Newton's Ring

Condition for Bright and Dark Rings

The optical path difference between the rays is given by $\Delta = 2\mu t \cos r - \frac{\lambda}{2}$. Since, $\mu = 1$ for air and $\cos r = 1$ for normal incidence of light,

$$\Delta = 2t - \lambda/2$$

Intensity maxima occur when the optical path difference $\Delta = m\lambda$. If the difference between the optical path between the two rays is equal to an integral number of full waves, then the rays meet each other in phase. The crest of one wave falls on the crest of the other and the waves interfere constructively.

Thus, if $2t - \lambda/2 = m\lambda$

$$\boxed{2t = (2m+1)\lambda/2}$$

bright fringe is obtained.

Intensity minima occur when the optical path difference is $\Delta = (2m+1)\lambda/2$. If the difference in the optical path between the two rays is equal to an odd integral number of half-waves, then the rays meet each other in opposite phase. The crests of one wave falls on the troughs of the other and the waves interfere destructively.

Hence, if $2t - \lambda/2 = (2m+1)\frac{\lambda}{2}$ or

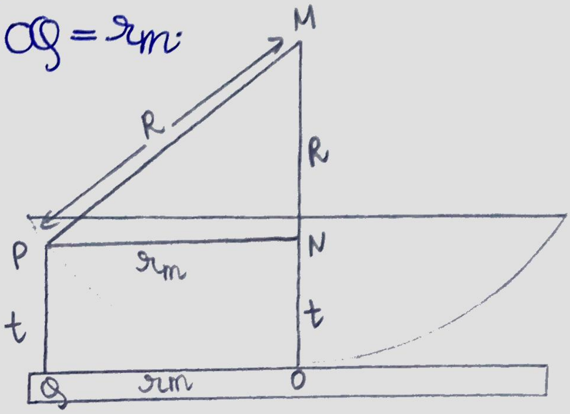
$$2t - \lambda/2 = (2m-1)\frac{\lambda}{2}$$

$$\boxed{2t = m\lambda}$$

Radii of Dark Fringes

Let R be the radius of curvature of lens. Let a dark fringe be located at Q. Let the thickness of the air film at Q be PQ = t. Let the radius of circular fringe at Q be OQ = r_m.

By the Pythagorus theorem,



$$PM^2 = PN^2 + MN^2$$

$$\therefore R^2 = r_m^2 + (R-t)^2$$

$$\text{or } r_m^2 = \cancel{R^2} - \cancel{R^2} - t^2 + 2Rt$$

$$r_m^2 = 2Rt - t^2$$

As $R >> t$, $2Rt >> t^2$.

$$\therefore r_m^2 \cong 2Rt$$

The condition for darkness at Q is that

$$2t = m\lambda$$

$$\therefore r_m^2 = m\lambda R$$

$$\boxed{r_m = \sqrt{m\lambda R}}$$

where m can be 1, 2, 3, ...

It means that the radii of dark rings are proportional to the underroot of natural numbers as well as underroot of wavelength.

$$\therefore r_m \propto \sqrt{m} \quad \text{and} \quad r_m \propto \sqrt{\lambda}$$

Ring Diameter

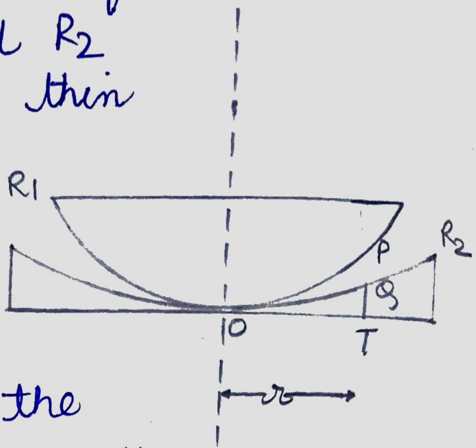
Diamter of m^{th} dark ring $= D_m = 2r_m$

