$$\theta = \frac{4.8 \times 10^{-7} \times 1800}{2 \times 1}$$

$$= 4.32 \times 10^{-4} \text{ radian}$$

$$\theta = \frac{4.32 \times 10^{-4} \times 180 \times 60 \times 60}{3.14} \text{ sec. of an arc}$$

$$= 89 \text{ seconds of an arc}$$

8.23 NEWTONS'S RINGS

When a plano-convex lens of long focal length is placed on a plane glass plate, a thin film of air is enclosed between the lower surface of the lens and the upper surface of the plate. The thickness of the air film is very small at the point of contact and gradually increases from the centre

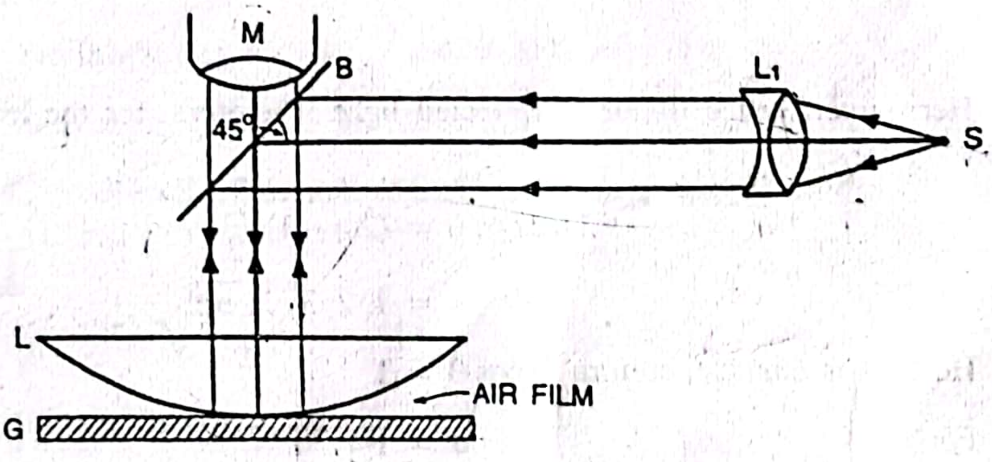

Fig. 8.25

outwards. The fringes produced with monochromatic light are circular. The fringes are concentric circles, uniform in thickness and with the point of contact as the centre. When viewed with white light, the fringes are coloured. With monochromatic light, bright and dark circular fringes are produced in the air film.

S is a source of monochromatic light at the focus of the lens L_1 (Fig. 8.25). A horizontal beam of light falls on the glass plate *B* at 45°. The glass plate *B* reflects a part of the incident light towards the air film enclosed by the lens *L* and the plane glass plate *G*. The reflected beam from the air film is viewed with a microscope. Interference takes place and dark and bright circular fringes are produced. This is due to the interference between the light reflected from the lower surface of the lens and the upper surface of the glass plate *G*.

Theory. **(i) Newton's rings by reflected light.** Suppose the radius of curvature of the lens is R and the air film is of thickness t at a distance of $OQ = r$, from the point of contact O.

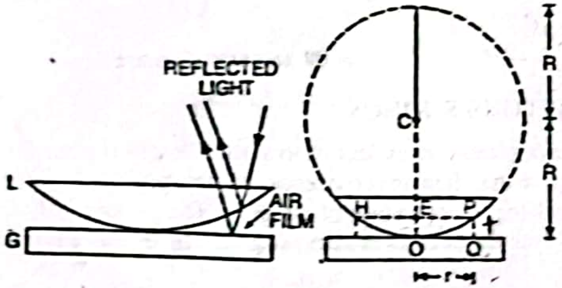

Fig. 8.26

Here, interference is due to reflected light. Therefore, for the bright rings

$$2\mu t \cos\theta = (2n-1)\frac{\lambda}{2} \quad ...(i)$$

where $n = 1, 2, 3 \ldots$ etc.

