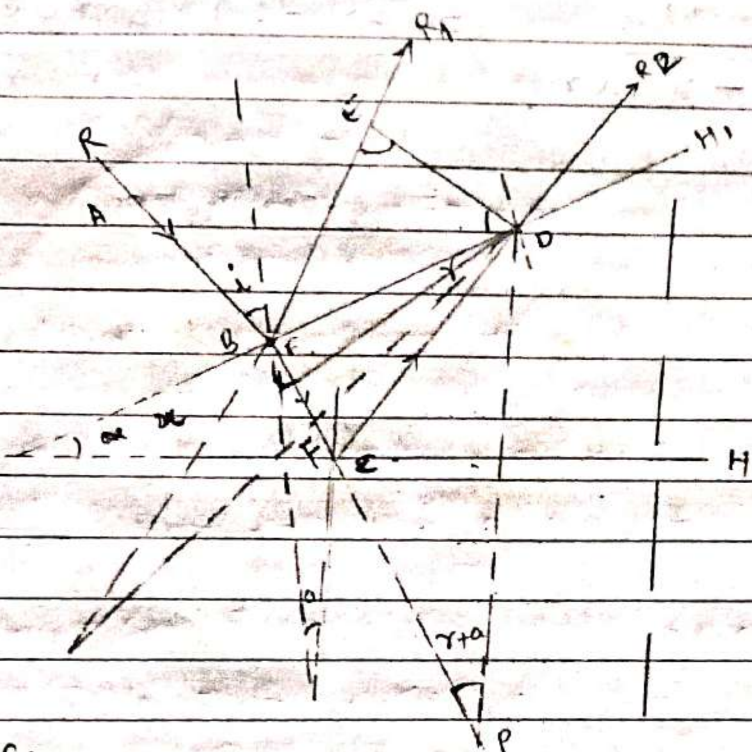
for Dark

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

$t = \frac{5893\times10^{-8}}{2\times1.42\times\cos 0} = 2075\times10^{-8}$ cm

$= \cancel{2.075\times10^{-5}}$ cm

Interference due to wedge shaped film:-



from figure

$\because$ $BE = \mu FB$

$\therefore$ $CD = CP$

$\cos(r+\alpha) = \frac{FP}{PD} = \frac{FP}{2t}$

$FP = 2t\cos(r+\alpha)$

P.D b/w two rays (R_1 & R_2)

$\Delta = \mu(BC + CD) - BE$

$= \mu(FB + FC + CD) - \mu FB$

$= \mu(FC + CD)$

$= \mu[FC + CP]$

$[\Delta = \mu FP]$

$$\boxed{\Delta = 2\mu t\cos(r+\alpha)}$$

According to Stoke's law.

The total p.D $= \Delta + \frac{\lambda}{2}$

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

Condition. constructiv interference

$$\Delta eff = 2n\frac{\lambda}{2}$$

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

$$2\mu t\cos(r+\alpha) = (2n-1)\frac{\lambda}{2} \quad n = 1, 2, 3, \ldots$$

② Destructive Interference

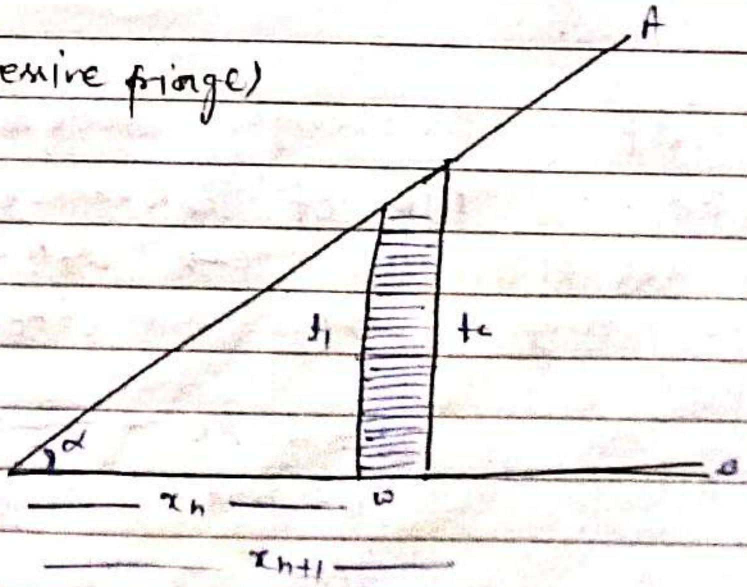
$$\Delta eff = (2n-1)\lambda/2$$

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

$$[\, 2\mu t\cos(r+\alpha) = n\lambda \,] \quad n = 0, 1, 2 \ldots$$

Fringe width (ω):

