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Chapter 03 "OPTICS"

Physical Properties of light

Interference — Diffraction — Polarization

* **Interference :-** When two light waves from coherent sources meet together, then the distribution of energy due to one wave is disturbed by the other.

This modification in the distribution of light energy due to super position of two light waves is called interference of light.

- **Coherent Sources :-**

Those sources of light which emit light waves continuously of same wavelength, and time period frequency and amplitude and have zero phase difference or constant phase difference are coherent sources.

There are two types of interference:

(1) Constructive interference.
(2) Destructive interference.

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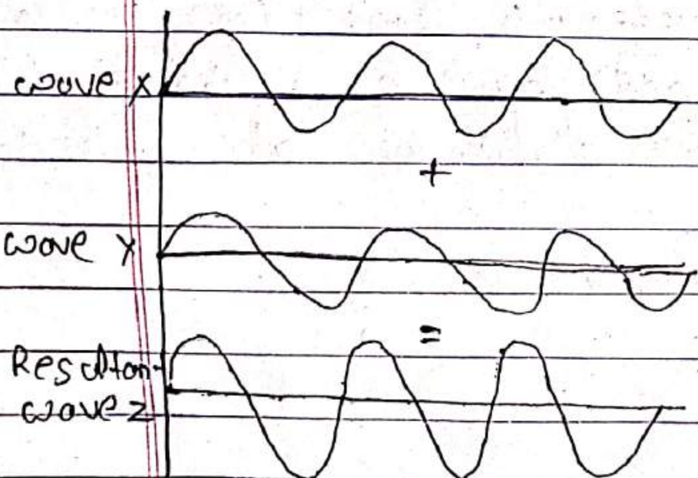
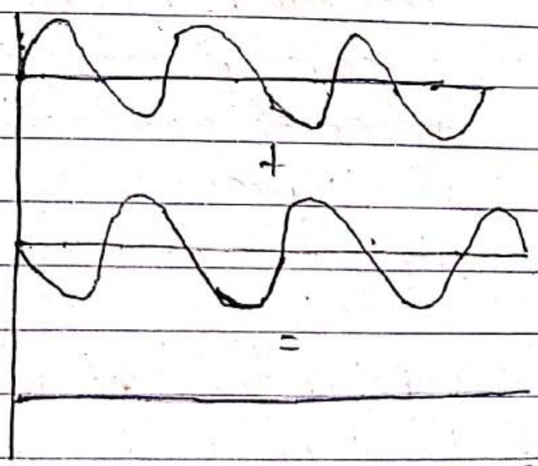
constructive Interference	Distructive Interference
① When two light waves superpose with each other in such away that the crest of one wave falls on the crest of the second wave, and trough of one wave falls on the trough of the second wave, then the resultant wave has larger amplitude and it is called constructive interference	When two light waves superpose with each other in such away that the crest of one wave falls on the trough of the second wave and trough of one wave falls on the crest of the second wave, then resultant wave has no amplitude and it is called destructive interference.
② i.e; Path difference = $n\lambda$, $n = 0, 1, 2, \ldots$	i.e; Path difference $= (2n+1)\frac{\lambda}{2}$, $n = 0, 1, 2, \ldots$



constructive interference



Destructive interference

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Young's double slit experiment / Theory Interference fringes.

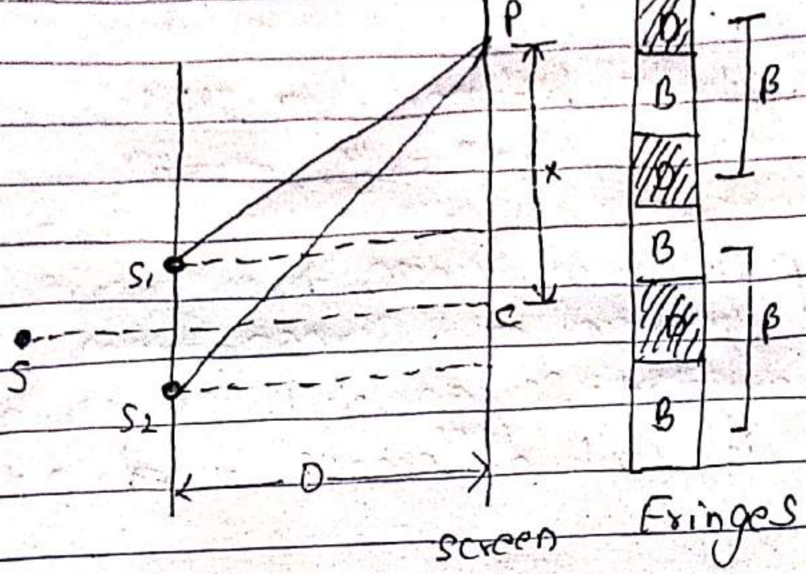

Fig:- Young's double slit experiment.

Let us consider a monochromatic source of light 'S'. Let S_1 and S_2 be the two slits which are equidistant from source S. S_1 and S_2 acts as two coherent sources of light. Light waves from S_1 and S_2 overlap each other so as to produce alternate dark and bright fringes.

From fig, the path difference between the waves from S_1 and S_2 reaching at point 'p' on the screen is S_2N as drawn normal for S_1 to S_2P.

S_1N meets CP at 90°, Then

$\angle CS_1N = \theta$; if $PCO = \theta$

~~consede~~

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In triangle $\Delta S_1 S_2 N$,

$$\sin\theta = S_2N/d$$

$$\Rightarrow S_2N = d\sin\theta \quad \text{--- (i)}$$

where,

d = distance between two slits

Again, from ΔPOC $\tan\theta = \frac{y}{D}$ --- (ii)

where, y = position of fringe from centre of screen

D = distance of screen from slits.