Here, θ is small, therefore $\cos\theta = 1$

For air, $\mu = 1$

$$2t = (2n-1)\frac{\lambda}{2} \quad ...(ii)$$

For the dark rings,

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

or $2t = n\lambda$

where $n = 0, 1, 2, 3 \ldots$ etc. ...(iii)

In Fig. 8.26,

$$EP \times HE = OE \times (2R - OE)$$

But $\therefore r^2 = t(2R - t)$ $EP = HE = r, \quad OE = PQ = t$

and $2R - t = 2R$ (approximately)

$$r^2 = 2Rt$$

or $$t = \frac{r^2}{2R}$$

Substituting the value of t in equations (ii) and (iii).

For bright rings

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

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

For dark rings,

$$r^2 = n\lambda R \quad ...(vi)$$

$$r = \sqrt{n\lambda R} \quad ...(vii)$$

When $n = 0$, the radius of the dark ring is zero and the radius of the bright ring is $\sqrt{\frac{\lambda R}{2}}$. Therefore, the centre is dark. Alternately dark and bright rings are produced (Fig. 8.27).

Result. The radius of the dark ring is proportional to (i) $\sqrt{n}$ (ii) $\sqrt{\lambda}$ and (iii) $\sqrt{R}$. Similarly the radius of the bright ring is proportional to

(i) $\sqrt{\frac{2n-1}{2}}$ (ii) $\sqrt{\lambda}$ and (iii) $\sqrt{R}$.

If D is the diameter of the dark ring,

$$D = 2r = 2\sqrt{n\lambda R} \quad ...(viii)$$

For the central dark ring

$$n = 0$$

$$D = 2\sqrt{n\lambda R} = 0$$

This corresponds to the centre of the Newton's rings. While counting the order of the dark rings 1, 2, 3, etc. the central ring is not counted.

Fig. 8.27.

Therefore for the first dark ring,

$$n = 1$$

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

For the second dark ring, $n = 2$,

$$D_2 = 2\sqrt{2\lambda R}$$

and for the n th dark ring,

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

Take the case of 16 th and 9 th rings,

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

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

The difference in diameters between the 16 th and the 9 th rings,

$$D_{16} - D_9 = 8\sqrt{\lambda R} - 6\sqrt{\lambda R} = 2\sqrt{\lambda R}$$

Similarly the difference in the diameters between the fourth and first rings,

$$D_4 - D_1 = 2\sqrt{4\lambda R} - 2\sqrt{\lambda R} = 2\sqrt{\lambda R}$$

Therefore, the fringe width decreases with the order of the fringe and the fringes got closer with increase in their order.

For bright rings,

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

or

$$D^2 = 2(2n-1)\lambda R \qquad ...(x)$$

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

In equation (ix), substituting $n = 1, 2, 3$ (number of the ring) the radii of the first, second, third etc., bright rings can be obtained directly.

(ii) Newton's rings by transmitted light. In the case of transmitted light (Fig. 8.28), the interference fringes are produced such that for bright rings,

$$2\mu t\cos\theta = n\lambda \qquad ....(xii)$$

and for dark rings

$$2\mu t\cos\theta = (2n-1)\frac{\lambda}{2} \qquad ..(xiii)$$

Here, for air

$$\mu = 1,$$

and $\qquad \cos\theta = 1$

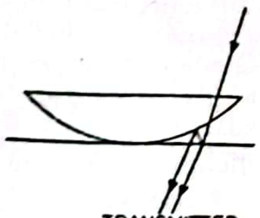

Fig. 8.28

For bright rings,

$$2t = n\lambda$$

and for dark rings $\qquad 2t = (2n-1)\dfrac{\lambda}{2}$

Taking the value of $t = \dfrac{r^2}{2R}$, where r is the radius of the ring and R the radius of curvature of the lower surface of the lens, the radius for the bright and dark rings can be calculated.

For bright rings,

$$r^2 = n\lambda R \qquad ...(xiv)$$

For dark rings,

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

where $\qquad n = 1, 2, 3\ldots$ etc.