$$\boxed{D_m = 2\sqrt{m\lambda R}}$$

Newton's ring formed by two curved surfaces

i) Lower surface concave

Let us consider two curved surfaces of radii of curvature R_1 and R_2 in contact at the point O. A thin air film is enclosed between the two surfaces. The dark and bright rings are formed and can be viewed with a travelling microscope. Suppose the radius of m^{th} dark ring is r. The thickness of the air film at P is



$$PQ = PT - QT$$

From geometry and from earlier derivation,

$$\because r_m^2 = 2Rt \Rightarrow t = \frac{r_m^2}{2R}$$

$$PT = \frac{r^2}{2R_1} \quad \text{and} \quad QT = \frac{r^2}{2R_2}$$

$$\therefore PQ = \frac{r^2}{2R_1} - \frac{r^2}{2R_2}$$

But $PQ = t$. The condition for dark rings in reflected light is given by $2\mu t \cos r = m\lambda$. As $\mu = 1$ and $\cos r = 1$ for normal incidence, the above condition reduces to $2t = m\lambda$.

$$\therefore 2\left(\frac{r^2}{2R_1} - \frac{r^2}{2R_2}\right) = m\lambda$$

$$= \frac{\cancel{2}r^2}{\cancel{2}}\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = m\lambda$$

$$r^2\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = m\lambda \quad \text{where } m = 0, 1, 2, 3, \ldots$$

For bright fringes the condition is

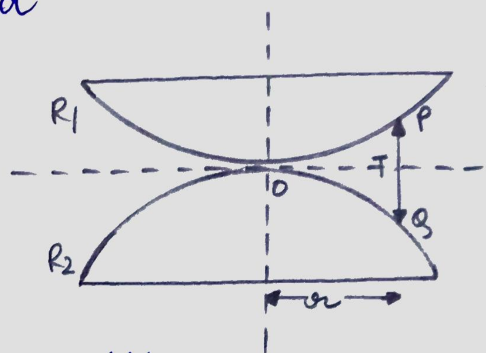
$$2\mu t \cos r = (2m+1)\cdot\frac{\lambda}{2}$$

which reduces to $2t = (2m+1)\lambda/2$

or $r^2\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{(2m+1)\lambda}{2}$ where $m = 0, 1, 2, \ldots$

Case 2: Lower surface convex

Let us consider two curved surfaces of radii of curvature R_1 and R_2 in contact at the point O. A thin air film is enclosed between the two surfaces.



The dark and bright rings are formed and can be viewed with a travelling microscope. Suppose the radius of the m^{th} dark ring is r. The thickness of the air film at P is

$$PQ = PT + TQ$$

From geometry, $PT = \frac{r^2}{2R_1}$ and $QT = \frac{r^2}{2R_2}$

$$\therefore \quad PQ = \frac{r^2}{2R_1} + \frac{r^2}{2R_2}$$

But $PQ = t$. The condition for dark rings in reflected light is given by $2\mu t \cdot \cos r = m\lambda$.

As $\mu = 1$ and $\cos r = 1$ for normal incidence, the above condition reduces to $2t = m\lambda$.

$$\therefore \quad 2\left(\frac{r^2}{2R_1} + \frac{r^2}{2R_2}\right) = m\lambda$$

$$r^2\left(\frac{1}{R_1}+\frac{1}{R_2}\right)=m\lambda$$

where $m=0, 1, 2, 3, \ldots$

For bright fringes the condition is $2\mu t \cos r = (2m+1)\frac{\lambda}{2}$

which reduces to $2t=(2m+1)\lambda/2$

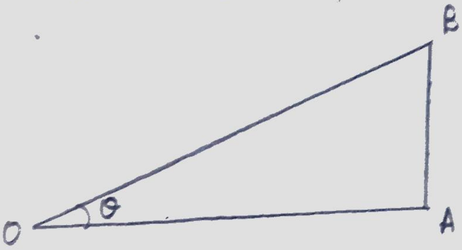
or $$r^2\left(\frac{1}{R_1}+\frac{1}{R_2}\right)=\frac{(2m+1)\lambda}{2}$$

where $m=0, 1, 2, 3, \ldots$

Q.1) Two glass plate enclose a wedge-shaped air film, touching at one edge and are separated by a wire of 0.05 mm diameter at a distance of 15 cm from the edge. Calculate the fringe width Monochromatic light of wavelength 6000 Å from a broad source falls normally on the film.