The point 'p' on the screen will correspond to bright fringe if path difference $= n\lambda$ --- (iii)

from (i) and (iii)

$$d\sin\theta = n\lambda \quad \text{--- (iv)}$$

if θ is small, then $\sin\theta \simeq \theta$ and $\tan\theta \simeq \theta$,

from (ii), $\theta = \frac{y}{D}$ --- (v)

and from (iv) $\frac{dy}{D} = n\lambda$

$$\Rightarrow y = \frac{n\lambda D}{d} \quad \text{--- (vi)}$$

when $n=0$, $y_0 = 0$

when $n=1$, $y_1 = \frac{\lambda D}{d}$

when $n=2$, $y_2 = \frac{2\lambda D}{d}$

Distance betn the two consecutive bright fringes will ~~by~~ be $y_1 - y_0 = y_2 - y_1$

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$$y_1 - y_0 = y_2 - y_1$$

or, $\frac{\lambda D}{d} - 0 = \frac{2\lambda D}{d} - \frac{\lambda D}{d}$

or, $\frac{\lambda D}{d} = \frac{\lambda D}{d}$

we get the difference $= \frac{\lambda D}{d}$ and its called fringe width denoted by $\beta = \frac{\lambda D}{d}$ —— (vi)

Similarly, the point p will correspond ~~the~~ to dark fringe if path diff $= (2n+1)\lambda/2$ —— (viii)

from (i) and (viii)

$d \sin\theta = (2n+1)\lambda/2$

or, $d\theta = (2n+1)\frac{\lambda}{2}$

or, $\frac{dy}{D} = (2n+1)\frac{\lambda}{2}$

$\Rightarrow y = (2n+1)\cdot\frac{\lambda D}{2d} \longrightarrow$ (IX) for $n = 0, 1, 2, -$

$\therefore y = \frac{\lambda D}{2d}, \frac{3\lambda D}{d}, \frac{5\lambda D}{d}, ---$

Then distance bet^n two consecutive dark fringes will again $\frac{\lambda D}{d}$ $\therefore \beta = \frac{\lambda D}{d} \longrightarrow$ (X)

we can conclude that bright and dark fringes are equal.

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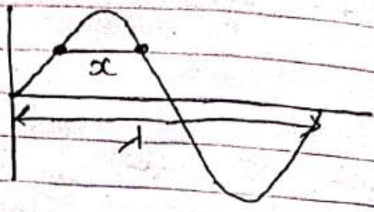
- **Relation between Phase difference (ϕ) and Path difference (x):-**

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



For λ Path difference, phase difference $= 2\pi$
For 1 " " , phase difference $= \frac{2\pi}{\lambda}$

For x path difference, " " $(\phi) = \frac{2\pi}{\lambda} x$

Imp (Q) **Mathematical or Analytical treatment of Interference : (9 marks : Long Q)**

Let the two light waves be represented by,

$$y_1 = A \sin \omega t$$

and $$y_2 = A \sin(\omega t + \phi)$$

where A, ω and ϕ are the amplitude, angular frequency and phase difference.

Now, the resultant wave is represented by

$$y_1 + y_2$$
$$= A \sin\omega t + A \sin(\omega t + \phi)$$
$$= A[\sin\omega t + \sin(\omega t + \phi)]$$

use the formula of $\sin(A+B)$

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$$y = A[\sin\omega t + (\sin\omega t\cos\phi + \cos\omega t\sin\phi)]$$

$$y = A[\sin\omega t(1+\cos\phi) + \cos\omega t\sin\phi] \quad \text{--- (i)}$$

Let $A(1+\cos\phi) = R\cos\theta$ --- (ii)

and $A\sin\phi = R\sin\theta$ --- (iii)

where R and θ are the amplitude and the corresponding phase of the resultant wave.

From (i), (ii), (iii),

$$y = R\cos\theta \sin\omega t + R\sin\theta\cos\omega t$$
$$= R[\cos\theta\sin\omega t + \sin\theta\cos\omega t]$$
$$= R\sin(\omega t + \theta)$$

which is the eqn of S.H.M

Squaring (ii) and (iii) and adding,

$$[A(1+\cos\phi)]^2 + A^2\sin^2\phi = R^2[\cos^2\theta + \sin^2\theta]$$

$\Rightarrow A^2(1 + 2\cos\phi + \cos^2\phi + \sin^2\phi) = R^2$

$\Rightarrow A^2(2 + 2\cos\phi) = R^2$

$\Rightarrow 2A^2(1+\cos\phi) = R^2$

$\Rightarrow 2A^2 \cdot 2\cos^2\frac{\phi}{2} = R^2$

$\Rightarrow \boxed{R^2 = 4A^2\cos^2\frac{\phi}{2}}$

Now, the intensity of the resultant wave is given by, $I = R^2 = 4A^2\cos^2\frac{\phi}{2}$.

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$$\Rightarrow \left[I = I_0 \cos^2 \frac{\phi}{2} \right]$$ where, $I_0 = 4A^2$, is the maximum intensity.

Cases:

(i) For constructive interference,

$$I = I_0, \text{ maximum}$$

$\Rightarrow \phi = 0, 2\pi, 4\pi, 6\pi, \ldots$

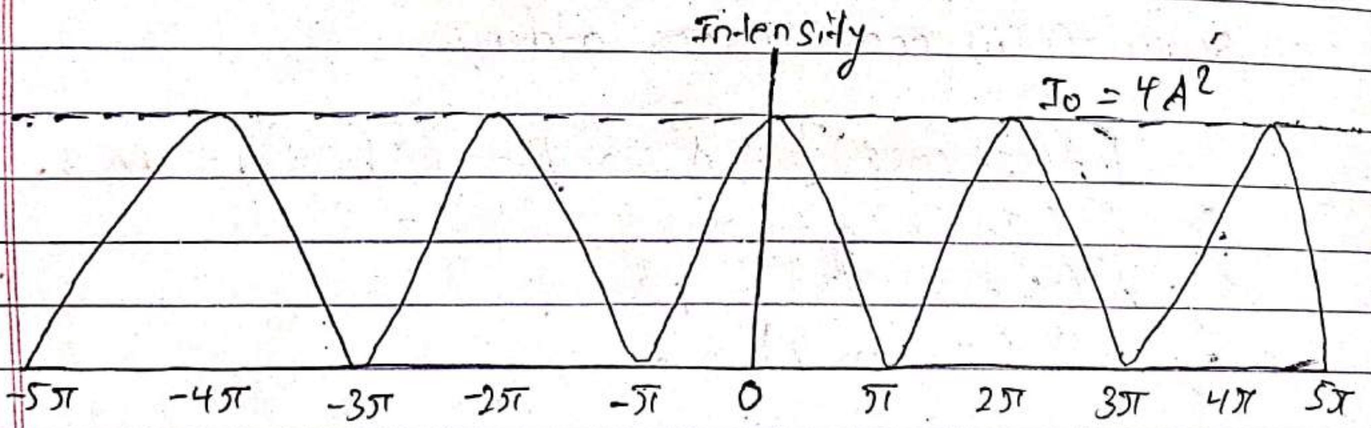
$\Rightarrow$ Path difference $= n\lambda$; $n = 0, 1, 2, \ldots$

(ii) For destructive interference,

$$I = 0, \text{ minimum}$$

$\Rightarrow \phi = \pi, 3\pi, 5\pi, 7\pi, \ldots$

$\Rightarrow$ path difference $= (2n+1)\frac{\lambda}{2}$, $n = 0, 1, 2, \ldots$



$\longleftarrow$ phase difference (ϕ) $\longrightarrow$

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Interference in thin film:

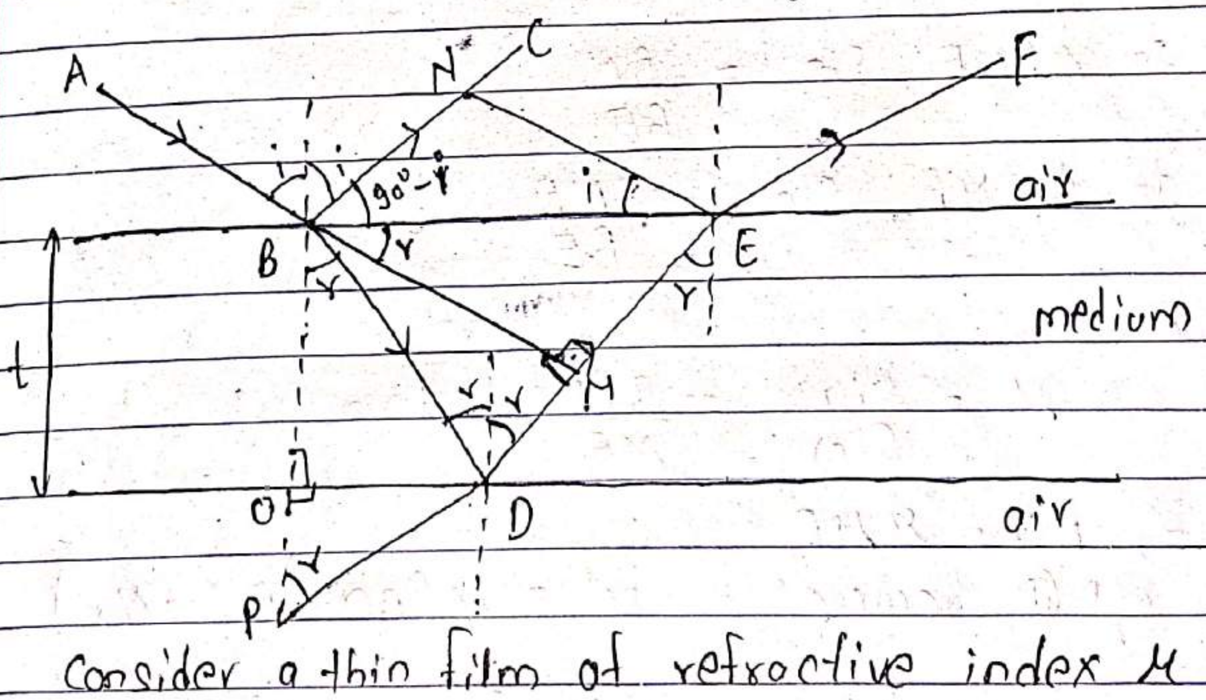
Thin film: A transparent medium of refractive index μ ($\mu > 1$) and of certain thickness t is called thin film. eg: soap film, oil film.

Interference in thin film is of two types:

(i) Interference due to reflected light

(ii) Interference due to transmitted light

(i) Interference due to reflected light:



Consider a thin film of refractive index μ and thickness t. Let AB be the incident ray on the air - medium interface. BC is the first reflected ray. BD is the ~~refle~~ refracted ray which is reflected by the medium-air interface along DE and finally emerges along EF.

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Now, the path difference between BC and EF is given by,

$$x' = \mu(BD + DE) + EF - BC \quad \text{--- (i)}$$

The refractive index is given by,

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

Now, draw EN and BM perpendicular to BC and DE.

Here, $NC = EF$
and $BC = BN + NC$
Then, eqn (i) becomes, $x' = \mu(BD + DE) - BN$ --- (ii)

In ΔBNE, $\sin i = \frac{BN}{BE}$

In ΔBME, $\sin r = \frac{ME}{BE}$

Then,

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

$\Rightarrow BN = \mu ME$
So eqn (ii) becomes, $x' = \mu(BD + DE - ME)$

$$\Rightarrow x' = \mu(BD + DM)$$

Now, produce ED back to the point P so as to meet the first normal.

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Here,

$\Delta BOD \cong \Delta POD$ (by AAS. axiom)

so, $BD = PD$ and

$BO = OP = t$

Then,

$[x' = \mu(BD + DM)]$ becomes:

$$x' = \mu(PD + DM)$$

$$\Rightarrow x' = \mu PM \quad \text{---} \text{(iii)}$$

In ΔBPM, $\cos r = \frac{PM}{BP}$

$$\Rightarrow PM = 2t \cos r$$

$$\Rightarrow x' = 2\mu t \cos r \quad \text{---} \text{(iv)}$$

In case of reflection, there is additional path difference of $\lambda/2$ since a phase change of π radian occurs.