When, $n = 0$, for bright rings

$$r = 0.$$

Therefore, in the case of Newton's rings due to transmitted light, the central ring is bright (Fig. 8.29) *i.e.*, just opposite to the ring pattern due to reflected light.

Fig. 8.29.

Example 8.46. *A thin equiconvex lens of focal length 4 metres and reflective index 1.50 rests on and in contact with an optical flat, and using light of wavelength 5460 Å, Newton's rings are viewed normally by reflection. What is the diameter of the 5 th bright ring ?*

The diameter of the n th bright ring is given by

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

Here $\qquad n = 5, \qquad \lambda = 5460 \times 10^{-8}$ cm

$$f = 400 \text{ cm}, \quad \mu = 1.50$$

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

Here $\qquad R_1 = R, \quad R_2 = -R$

$$\therefore \quad \frac{1}{f} = (\mu - 1)\left(\frac{2}{R}\right)$$

$$\frac{1}{400} = (1.50 - 1)\left(\frac{2}{R}\right)$$

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

$$\therefore \quad D_n = \sqrt{2 \times (2 \times 5 - 1) \times 5460 \times 10^{-8} \times 400}$$

$$D_n = 0.627 \text{ cm}$$

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8.24 DETERMINATION OF THE WAVELENGTH OF SODIUM LIGHT USING NEWTONS'S RINGS

The arrangement used is shown in Fig. 8.25. S is a source of sodium light. A parallel beam of light from the lens L_1 is reflected by the glass plate B inclined at an angle of 45° to the horizontal. L is a plano-convex lens of large focal length. Newton's rings are viewed through B by the travelling microscope M focussed on the air film. Circular bright and dark rings are seen with the centre dark. With the help of a travelling microscope, measure the diameter of the n th dark ring. Fig - 8.25

Suppose, the diameter of the n th ring $= D_n$ Newton Theory

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

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But, $$r_n = \frac{D_n}{2}$$

$$\therefore \quad \frac{(D_n)^2}{4} = n\lambda R$$

or $$D_n^2 = 4n\lambda R \qquad ...(i)$$

Measure the diameter of the $n+m$ th dark ring.

Let it be D_{n+m}

$$\therefore \quad \frac{(D_{n+m})^2}{4} = (n+m)\lambda R$$

or $$(D_{n+m})^2 = 4(n+m)\lambda R \qquad ...(ii)$$

Subtracting (i) from (ii)

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

or $$\lambda = \frac{(D_{n+m})^2 - (D_n)^2}{4mR} \qquad ...(iii)$$

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Hence, λ can be calculated. Suppose the diameters of the 5 th ring and the 15 th ring are determined. Then, $m = 15 - 5 = 10$.

$$\therefore \quad \lambda = \frac{(D_{15})^2 - (D_5)^2}{4 \times 10 R} \qquad ...(iv)$$

The radius of curvature of the lower surface of the lens is determined with the help of a spherometer but more accurately it is determined by

Boy's method. Hence the wavelength of a given monochromatic source of light can be determined.

Example 8.47. *A plano-convex lens of radius 300 cm is placed on an optically flat glass plate and is illuminated by monochromatic light. The diameter of the 8 th dark ring in the transmitted system is 0.72 cm. Calculate the wavelength of light used.*

[Delhi B.Sc (Hons) 1991]

For the transmitted system,

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

Here $n = 8, \quad D = 0.72$ cm, $\quad r = 0.36$ cm

$R = 300$ cm, $\quad \lambda = ?$

$$\lambda = \frac{2r^2}{(2n-1)R} = \frac{2 \times (0.36)^2}{(2 \times 8 - 1)\,300}$$

$$= 5760 \times 10^{-8} \text{ cm}$$

or $$\lambda = 5760 \text{ Å}$$

Example 8.48. *In a Newton's rings experiment the diameter of the 15 th ring was found to be 0.590 cm and that of the 5 th ring was 0.336 cm. If the radius of the plano-convex lens is 100 cm, calculate the wavelength of light used.*

Here $D_5 = 0.336$ cm $\quad D_{15} = 0.590$ cm.