⇒ Diameter of the wire (d) = 0.05 mm = 0.005 cm
Distance of wire from the edge of the plates = 15 cm

$$\theta = \frac{AB}{OA} = \frac{0.005}{15} = 0.00033$$



Fringe width $\beta = \frac{\lambda}{2\theta}$

$$= \frac{\overset{3}{\cancel{6000}} \times 10^{-10}}{\cancel{2} \times \frac{1}{3} \times \frac{1}{1000}}$$

$$= 9 \times 10^{6-10} = 9 \times 10^{4} = 0.9\,mm$$

Q.2) Light of wavelength 6000 Å falls normally on a thin wedge shaped film of refractive index $\mu = 1.4$ forming fringes that are 2mm apart. Find the angle of the wedge?

⇒ Given, $\lambda = 6000$ Å $= 6000 \times 10^{-10} m$.

$\beta = 2mm = 2 \times 10^{-3} m$

$\mu = 1.4$

We know, $\beta = \frac{\lambda}{2\mu\theta}$ or $\theta = \frac{\lambda}{2\mu\beta}$

$$\therefore \theta = \frac{6000 \times 10^{-10}}{2 \times 1.4 \times 2 \times 10^{-3}} = \frac{\overset{3}{\cancel{6}} \times 10^{-7+3}}{\cancel{2} \times 1.4 \times 2} = 1.07 \times 10^{-4} \text{ radian}$$

Q.3) A square piece of thin film with R.I = 1.5 has a wedge shaped section so that its thickness at two opposite sides are t_1 & t_2. If with $\lambda = 6000$ Å, the number of fringes observed is 10, find $t_2 - t_1$

⇒ Given, $\mu = 1.5$, $\lambda = 6000$ Å, number of fringes is 10.

condition for darkness is $2\mu t \cos(r+\theta) = m\lambda$.
For normal incidence and small wedge angle $\cos(r+\theta) = 1$.

Let m^{th} fringe is obtained at thickness t_1.

$$2\mu t_1 = m\lambda \quad \text{- - - - 1)}$$

Thickness is t_2 where 10^{th} fringe is observed
Therefore,

$$2\mu t_2 = (m+10)\lambda$$

$$\therefore \; t_2 - t_1 = \frac{(m+10)\lambda}{2\mu} - \frac{(m\lambda)}{2\mu} = \frac{10\lambda}{2\mu}$$

$$= \frac{10 \times 6000 \times 10^{-10}}{2 \times 1.5} = \frac{\overset{2}{\cancel{6}} \times 10^{-6}}{\cancel{3}} = 2 \times 10^{-6}\,m$$

Q.4) Newton's rings are observed in reflected light of wavelength 6000 Å. The diameter of the 10^{th} dark ring is 0.5 cm. Find the radius of curvature of the lens and the thickness of the air film.

⇒ Given that $\lambda = 6000\,\text{Å} = 6000 \times 10^{-10}\,m$, $m = 10$

The radius of m^{th} dark ring is given by

$$\therefore \quad R = \frac{r^2}{m\lambda} = \frac{(0.5 \times 10^{-2})^2}{10 \times 6000 \times 10^{-10}} = \frac{25 \times \cancel{10^{-6}}}{6 \times \cancel{10^{-6}}} = 4.16\,m$$

The thickness of air film is given by

$$\therefore \quad t = \frac{m\lambda}{2} = \frac{10 \times 6000 \times 10^{-10}}{2} = 3 \times 10^{-6}\ m$$

$$= 3\,\mu m$$