(space b/w two successive fringe)



from fig $\tan\alpha = \frac{t_1}{x_n}$

$t_1 = x_n \tan\alpha$

Similarly

$l_2 = x_{n+1} \tan\alpha$

for dark fringe

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

for normal incident $r = 0$

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

$\therefore \quad 2\mu x_n \tan\alpha \cos\alpha = n\lambda$ — ①

Similarly $\quad 2\mu x_{n+1} \tan\alpha \cos\alpha = (n+1)\lambda$ — ②

from eqn ① & ② we get

$2\mu(x_{n+1} - x_n) \tan\alpha \cos\alpha = (n+1)\lambda - n\lambda$

$2\mu\omega \frac{\sin\alpha}{\cancel{\cos\alpha}} \cancel{\cos\alpha} = \lambda$

$$\boxed{\omega = \frac{\lambda}{2\mu \sin\alpha}}$$

$\because \sin\alpha \approx \alpha$ in rad

$$\boxed{\omega = \frac{\lambda}{2\mu\alpha}}$$

Q. light of wavelength 6000 A' falls normaly on a thin wedge. film of infrective index 1.4 forming fringes than an ~~ez~~ 2.0 ~~apart~~ A part find the angle wedge in second.

$\lambda = 6000\ A' = 6000 \times 10^{-8}\ cm$

$\mu = 1.4$

$w = 0.20\ cm$

$$w = \frac{\lambda}{2\mu\alpha}$$

$$\alpha = \frac{\lambda}{2w\mu}$$

$$\alpha = \frac{6000 \times 10^{-8}}{2 \times 0.20 \times 1.4}$$

$$= 10.71 \times 10^{-5} \times \frac{180}{\pi}$$

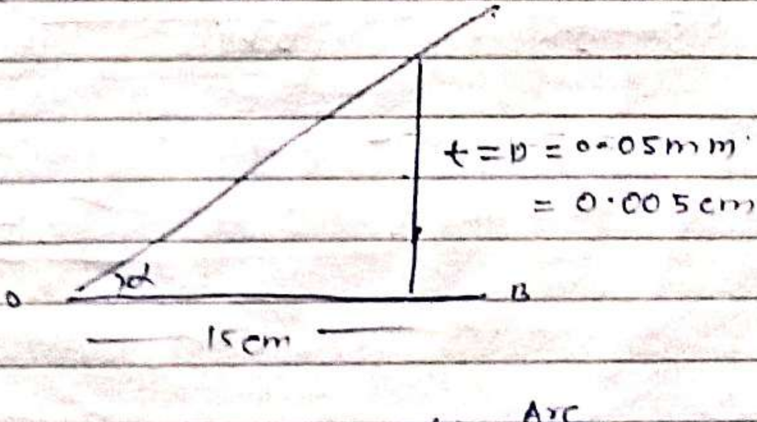
$$\alpha = 0.0061^{\circ}$$

$$\alpha = 0.0061 \times 60 \times 60$$

$$\boxed{\alpha = 21.96\ sec}$$

8. Two glass plate inclose a wedeg shap air film, touching at one wedge and are sperated by a wire of 0.05 mm diameter at a distance of 15cm from the edge. Claculate the fringe width. ($\lambda = 6000 A'$) from a red source false normaly on then film.

Sol^n $\lambda = 6000 \times 10^{-8}\ cm$ $\mu = 1$



$$\alpha = \frac{Arc}{radious}$$

$$\alpha = \frac{0.005}{15}$$

$$\omega = \frac{\lambda}{2\mu\alpha}$$

$$\omega = \frac{6000\times10^{-8}\times15}{2\times1\times0.005}$$

$\omega = 0.9$ $\boxed{w = 0.09\ cm}$

Q To plane glass surface in contect along one edge are suprated at the opposite edge by a thane wire if 20 interfrendge are observed b/w these edge in sodium light of $\lambda = 5890$ Å of normal incident. find the daimeter of thin wire.