Hence, the actual path difference in thin film due to reflected light is given by,

$$x = x' - \frac{\lambda}{2}$$

$$\Rightarrow \boxed{x = 2\mu t \cos r - \frac{\lambda}{2}}$$

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Cases :

(i) For constructive interference, bright or maxima,

path difference $= n\lambda$, $n = 0, 1, 2, 3, \ldots$

$$\Rightarrow \left[x = 2\mu t\cos r - \frac{\lambda}{2} = n\lambda\right]$$

$$\Rightarrow \left[2\mu t\cos r = n\lambda + \frac{\lambda}{2}\right]$$

$$\Rightarrow \left[2\mu t\cos r = (2n+1)\frac{\lambda}{2}\right], \quad n = 0, 1, 2, 3, \ldots$$

(ii) For destructive interference, dark or minima,

path difference $= (2n+1)\frac{\lambda}{2}$, $n = 0, 1, 2, 3, \ldots$

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

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

$$\Rightarrow x = 2\mu t\cos r = (n+1)\lambda, \quad n = 0, 1, 2, 3, \ldots$$

$$\Rightarrow \left[2\mu t\cos r = n'\lambda\right], \quad n' = 1, 2, 3, \ldots$$

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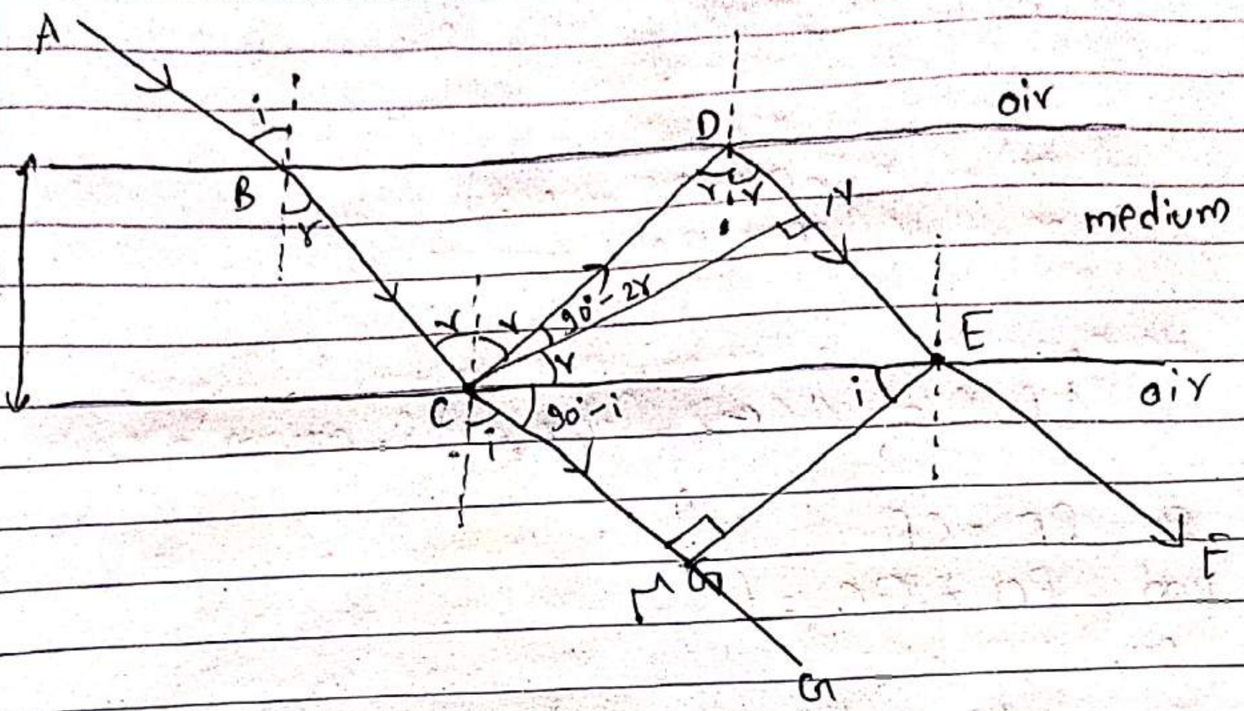
(ii) Interference due to transmitted light :



Interference is due to two transmitted rays EF and CG.
The path difference between EF and CG is

$$x = \mu(CD + DE) + EF - CG$$

But, $EF = MG$ and
$CG = CM + MG$

$$\Rightarrow x = \mu(CD + DE) - CM \quad \text{--- (1)}$$

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

where, $\sin i = \frac{CM}{CE}$, $\sin r = \frac{NE}{CE}$

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$$\Rightarrow \mu = \frac{CM}{NE}$$

$$\Rightarrow [CM = \mu NE] \quad \text{——} \quad (2)$$

$$\Rightarrow x = \mu(CD + DE - NE)$$

$$\Rightarrow x = \mu(CD + DN). \quad \text{——} \quad (3)$$

Here,

$\Delta POD \cong \Delta COD$ (by AAS axiom)

So, $PD = CD$

and, $PO = OC = t$

So,

$x = \mu(CD + DN)$ —— (3) becomes,

$$x = \mu(PD + DN)$$

$$\Rightarrow x = \mu PN \quad \text{——} \quad (4)$$

In ΔPCN, $\cos r = \frac{PN}{PC}$

$$\Rightarrow PN = 2t\cos r$$

Hence, the path difference $= 2\mu t \cos r$

In case of transmitted light, there is no additional path difference of $\lambda/2$.

Hence, the actual path difference $= 2\mu t \cos r$.