$R = 100$ cm ; $m = 10$,

$$\lambda = \frac{(D_{n+m})^2 - (D_n)^2}{4mR} = \frac{D_{15}^2 - D_5^2}{4 \times 10 \times R}$$

$$\lambda = \frac{(0.590)^2 - (0.336)^2}{4 \times 10 \times 100} = 5880 \times 10^{-8} \text{ cm}$$

$$\lambda = 5880 \text{ Å}$$

Example 8.49. *In a Newton's rings experiment, the diameter of the 5 th ring was 0.336 cm and the diameter of the 15 th ring = 0.590 cm. Find the radius of curvature of the plano-convex lens, if the wavelength of light used is 5890 Å.*

Here $D_5 = 0.336$ cm., $D_{15} = 0.590$ cm,

and $m = 10, \quad \lambda = 5890 \times 10^{-8}$ cm, $\quad R = ?$

$$R = \frac{(D_{n+m})^2 - (D_n)^2}{4m\lambda} = \frac{D_{15}^2 - D_5^2}{4 \times 10 \times \lambda}$$

$$R = \frac{(0.590)^2 - (0.336)^2}{4 \times 10 \times 5890 \times 10^{-8}}$$

$$= 99.82 \text{ cm}$$

Example 8.50. *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 3.2 mm. The light is falling at such an angle that it passes through the air film at an angle of zero degree to the normal.*

[*Rajasthan, 1987*]

For dark rings

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

Here $r = \frac{3.2}{2}$ mm $= 1.6$ mm $= 0.16$ cm

$$n = 3 \;;\; \lambda = 5890 \times 10^{-8} \text{ cm}$$

$$\therefore \quad R = \frac{(0.16)^2}{3 \times 5890 \times 10^{-8}}$$

$$R = 144.9 \text{ cm}$$

wE 8(b)

8.25 REFRACTIVE INDEX OF A LIQUID USING NEWTON'S RINGS

The experiment is performed when there is an air film between the plano-convex lens and the optically plane glass plate. These are kept in a metal container C. The diameter of the n th and the $(n+m)$ th dark rings are determined with the help of a travelling microscope (Fig. 8.30).

For air, $(D_{n+m})^2 = 4\,(n+m)\,\lambda R \;;\; D_n^2 = 4n\lambda R$

$$D_{n+m}^2 - D_n^2 = 4m\lambda R \qquad \ldots(i)$$

The liquid is poured in the container C without disturbing the arrangement. The air film between the lower surface of the lens and the upper surface of the plate is replaced by the liquid. The diameters of the n th ring and the $(n+m)$ th ring are determined.

For the liquid, $2\mu t \cos\theta = n\lambda$ for dark rings

or $2\mu t = n\lambda$. But, $t = \frac{r^2}{2R}$

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

or $$r^2 = \frac{n\lambda R}{\mu}. \text{ But } r = \frac{D}{2} \;;\; D^2 = \frac{4n\lambda R}{\mu}$$

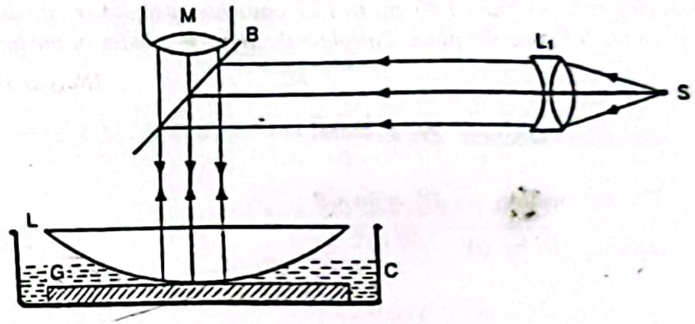

Fig. 8.30

If D_n' is the diameter of the n th ring and D'_{n+m} is the diameter of the $(n+m)$ th ring