Soln.

$$\lambda = 5890\times10^{-8} cm$$
$$n = 20$$

$$\alpha = \frac{t}{x} = \frac{D}{nw}$$

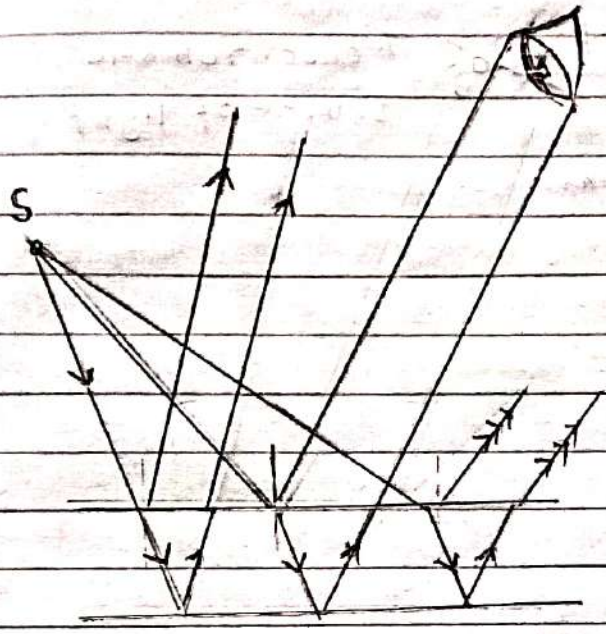
$$\omega = \frac{\lambda}{2\mu\alpha}$$

$$\omega = \frac{\lambda n w}{2\mu D}$$

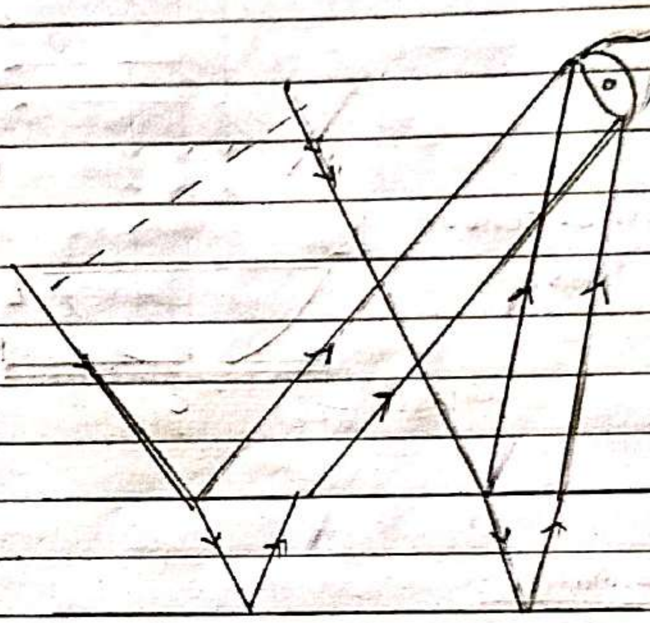
$$D = \frac{n\lambda}{2\mu} = \frac{20\times5890\times10^{-8}}{2\times1}$$

$$\boxed{D = 5.8\times10^{-4}\ cm}$$

Necessity of extended sources:- The entire film can be viewed simultaneously by keeping the eye at one place only due to extended source.