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Cases:

(i) For constructive interference, bright or maxima,

path difference $= n\lambda$, $n = 0, 1, 2, 3, \ldots$

$\Rightarrow \boxed{x = 2\mu t \cos r = n\lambda}$

(ii) For destructive interference, dark or minima,

path difference $= (2n+1)\frac{\lambda}{2}$, $n = 0, 1, 2, 3, \ldots$

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

Hence, the interference pattern in thin film due to transmitted ~~to~~ light and reflected light are opposite for bright and dark fringes.

Numericals (Thin film: Interference):

1. A soap film 5×10^{-5} cm thick is viewed at an angle of $35°$ to the normal. Find the wavelengths of light in the visible spectrum which will be absent from the reflected light if the refractive index of the soap film is 1.33.

Soln,

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Given, $i = 30°$, $\mu = 1.33$, $t = 5 \times 10^{-5}$ cm

we know,

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

$$1.33 = \frac{\sin 30°}{\sin r} \Rightarrow r = 25.55°$$

$\therefore \cos r = 0.90$

In case of reflected system - dark fringe, ~~$2\mu t \cos r$~~

$2\mu t \cos r = n\lambda$, $n = 1, 2, 3, \ldots$ etc.

1. When $n = 1$, $\lambda_1 = 1200$ nm (invisible)
2. When $n = 2$, $\lambda_2 = 600$ nm (visible)
3. When $n = 3$, $\lambda_3 = 400$ nm (visible)
4. When $n = 4$, $\lambda_4 = 300$ nm (invisible)

Hence, the wavelength in visible spectrum which are absent from the reflected light are λ_2 and λ_3.

2.) A beam of parallel rays is incident at an angle of 30° with the normal on a plane parallel film of thickness 4×10^{-5} cm and refractive index 1.50. Show that the reflected light whose wavelength is 1.539×10^{-5} cm, will be strengthened by reinforcement.

Soln,

Here, $t = 4 \times 10^{-5}$ cm, $\lambda = 1.539 \times 10^{-5}$ cm

$\mu = 1.50$

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For the film to appear bright by reflection,

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

$2\mu t\cos r = n'\frac{\lambda}{2}$, n' is odd. we know,

$n' = \frac{4\mu t\cos r}{\lambda}$

Here, $i = 30°$, $\mu = \frac{\sin i}{\sin r}$

$1.5 = \frac{\sin 30°}{\sin r}$

$\therefore r = 19.4°$

$\therefore \cos r = 0.9432$. So, $n' = 3$.

As, n' is odd, the thin film appears bright by reflected light.

3. A thin film of soap solution is illuminated by white light at an angle of incidence $i = \sin^{-1}(4/5)$. In reflected light, two dark consecutive overlapping fringes are observed corresponding to wavelengths 6.1×10^{-5} cm and 6.0×10^{-5} cm. μ for the soap solution is 4/3. Calculate the thickness of the film.

Soln,

Here the path difference is same.

$2\mu t\cos r = n\lambda_1 = (n+1)\lambda_2$.

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$$n \times 6.1 \times 10^{-7} = (n+1) \times 6.0 \times 10^{-7}$$
$$n = 60$$

Also, $\sin i = \frac{4}{5}$ and $\mu = \frac{4}{3}$

$$\mu = \frac{\sin i}{\sin r} = \sin r = 0.6 = \cos r = 0.8$$

$$2\mu t = \cos r = n d_1$$

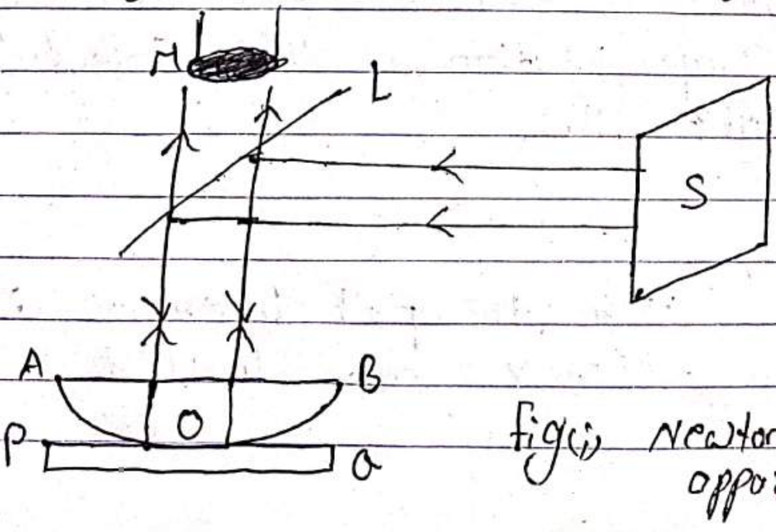
$$t = \frac{n \lambda_1}{2\mu t \cos r} = \frac{60 \times 6.1 \times 10^{-7}}{2 \times (4/3) \times 0.8} = 1.72 \times 10^{-2} \text{ mm}$$

Newton's ring:-

(i) Due to reflected light

(ii) Due to transmitted light.

(i) Newton's ring due to reflected light:-



fig(i) Newton's ring apparatus

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Here, S is the source of monochromatic light. L is the partially silvered glass plate placed at an angle of 45° with the horizontal.

Light from 'S' is reflected by the glass plate L to the plano-convex lens AOB placed over the glass plate POQ. It is reflected by the two surfaces AOB and POQ back to L which transmit light to the travelling microscope M.

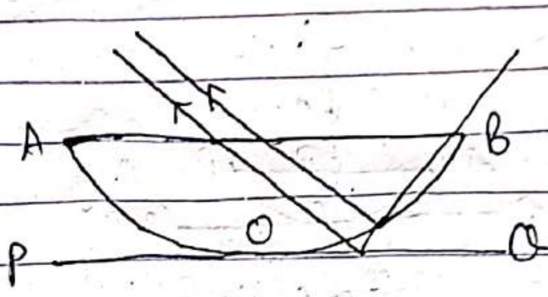

fig (ii) Reflected light

Air is enclosed within AOB and POQ. The thickness of air is zero at the point of contact O and increases on the other side. Circular concentric rings are observed called Newton's ring.