then, $$(D'_{n+m})^2 = \frac{4(n+m)\lambda R}{\mu} \;;\; (D_n')^2 = \frac{4n\lambda R}{\mu}$$

or $$(D'_{n+m})^2 - (D_n')^2 = \frac{4m\lambda R}{\mu} \qquad \ldots(ii)$$

or $$\mu = \frac{4m\lambda R}{(D'_{n+m})^2 - (D_n'^2)} \qquad \ldots(iii)$$

If m, λ, R, D'_{n+m} and D'_n are known μ can be calculated. If λ is not known, then divide (*iii*) By (*i*)

$$\mu = \frac{(D_{n+m})^2 - (D_n)^2}{(D'_{n+m})^2 - (D'_n)^2} \qquad \ldots(iv)$$

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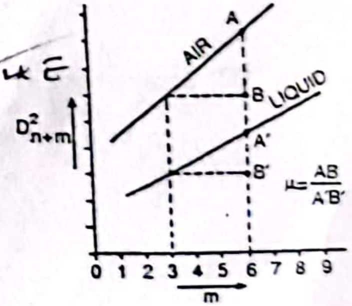

Fig. 8.31

Graphical method. The diameters of the dark rings are determined for various orders, varying from the n th ring to the $(n+m)$ th ring, first with air as the medium and then with the liquid. A graph is plotted between D^2_{n+m} along the y-axis and m along the x-axis, where

$m = 0, 1, 2, 3 \ldots$ etc. The ratio of the slopes of the two lines (air and liquid), gives the refractive index of the liquid.

$$\mu = \frac{AB}{A'B'}$$

Example 8.51. *In a Newton's rings experiment the diameter of the 10 th ring changes from 1.40 cm to 1.27 cm when a liquid is introduced between the lens and the plate. Calculate the refractive index of the liquid.*

(*Nagpur* 1985)

For liquid medium $D_1^2 = \dfrac{4n\lambda R}{\mu}$ ...(*i*)

For air medium $D_2^2 = 4n\lambda R$ ...(*ii*)

Dividing (*ii*) by (*i*)

$$\mu = \left(\frac{D_2}{D_1}\right)^2$$

Here $D_1 = 1.27$ cm, $D_2 = 1.40$ cm

$$\therefore \quad \mu = \left(\frac{1.40}{1.27}\right)^2 = 1.215$$

Example 8.52. *In a Newton's rings arrangement, if a drop of water (μ = 4/3) be placed in between the lens and the plate, the diameter of the 10 th 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 Å.*

(*Delhi* 1983)

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

Here $\mu = \dfrac{4}{3}$, $D_n = 0.6$ cm

$n = 10$, $\lambda = 6000$ Å $= 6 \times 10^{-5}$ cm

$R = ?$

$$R = \frac{4 \times (0.6)^2}{3 \times 4 \times 10 \times 6 \times 10^{-5}}$$

$$= 200 \text{ cm}$$

Example 8.53. *Newton's rings are formed by reflected light of wavelength 5895 Å with a liquid between the plane and curved surfaces. If the diameter of the 5 th bright ring is 3 mm and the radius of curvature of the curved surface is 100 cm, calculate the reflective index of the liquid.*

(*Gorakhpur* 1986)

Here, for the n th bright ring,

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

Here $n = 5$, $\lambda = 5895 \times 10^{-8}$ cm, $R = 100$ cm, $r = \dfrac{3}{2}$ mm $= 0.15$ cm

$\mu = ?$

$$\mu = \frac{(2 \times 5 - 1) \times 5895 \times 10^{-8} \times 100}{2\,(0.15)^2}$$

$$\mu = 1.179$$

Example 8.54. *In a Newton's rings experiment the diameter of the 15 th ring was found to be 0.590 cm and that of the 5 th ring was 0.336 cm. If the radius of the plano-convex lens is 100 cm, calculate the wavelength of light used.* (*Delhi* ; 1984)