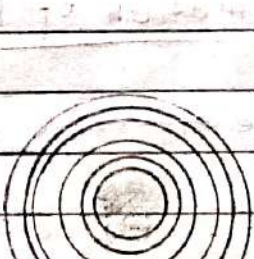


(a)

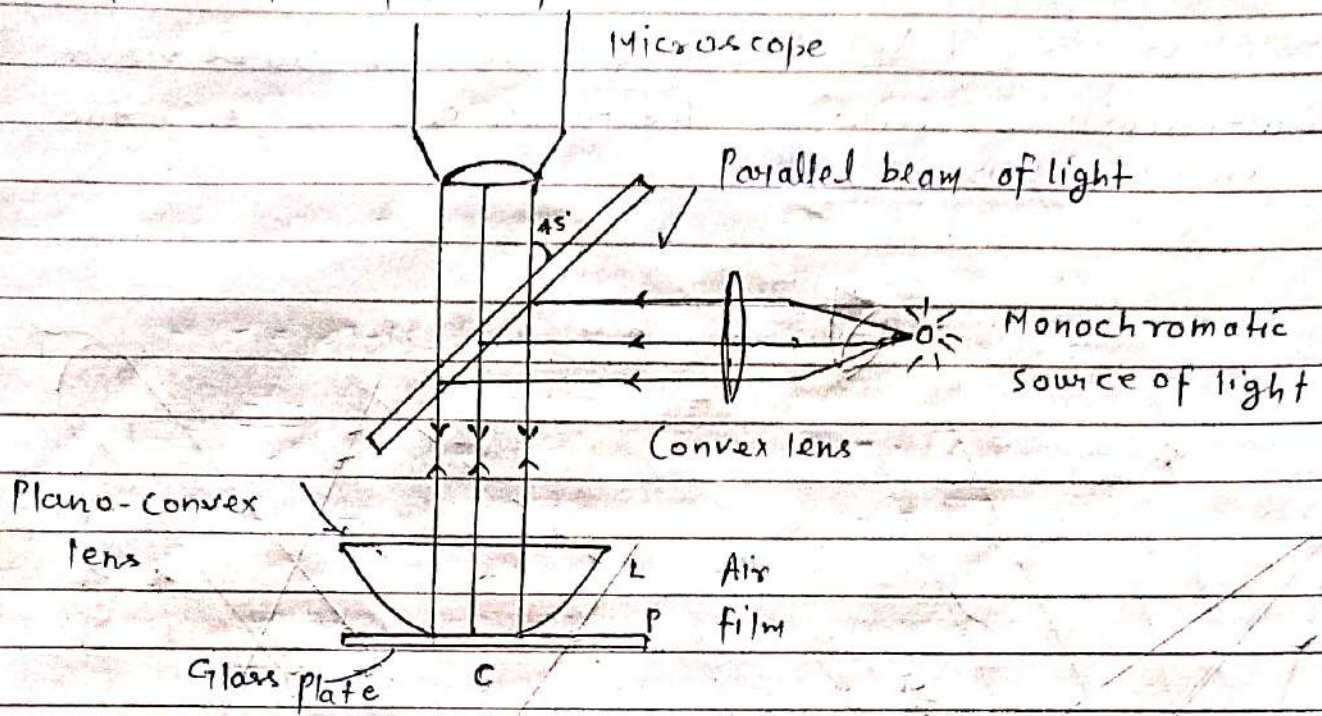


(b)

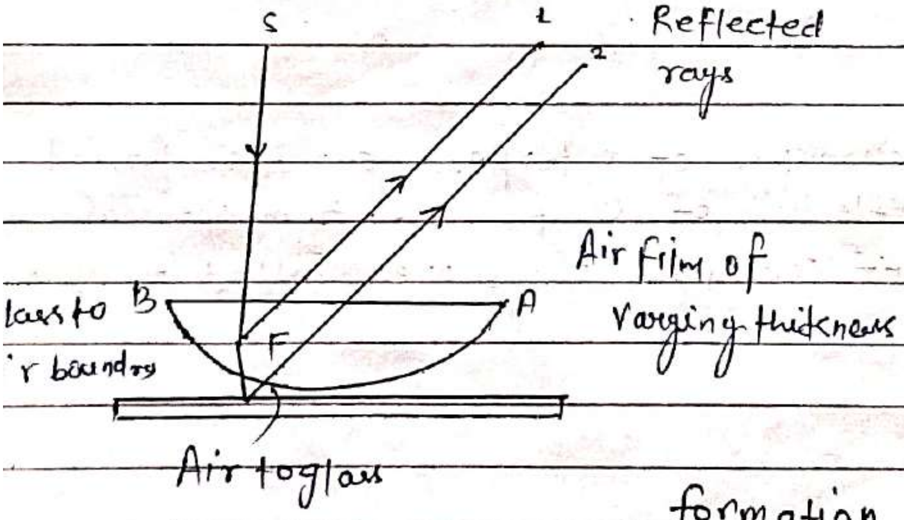
Newton's rings: The phenomenon of interferance pattern formed by the reflection of light waves from sperical surface in the form of concentric rings are called Newton's rings.