In case of reflected light, the center of Newton's ring is dark.

The dark rings due to reflected light is given by

$$[2\mu t \cos\theta = n\lambda], \quad n = 0, 1, 2, 3, \ldots \quad (1)$$

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For air, $\mu = 1$.
For normal incident, $\theta \approx 0^\circ$
$\Rightarrow \cos\theta \approx 1$

So, eqn (1) becomes,

$$[2t = n\lambda] \text{ — (2)}$$

To find t:

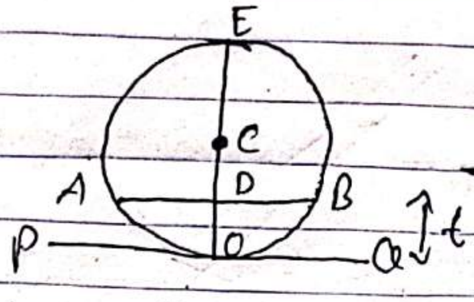

fig (iv):

Let C be the center such that EC = R,
Radius of curvature of the plano-convex lens.

Let AD = DB = r and OD = t
From geometry,

$$ED \times DO = AD \times DB \Rightarrow (2R-t) \times t = r \times r$$
$$\Rightarrow 2Rt - t^2 = r.r$$

Since $R >> t$,
$$2Rt = r^2$$

$$\Rightarrow \left[2t = \frac{r^2}{R}\right] \text{ — (3)}$$

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From (2) and (3),

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

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

$$r = \sqrt{n\lambda R} \Rightarrow \left[r_n = \sqrt{n\lambda R}\right], \ n = 0, 1, 2, 3, \ldots$$

which gives the radius of the nth dark ring due to reflected light.

for $n = 0$, $r_0 = 0$
Hence, the center of Newton's ring due reflected light is dark

For bright rings due to reflected light,

$$2\mu t \cos\theta = (2n-1)\frac{\lambda}{2}; \ n = 1, 2, 3, \ldots$$

For air, $\mu = 1$
For normal incidence, $\theta \approx 0°$
$\Rightarrow \cos\theta \approx 1$

so,

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

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

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

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

$$\Rightarrow \left[r_n = \sqrt{(2n-1)\frac{\lambda R}{2}} \right],$$

which gives the radius of the nth bright ring due to reflected light. The diameter of the nth dark ring is given by,

$$\left[D_n = 2r_n = 2\sqrt{n\lambda R} \right], \quad n = 0, 1, 2, 3, \ldots$$

And for the n^{th} bright ring,

$$\boxed{D_n = 2r_n = 2\sqrt{(2n-1)\frac{\lambda R}{2}}}, \quad n = 1, 2, 3, \ldots$$

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

Q.) Show that rings or fringes get closer or fringe width decreases as we move away from the center.

Soln,

Since for the nth dark ring due to reflected light, diameter is given by,

$$\left[D_n = 2\sqrt{n\lambda R} \right]$$

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For the 1st dark ring, $n=1$

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

And for the 4th, 9th and 16th dark rings,

$D_4 = 2\sqrt{4\lambda R} = 4\sqrt{\lambda R}$

$D_9 = 2\sqrt{9\lambda R} = 6\sqrt{\lambda R}$

$D_{16} = 2\sqrt{16\lambda R} = 8\sqrt{\lambda R}$

Hence,

$$D_4 - D_1 = 2\sqrt{\lambda R} = D_{16} - D_9$$

Hence, the rings or fringes get closer or fringe width decreases as we move away from the center.

(ii) Newton's rings: Due to transmitted light :-

Fig : Transmitted light

Fig: Newton's rings due to transmitted light (center is bright)

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In case of transmitted light, the center of Newton's rings is bright.

The bright rings due to transmitted light are given by,

$$2\mu t \cos\theta = n\lambda, \quad n = 0, 1, 2, 3, \ldots$$

For air, $\mu = 1$, and $\cos\theta \approx 1$

Then, $\left[2t = n\lambda\right]$, $n = 0, 1, 2, 3, \ldots$

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

combining we get,

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

$$\Rightarrow r = \sqrt{n\lambda R}$$

$$\Rightarrow r_n = \sqrt{n\lambda R}, \quad n = 0, 1, 2, 3, \ldots$$

This gives the radius of the nth bright ring due to transmitted light.

For dark rings due to transmitted light,

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

For, air $\mu = 1$, and $\cos\theta \approx 1$

so,

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$$\left[2t = (2n-1)\frac{\lambda}{2}\right], n = 0, 1, 2, 3, \ldots$$

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

So,

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

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

$$\left[\therefore r_n = \sqrt{(2n-1)\frac{\lambda R}{2}}\right], n = 1, 2, 3, \ldots$$

This gives the radius of the nth dark ring due to transmitted light.

Application of Newton's ring: (To find λ, μ)

(i) To find the wavelength of monochromatic light (λ) by using Newton's rings method:

The radius of the n^{th} dark ring due to reflected light is given by,

$$r_n = \sqrt{n\lambda R}$$

$$\text{or, } D_n = 2r_n = 2\sqrt{n\lambda R}$$

$$\text{or, } D_n^2 = 4n\lambda R$$

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Similarly, for m^{th} dark ring,

$$D_m^2 = 4m\lambda R$$

Subtracting, we get,

$$D_n^2 - D_m^2 = 4(n-m)\lambda R$$

$$\text{or, } \lambda = \frac{D_n^2 - D_m^2}{4(n-m)R}$$

(Note: For a single ring, say n^{th} ring,

$$\lambda = \frac{D_n^2}{4nR}\;)$$

(ii) To determine the refractive index (μ) of a given liquid:-

In air, the diameters of the n^{th} and m^{th} dark rings are given by,

$$D_n^2 = 4n\lambda R$$

$$\text{and } D_m^2 = 4m\lambda R$$

Subtracting, we get,

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

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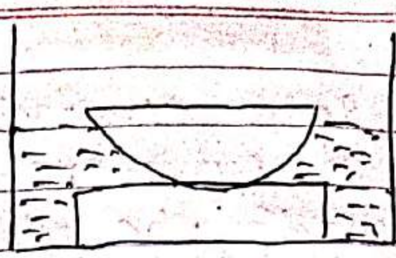
If a liquid is placed in between the plano-convex lens and the glass plate,



the diameter of the n^{th} and m^{th} dark rings in the liquid become,

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

and $$D_m'^2 = \frac{4m\lambda R}{\mu}$$

subtracting, we get,

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

using (i) we get,

$$D_n'^2 - D_m'^2 = \frac{D_n^2 - D_m^2}{\mu}$$

$$\left[\therefore \mu = \frac{D_n^2 - D_m^2}{D_n'^2 - D_m'^2}\right]$$

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Numericals.

