CC 4 Expt. 5

..id

	μ
(i)]	[from Eq. (iii)]
	...

... (v)

$, \frac{h}{2} << \frac{d^2}{6h}$, and therefore,

... (vi)

eter. With a set of typical
...portional error in μ is

...in and its real, inverted

...paraxial rays take part in
...oided.

...void the backlash error.
...p of its image below the

Ref: Chattopadhyay Rakshit

...ewise causes a relative
...ax.

2. How do you avoid parallax in this experiment?

   Ans. The object pin is raised or lowered till its tip and the tip of its real inverted image (which touch each other) move together without any relative shift between them as the eye is moved sidewise. In this way, parallax is avoided.

3. What type of image is obtained here? How do you ensure it?

   Ans. Real image. It is ensured by the fact that the image is inverted.

4. What is the nature of the liquid lens?

   Ans. Plano-concave lens.

5. Is the focal length of the liquid lens greater or smaller than the focal length of the convex lens?

   Ans. Greater, since the combination acts as a convex lens.

6. Is there any limit to the value of the refractive index measured by this method?

   Ans. Yes. If the refractive index of the liquid is such that the focal length f_1 of the convex lens and the focal length f_2 of the plano-concave liquid lens are equal, the combination does not behave as a lens and the method fails. If an equiconvex glass lens of refractive index 1.5 is taken, then its focal length f_1 is equal to the radius r of any of its surface. From Eq. (iii), the maximum refractive index of the liquid is found to be $\mu_{max} = 1 + \frac{f_1}{f_2} = 2$, when $f_1 = f_2$.

7. Can you avoid the use of the spherometer?

   Ans. Yes. In that case, a liquid of known refractive index (say, μ') is required. The focal length f'_2 of this liquid concave lens is found following the procedure of this experiment. Equation (iii) gives $\mu' = 1 + \frac{r_1}{f'_2}$ or, $r_1 = (\mu' - 1)f'_2$. The refractive index of the liquid under test is obtained from

$$\mu = 1 + \frac{r_1}{f_2} = 1 + \frac{(\mu' - 1)f'_2}{f_2}.$$

[See also the 'Aids to the Viva Voce' of Expt. No. O2A]

~~Experiment No. O3~~

TO DETERMINE THE RADIUS OF CURVATURE OF THE CONVEX SURFACE OF A LENS BY NEWTON'S RINGS

Theory :

When a parallel beam of monochromatic light is incident normally on a combination of a plano-convex lens L and a glass plate P, as shown in Fig. 3.O3(i), a part of each incident ray is reflected from

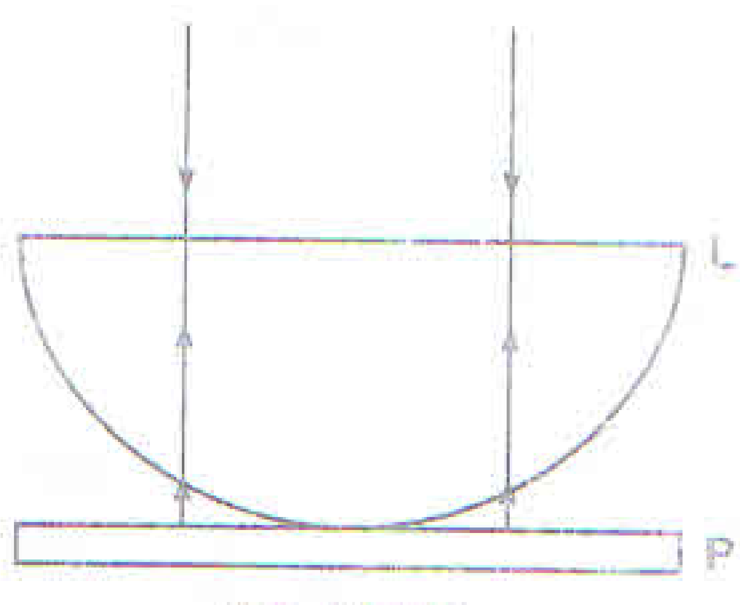

Fig. 3.O3(i)

the lower convex surface of the lens, and a part, after refraction through the air film between the lens and the plate, is reflected back from the plate surface. These two reflected rays are coherent. Hence the reflected rays will interfere and produce a system of alternate dark and bright rings with the point of contact between the lens and the plate as the centre. These rings are known as Newton's rings.

If D_m is the diameter of the mth bright ring, counted from the centre, we have

$$\frac{D_m^2}{4R} = (2m+1)\frac{\lambda}{2}, \qquad \text{... (i)}$$

where R is the radius of curvature of the lower surface of the lens L, and λ is the wavelength of the light. For the $(m + n)$th bright ring from the centre, we obtain

$$\frac{D_{m+n}^2}{4R} = (2m+2n+1)\frac{\lambda}{2}, \qquad \text{... (ii)}$$

where D_{m+n} is the diameter of the $(m + n)$th ring.