Here $D_5 = 0.336$ cm $= 3.36 \times 10^{-3}$ m

$D_{15} = 0.590$ cm $= 5.90 \times 10^{-3}$ m

$R = 100$ cm $= 1$ m, $\lambda = ?$

$$\lambda = \frac{(D_{n+m})^2 - D_n^2}{4mR} = \frac{D_{15}^2 - D_5^2}{4 \times 10 \times R}$$

$$\lambda = \frac{(5.9 \times 10^{-3})^2 - (3.36 \times 10^{-3})^2}{4 \times 10 \times 1}$$

$$= 5.880 \times 10^{-7} \text{ m}$$

$$\lambda = 5880 \text{ Å}$$

Example 8.55. *In a Newton's rings experiment the diameter of the 12 th ring changes from 1.50 cm to 1.35 cm when a liquid is introduced between the lens and the plate. Calculate the refractive index of the liquid.*

(*Delhi* 1990)

For liquid medium

$$D_1^2 = \frac{4n\lambda R}{\mu} \qquad \ldots(i)$$

For air medium

$$D_2^2 = 4n\lambda R \qquad \ldots(ii)$$

Dividing (*ii*) by (*i*)

$$\mu = \left(\frac{D_2}{D_1}\right)^2$$

Here $\quad D_1 = 1.35$ cm

$D_2 = 1.50$ cm

$$\mu = \left(\frac{1.50}{1.35}\right)^2$$

$$\mu = 1.235$$

Example 8.56. *Newton's rings are observed in reflected light of* $\lambda = 5.9 \times 10^{-5}$ cm. *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.*

(*Delhi, 1991*)

(*i*) Here. $\quad r^2 = n\lambda R$

$$\lambda = 5.9 \times 10^{-5} \text{ cm} = 5.9 \times 10^{-7} \text{ m}$$

$$n = 10$$

$$\therefore \quad R = \frac{(2.5 \times 10^{-3})^2}{10 \times 5.9 \times 10^{-7}}$$

$$R = 1.059 \text{ m}$$

(*ii*) Thickness of the air film $= t$

$$2t = n\lambda$$

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

$$= \frac{10 \times 5.9 \times 10^{-7}}{2}$$

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

8.26 NEWTON'S RINGS FORMED BY TWO CURVED SURFACES

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 (Fig. 8.32). The dark and bright rings are formed and can be viewed with a travelling microscope. Suppose the radius of the n th dark ring $= r$. The thickness of the air film at P, is

$$PQ = PT - QT$$

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 $\quad PQ = t$

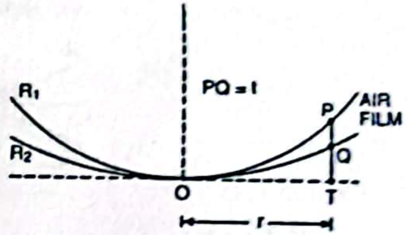

Fig. 8.32.

For reflected light,

$$2\mu t \cos\theta = n\lambda, \text{ for dark rings.}$$

Here, for air $\quad \mu = 1$

$$\cos\theta = 1$$

$$2t = n\lambda$$

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

$$r^2\left[\frac{1}{R_1} - \frac{1}{R_2}\right] = n\lambda \qquad \text{...(i)}$$

where $\quad n = 0, 1, 2, 3 \ldots$ etc.

For bright rings,

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

Taking $\quad \mu = 1$

and $\quad \cos\theta = 1$

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

or $$r^2\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{(2n+1)\lambda}{2} \qquad \text{...(ii)}$$

where $n = 0, 1, 2, 3 \ldots$ etc.

For the 10 th bright ring, the value of $n = 10 - 1 = 9$

$\therefore$ For n th bright ring,

$$r_n^2\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \left[\frac{[2(n-1)+1]\lambda}{2}\right] = \frac{(2n-1)\lambda}{2} \qquad \text{...(iii)}$$

Special Case. When the lower surface as seen from above is convex (Fig. 8.33).

$$PQ = PT + QT$$

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

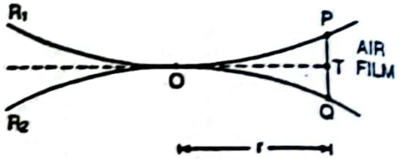

Fig. 8.33.