Experimental setup:



formation:



formation of Newton's rings:

So, the effective path diff b/w two rays

$$\boxed{\Delta_{eff} = 2\mu t\cos r \pm \frac{\lambda}{2}}$$

for normal incidence. $r = 0$

$$\left[\Delta eff = 2\mu t \pm \frac{\lambda}{2} \right]$$

Condition 1. Bright rings.

$$\Delta eff = 2n\frac{\lambda}{2}$$

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

$$\left[2\mu t = (2n-1)\frac{\lambda}{2} \right] \quad n = 1, 2, 3$$

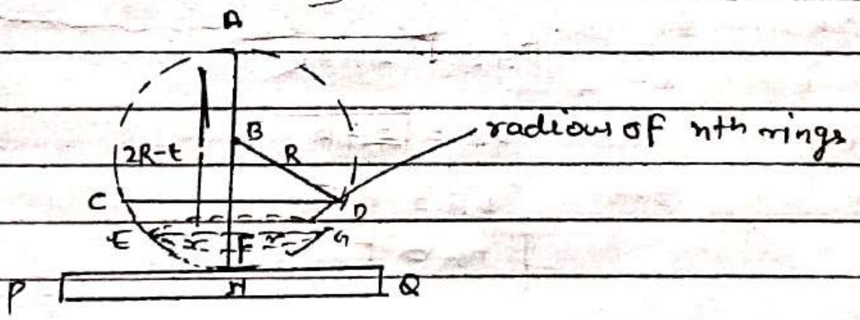
2. Dark rings. $\Delta eff = (2n-1)\frac{\lambda}{2}$

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

$$\left[2\mu t = n\lambda \right] \quad n = 0, 1, 2 \dots$$

Imp

Diameters of bright and dark rings:



from property of circle

$FG \times EF = FH \times AF$

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

$r^2 = 2Rt - t^2$

$\because t << R$ then $2Rt - t^2 = 2Rt$

$r^2 = 2Rt$

$$\left[t = \frac{r^2}{2R} \right]$$

$\because$ for air film $\mu = 1$

① for Bright rings

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

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

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

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

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

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

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

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

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

$$\left[D_n \propto \sqrt{(2n-1)} \right] \quad n = 1, 2, 3$$

② for Dark rings

$2\mu t = n\lambda$

$\frac{2\mu r_n^2}{2R} = n\lambda$

$r_n^2 = \frac{n\lambda R}{\mu}$

$\frac{D_n^2}{4} = \frac{n\lambda R}{\mu}$

$$\left[D_n^2 = \frac{4n\lambda R}{\mu} \right]$$

for air film $\mu = 1$

$D_n^2 = 4n\lambda R$

$D_n = \sqrt{4n\lambda R}$

$D_n = \sqrt{4\lambda R}\sqrt{n}$

$D_n = K\sqrt{n}$

$$\left[D_n \propto \sqrt{n} \right]$$

Determination of wavelength of sodium light: If D_n and D_{n+p} be the diameter of nth and $(n+p)$th dark rings respectively.

$$D_n^2 = \frac{4n\lambda R}{\mu}$$

$$D_n^2 = 4n\lambda R \quad \text{——} (1)$$

Similarly,

$$D^2_{n+p} = 4(n+p)\lambda R \quad \text{——} (2)$$

Substracting eqn (1) from eqn (2) we get

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

$$D^2_{n+p} - D_n^2 = 4P\lambda R$$

$$\boxed{\lambda = \frac{D^2_{n+p} - D_n^2}{4PR}}$$

n = No of rings
p = No of integer
R = radius of curvature

Determination of Refractive index of liquid:-

If D_n and D_{n+p} be the diameter of nth and $(n+p)$th dark rings respectively (for air film)