1) In a Newton's rings experiment, find the radius of curvature of the lens surface in contact with the glass plate when with a light of wavelength 5890×10^{-8} cm, the diameter of the third dark ring is 3.2mm. The length is falling at such an angle that is passes through air film at an angle of zero degree to the normal.

Soln,

Given, wavelength (λ) = 5890×10^{-8} cm

Diameter of the 3rd darking (D_3) = 3.2mm $= 3.2 \times 10^{-1} = 0.32$ cm

angle (θ) = 0°

Radius of curvature (R) = ?

we have,

$$D = 2\sqrt{n\lambda R}$$

or, $(0.32)^2 = 4 \times 3 \times 5890 \times 10^{-8} R$

or, $R = \dfrac{(0.32)^2}{4 \times 3 \times 5890 \times 10^{-8}}$

$\therefore$ $R = 144.9$ cm.

2) A plano-convex lens of radius 300cm is placed on an opticaly flat glass plate and is illuminated by monochromatic light. The diameter of the 8th dark ring in the transmitted system is 0.72cm. Calculate the wavelength of light used.

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Soln,

Given, Radius of plano-convex lens (R) = 300cm
Diameter of 8th ring (D_8) = 0.72 cm
wavelength (λ) = ?

we have,

$$D_8 = 2\sqrt{(2n-1)\frac{\lambda R}{2}}$$

or, $(0.72)^2 = 4 \times (2\times 8-1) \times \frac{\lambda}{2} \times 300$

or, $\lambda = \frac{(0.72)^2 \times 2}{4\times(16-1)\times 300}$

or, $\lambda = 5.76 \times 10^{-5}$ cm

$\therefore \lambda = 5760$ A°

3) A thin equiconvex lens of focal length 4m and refractive index 1.50 rests on a and in contact with an optical flat, and using light of wavelength 5460 A°, Newton's rings are viewed normally by reflection. What is the diameter of the 5th bright ring?

Soln, Given, focal length (f) = 4m
Refractive index (μ) = 1.50
wavelength (λ) = 5460 A°
$= 5.460 \times 10^{-5}$ cm
order of ring (n) = 5

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Bright ring due to reflected light is given by,

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

where,

$$\frac{1}{F} = (\mu - 1)\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

where, $R_1 = R_2 = R$

now,

$$\frac{1}{4} = (1.50 - 1)\left(\frac{2}{R}\right)$$

or, $R = \frac{1}{2} \times 2 \times 4$

$\therefore R = 400 \text{ cm}$

Now,

eq^n (1) becomes

$$D_5 = 2\sqrt{(2n-1)\frac{\lambda}{2}R}$$

$$= 2\sqrt{(2\times5-1)\frac{5.460\times10^{-5}}{2}\times400}$$

$$= 0.627 \text{ cm}$$

4.) Newton's ring are formed by the reflected light of a wavelength 5895 A° with a liquid between the plane and curved surfaces. If the diameter of the 5th bright ring is 3 mm and the radius of curvature of the curved surface is 100 cm, calculate the refractive index of liquid.

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Soln,

Given wavelength (λ) $= 5895\ A^\circ$
$= 5.895 \times 10^{-7}$ m

Diameter of 5th bright ring (D_5) $= 3\times10^{-3}$ m

Radius of curvature (R) $= 100$ cm $= 1$m

Refractive index of liquid (μ) $= ?$

we have,

$$D_5 = \sqrt{\frac{2(2n-1)\lambda R}{\mu}}$$

$$\left(\frac{3}{1000}\right)^2 = \frac{2(2\times5-1)\times5.895\times10^{-7}}{\mu}$$

$$\text{or, } \mu = \frac{1.0611\times10^{-5}}{9\times10^{-6}}$$

$$\therefore \mu = 1.179$$ //

5.) In a Newton's rings experiment, if a drop of water ($\mu = \frac{4}{3}$) be placed in between the lens and the plate, the diameter of the ~~100~~ 10th ring is found to be 0.6 cm. Obtain the radius of curvature of the face of the lens in contact with the plate. The wavelength of light used is 6000 A°.

Soln,

Given, Refractive index (μ) $= 4/3 = 1.33$

Diameter of 10th ring (D_{10}) $= 0.6$ cm

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wavelength (λ) = 6000 A°
Radius of curvature (R) = ?
we have,

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

$$or,\ D_{10}^2 = \frac{4\times10\times6000\times10^{-8}\times R}{1.33}$$

$$or,\ R = \frac{1.33\times(0.6)^2}{40\times6000\times10^{-8}}$$

$$or,\ R = 199.5$$

$$\therefore\ R = 200\ cm.$$

6) Newton's rings are observed in reflected light of $\lambda = 5.9\times10^{-5}$ cm. The diameter of the 10^{th} dark ring is 0.5cm. Find the radius of curvature of the lens and the thickness of the air film.

Soln,

Given, wavelength (λ) = 5.9×10^{-5} cm
Diameter of the 10^{th} dark ring (D_{10}) = 0.5 CM

Radius of curvature (R) = ?
Thickness of air film (t) = ?