For dark rings,

$$2PQ = n\lambda$$

$$r^2\left(\frac{1}{R_1}+\frac{1}{R_2}\right) = n\lambda \quad ...(iii)$$

For bright rings,

$$2PQ = (2n+1)\frac{\lambda}{2}$$

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

When $n = 0, 1, 2, 3 \ldots$ etc.

For the first bright ring, $n = 0$

$$\therefore \quad r_1^2\left(\frac{1}{R_1}+\frac{1}{R_2}\right) = \frac{\lambda}{2}$$

For the 10 th bright ring, $n = 9$

$$r_{10}^2\left(\frac{1}{R_1}+\frac{1}{R_2}\right) = [2(9)+1]\frac{\lambda}{2}$$

For the n th bright ring

$$r_n^2\left(\frac{1}{R_1}+\frac{1}{R_2}\right) = [2(n-1)+1]\frac{\lambda}{2}$$

$$r_n^2\left[\frac{1}{R_1}+\frac{1}{R_2}\right] = \frac{(2n-1)\lambda}{2} \quad ...(iv)$$

Example 8.57. *A convex surface of radius 300 cm of a planoconvex lens rests on a concave spherical surface of radius 400 cm and Newton's rings are viewed with reflected light of wavelength 6×10^{-5} cm. Calculate the diameter of the 13 th bright ring.*

Here, $R_1 = 300$ cm, $R_2 = 400$ cm, $n = 13$, $\lambda = 6 \times 10^{-5}$ cm

For the bright ring,

$$R_n^2\left(\frac{1}{R_1}-\frac{1}{R_2}\right) = \frac{(2n-1)\lambda}{2}$$

$$r_{13}^2\left(\frac{1}{300}-\frac{1}{400}\right) = \frac{25}{2}\times 6\times 10^{-5}$$

or $\quad r_{13} = 0.95$ cm

$\therefore$ Diameter of the 13 th bright ring $D_{13} = 2r_{13} = 1.90$ cm

Example 8.58. *If in the example 8.57 the plano-convex lens rests on a convex spherical surface (the other data remaining the same), calculate the diameter of the 11 th bright ring.*

Here, $R_1 = 300$ cm, $R_2 = 400$ cm, $n = 11$, $\lambda = 6\times 10^{-5}$ cm

For the bright ring,

$$r_n^2\left(\frac{1}{R_1}+\frac{1}{R_2}\right) = \frac{(2n-1)\lambda}{2}$$

$$r_{11}^2\left(\frac{1}{300}+\frac{1}{400}\right) = \frac{21\times 6\times 10^{-5}}{2}$$

$$r_{11} = 0.33 \text{ cm}$$

$\therefore$ Diameter of the 11th bright ring

$$= 2r_{11} = 0.66 \text{ cm}$$

8.27 NEWTON'S RINGS WITH BRIGHT CENTRE DUE TO REFLECTED LIGHT

The rings formed by reflected light have a dark centre when there is an air film between the lens and the plane glass plate. At the centre, the two surfaces are just in contact but the two interfering rays are reflected under different conditions due to which a path difference of half a wavelength occurs (since one of the rays undergoes a phase change of π, when reflected from the glass plate).

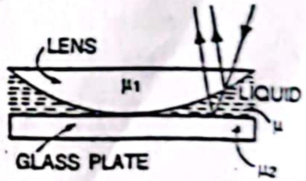

Fig. 8.34.

Consider a transparent liquid of refractive index μ trapped between the two surfaces in contact (Fig. 8.34). The refractive index of the material of the lens is μ_1 and that of the glass plate is μ_2 such that $\mu_1 > \mu > \mu_2$. This is possible if a little oil of sassafaras is placed between a convex lens of crown glass and a plate of flint glass. The reflections in both the cases will be from denser to rarer medium and the two interfering rays are reflected under the same conditions. Therefore, in this case the central spot will be bright.