$\cancel{D_n^2 = 4n\lambda R}$

$$D^2_{n+p} - D_n^2 = 4p\lambda R \quad \text{——} (1)$$

If D'_n and D'_{n+p} be the diameter of nth and $(n+p)$th dark rings respectively (for liquid film)

$$D'^2_{n+p} - D'^2_n = \frac{4P\lambda R}{\mu'} \quad \text{——} (2)$$

Dividing eqⁿ $\frac{(1)}{(2)}$ we get

$$\left[\frac{D^2_{n+p} - D_n^2}{D'^2_{n+p} - D'^2_n} = \mu' \right]$$

Numerical

Q. Newton's ring are observed normally in reflected light of wavelength 6000A°. The diameter of the 10th dark ring is 0.50cm. find the radious of curvature of the lens & the thickness of the film.

Sol. $\lambda = 6000A° = 6000 \times 10^{-8}$ cm & $n = 10$

$D = 0.50$ cm $R = ?$ $t = ?$

$$D^2_n = \frac{4n\lambda R}{\mu}$$

$R = D_n^2$:

Q. In Newton's ring experiment the diameter of 4th & 12th Dark ring are 0.400 cm and 0.007 cm respectively. Reduce the daimeter of 20th dark ring.

Soln.

$$D_4 = 0.400\,cm, \quad D_{12} = 0.700\,cm$$

$$\because D^2_{n+p} - D_n^2 = 4p\lambda R$$

$$\therefore D^2_{12} - D_4^2 = 4 \times 8 \times \lambda R \quad \text{—— (1)}$$

Similarly

$$D_{20}^2 - D_4^2 = 4 \times 16 \times \lambda R \quad \text{—— (2)}$$

Deivide $\frac{(2)}{(1)}$ we get

$$\frac{D_{20}^2 - D_4^2}{D^2_{12} - D_4^2} = 2$$

$$D^2_{20} - D_4^2 = 2D_{12}^2 - 2D_4^2$$

$D_{20}^2 = 2D_{12}^2 - D_4^2 \Rightarrow 2 \times (0.7)^2 - (0.4)^2$

$\left[D_{20} = 0.906 cm \right]$

Q. In Newton's ring experiment spacing b/w the consecutive rings decreases the increasing order of rings explain?

Ans. $D_n = \sqrt{4n\lambda R}$

$D_1 = \sqrt{4\lambda R}$

$D_1 = 2\sqrt{\lambda R}$

$D_4 = 4\sqrt{\lambda R}$

$\left[D_4 - D_1 = 2\sqrt{\lambda R} \right]$ (No of rings 3)

Also $D_9 = 6\sqrt{\lambda R}$

$D_{16} = 8\sqrt{\lambda R}$

So $\left[D_{16} - D_9 = 2\sqrt{\lambda R} \right]$ No of rings 7/

Q. what will happen when if a liquid introducing b/w plate and lens on Newton's ring.

Ans. The daimeter of rings is reduce by a factor of $\sqrt{\mu}$.

Proof Since Diameter of dark ring in air medium.

$(D_n^2)_{air} = 4\lambda n R$ — ①

In liquid medium

$$(D_n^2)_{liquid} = \frac{4n\lambda R}{\mu} \quad \text{---(2)}$$

Divide eqn $(2)/(1)$ we get

$$\frac{(D_n^2)_{liquid}}{D_n^2\, air} = \frac{1}{\mu}$$

$$\boxed{(D_n)_{liquid} = \frac{(D_n)_{air}}{\sqrt{\mu}}}$$

Q. Why is the center of the Newton's rings dark?

Ans. At the point of center $t=0$, the effective part difference $= \frac{\lambda}{2}$, this is the condition of minimum intensity. Hence center of the ring appears dark.

Q. Why are Newton ring circular?

Ans. Because these rings are foci of constant thikness of the air film. And these foci beingConsprick circle hence rings are circular.

Q. On what factor does the daimeter of rings depend?

Ans. (1) Refractive index of medium.

(2) Radious of curvature.

(3) wavelength of light.

Q. Why do you use standard sources of lights?

Ans The entire film can be viewd simulticely by keeping the eye at one place only due to extended source.