Diameter of the 10^{th} dark ring due to reflected light $D_n = 2\sqrt{n\lambda R}$

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or, $D_{10} = 2\sqrt{10 \lambda R}$

or, $(0.5)^2 = 4 \times 10 \times 5.9 \times 10^{-5} \times R$

or, $R = \dfrac{(0.5)^2}{4 \times 10 \times 5.9 \times 10^{-5}}$

$\therefore R = 1.059\ m$

Thickness (t),

$2t = n\lambda$

or, $2 \times t = 10 \times 5.9 \times 10^{-9}$

or, $t = 2.95 \times 10^{-4} \times 10^{-2}$

$\therefore t = 2.95 \times 10^{-6}\ m$

7) The radii of nth and (n+20)th bright ring in Newton's ring experiment are 0.162 cm and 0.368 cm respectively. Calculate the radius of curvature of lower surface of lens. ($\lambda = 546$ nm).

(Ans; 99.98 cm)

soln,

wavelength (λ) = 546 nm

$= 546 \times 10^{-9}$ m

$= 5.46 \times 10^{-5}$ cm

→ The radius of n^{th} bright ring due to reflected light is given by,

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

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

$$\text{or, } 2\times(0.162)^2 = (2n-1)\times 5.46\times10^{-5} R$$

$$\text{or, } 0.0524\,88 = (2n-1)5.46\times10^{-5} R \quad \text{--- (A)}$$

→ The radius of $(n+20)^{th}$ bright ring due to reflected light $r_n = \sqrt{\frac{(2n-1)\lambda R}{2}}$

$$\text{or, } 2\times(0.368)^2 = (2n+39)\,5.46\times10^{-5} R \quad \text{--- (B)}$$

subtracting (A) from (B),

$$\text{or, } 0.21836 = 2.184\times10^{-3} R$$

$$\text{or, } R = \frac{0.21836}{2.184\times10^{-3}} \quad \therefore R = 99.8\text{ cm}\#$$

8. In a newton's ring arrangement, a source emitting two wavelengths 6×10^{-7} m and 5.9×10^{-7} m is used. It is found that nth dark ring due to one wavelength coincides with (n+1)th dark ring due to another. Find the diameter of the nth dark ring if the radius of curvature of lens is 0.9m

Soln, Given, Two wavelengths, $R = 0.9$m

$\lambda_1 = 6\times10^{-7}$ m

$\lambda_2 = 5.9\times10^{-7}$ m

n^{th} dark ring due to λ_1 = $(n+1)^{th}$ darkring due to λ_2.

$$D_n^2 = D_{(n+1)}^2$$

$$\text{or, } 4n\lambda_1 R = 4(n+1)\lambda_2 R$$

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$$\text{or, } n\lambda_1 = (n+1)\lambda_2$$
$$\text{or, } n\lambda_1 = n\lambda_2 + \lambda_2$$
$$\text{or, } n = \frac{\lambda_2}{\lambda_1 - \lambda_2}$$

$$\therefore n = ~~5~~ 59.$$

Again, $D_n = 2\sqrt{n\lambda_1 R}$
$= 2\sqrt{59 \times 6 \times 10^{-7} \times 0.9}$
$= 7.128\,cm.$

9. Newton's rings are formed by reflected light of wavelength 5895 A° with a liquid between the plane and curved surfaces. If the diameter of the 6^{th} bright ring is 3 mm and the radius of curved surface is 100 cm, calculate the refractive index of the liquid.

Soln,

wavelength (λ) = 5895 A°
$= 5.895 \times 10^{-7}$ m

Diameter of 6^{th} bright ring (D_6) = 3mm

Radius of curved surface (R) = 100cm
= 1000 mm

Refractive index (μ) = ?

We have,

$$D_6 = \sqrt{\frac{2(2\times 6-1)\lambda R}{\mu}}$$

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or, $\mu = \frac{2 \times 11 \times 5.895 \times 10^{-7}}{9 \times 10^{-6} \times 10^{3}}$

$\therefore \mu = 1.441$ #

10) Light containing the two wavelengths λ_1 and λ_2 falls normally on a plano-convex lens of radius of curvature R resting on a glass plate. If the nth dark ring due to λ_1 coincides with the (n+1)th dark ring due to λ_2, prove that the radius of nth dark ring of λ_1 is $\sqrt{\frac{\lambda_1\lambda_2 R}{\lambda_1-\lambda_2}}$

Soln, Given,

wavelength = λ_1 & λ_2

nth dark ring due to λ_1

$r_n = \sqrt{n\lambda R}$

$r_n = \sqrt{n\lambda_1 R}$

$r_n^2 = n\lambda_1 R$

$(n+1)^{th}$ dark ring due to λ_2

$r_{n+1} = \sqrt{(n+1)\lambda_2 R}$

$r_{n+1} = \sqrt{(n+1)\lambda_2 R}$

$(r_{n+1})^2 = (n+1)\lambda_2 R$

Equating r_n^2 and $(r_{n+1})^2$

$n\lambda_1 \cancel{R} = (n+1)\lambda_2 \cancel{R}$

or, $n\lambda_1 = n\lambda_2 + \lambda_2$

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$$or,\ n(\lambda_1 - \lambda_2) = \lambda_2$$

$$\therefore\ n = \frac{\lambda_2}{\lambda_1 - \lambda_2}\ \text{proved.}$$

11) In an experiment on Newton's rings the light has a wavelength of 600nm. The lens has a refractive index of 1.5 and a radius of curvature of 2.5m. Find the radius of 5^{th} bright fringe.

Soln,

Given, wavelength $(\lambda) = 600nm = 6\times10^{-7}m$

Refractive index $(\mu) = 1.5$

Radius of curvature $(R) = 2.5m$

$= 0.025cm$

Radius of 5^{th} bright fringe $(r_5) = ?$

We have,

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

$$r_5 = \sqrt{(2\times5-1)\times\frac{6\times10^{-5}}{2}\times0.025}$$

$$\therefore\ r_5 = 2.6\times10^{-3}m$$