The diameter of the n th bright ring,

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

The central spot will also be bright, if $\mu_1 < \mu < \mu_2$, because a path difference of $\frac{\lambda}{2}$ takes place at both the upper and the lower glass-liquid surfaces. Here again the two interfering beams are reflected under similar conditions. In this case also the central spot is bright due to reflected light.

8.28 NEWTON'S RINGS WITH WHITE LIGHT

With monochromatic light, Newton's rings are alternately dark and bright. The diameter of the ring depends upon the wavelength of light used. When white light is used, the diameter of the rings of the different colours will be different and coloured rings are observed. Only the first few rings are clear and after that due to overlapping of the rings of different colours, the rings cannot be viewed.

Example 8.59. *Light containing 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 n th dark ring due to λ_1, coincides with the (n + 1) th dark ring due to λ_2, prove that the radius of the n th dark ring of λ_1 is*

$$= \sqrt{\frac{\lambda_1\lambda_2 R}{\lambda_1 - \lambda_2}}$$

(*Mysore 1971*)

The radius of the n th dark ring due to λ_1

$$= \sqrt{n\lambda_1 R} \qquad \ldots(i)$$

The radius of the $(n + 1)$ th dark ring due to λ_2

$$= \sqrt{(n+1)\lambda_2 R} \qquad \ldots(ii)$$

As (*i*) and (*ii*) are equal

$$r = \sqrt{n\lambda_1 R} = \sqrt{(n+1)\lambda_2 R} \qquad \ldots(iii)$$

$$\therefore \quad n\lambda_1 R = (n+1)\lambda_2 R$$

or

$$n = \frac{\lambda_2}{\lambda_1 - \lambda_2}.$$

Substituting the value of n in equation (*iii*)

$$n = \sqrt{n\lambda_1 R} = \sqrt{\frac{\lambda_1\lambda_2 R}{\lambda_1 - \lambda_2}}$$

Example 8.60. *Newton's rings arrangement is used with a source emitting two wavelengths λ_1 and λ_2. It is found that the n th dark ring due to λ_1 coincides with (n + 1) th dark ring due do λ_2. Find the diameter of the n th dark ring for wavelength λ_1 given $\lambda_1 = 6 \times 10^{-5}$ cm, $\lambda_2 = 5.9 \times 10^{-5}$ cm and radius of curvature of the lens is 90 cm.*

(*Gorakhpur 1967*)

$$d = 2r = 2 \times \sqrt{\frac{\lambda_1\lambda_2 R}{\lambda_1 - \lambda_2}}$$

$$d = 2 \times \sqrt{\frac{6 \times 10^{-5} \times 5.9 \times 10^{-5} \times 90}{(6 - 5.9) \times 10^{-5}}}$$

$$d = 1.129 \text{ cm}$$

8.29 HAIDINGER'S FRINGES

In the relation $2\mu t \cos r = n\lambda$, if t is large, a very small change in r will change the path difference by one wavelength. In this case the ray must pass through a plate as a parallel beam and must be received by the eye or the telescope focussed for infinity. The interference patterns are known as fringes of equal inclination. These are different from Newton's rings. These fringes of equal inclination were first observed by Haidinger and afterwards studied by Lummer and Mascart. From an extended source S, light rays fall on the plate. The rays striking at the same angle and refracted at the same angle form a parallel beam and are viewed through the telescope focussed for infinity (Fig. 8.35). The pattern is a series of concentric circles whose centre is the principal focus of the objective of the telescope.

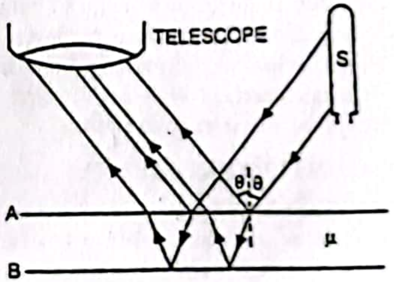

Fig. 8.35.