From Eqs. (i) and (ii) we get $R = \dfrac{D_{m+n}^2 - D_m^2}{4n\lambda}$. ... (iii)

Equation (iii) is used as the *working formula* for calculating R. When the diameters and the wavelength are in m, R is obtained in m.

Apparatus :

1. The apparatus commonly used for this experiment is shown in Fig. 3.O3(ii). The combination of L and P is enclosed in a cylindrical case (not shown in the figure) provided with three levelling screws. The inside of the case is coated black. The top of the case is open and provided with a screw cap to apply suitable pressure uniformly on the rim of the lens.

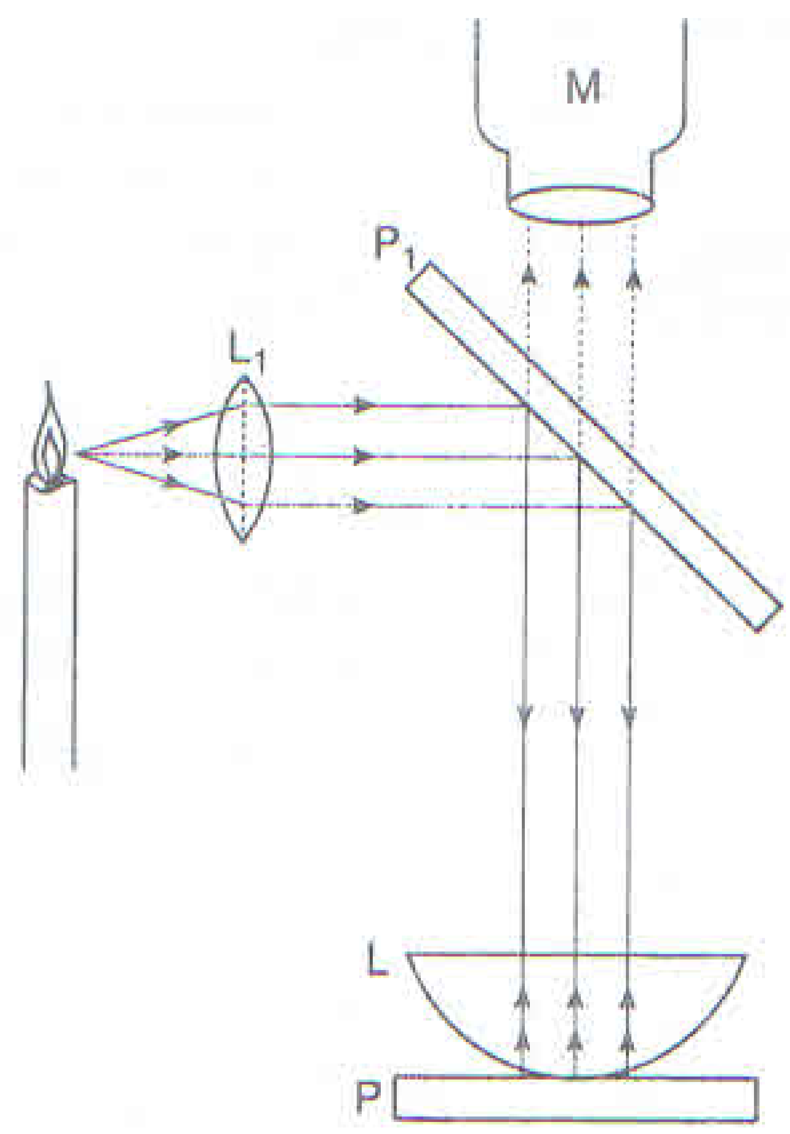

Fig. 3.O3(ii)

A glass plate P_1 is placed above the top of the case and is inclined to the vertical at an angle of 45°. A bunsen flame, illuminated with sodium salt, is placed at the focal plane of another convex lens L_1, so that a parallel beam of light falls on the glass plate P_1 at an angle of 45°. *Alternatively*, a sodium lamp can be used in place of the sodium flame. The light rays, after reflection from the plate P_1, fall normally on the wedge-shaped air film enclosed between the lens L and the glass plate P. A travelling microscope M, directed vertically downwards, is used to view the magnified system of rings which practically form on the glass plate P.

Procedure :

1. Place a spirit leve
it so that the scale along wh
vertical. Focus the eye-piece
constant of the horizontal sc

2. Take away the lens
means of cotton moistened w
of the glass plate and insert it
marked point. Now place the
marked point.

3. Produce a sodium f
salt, into the nonluminous pa
an extended bright surface of
to its focal length. (*Alternativ*
alternate dark and bright ring

4. Adjust the glass pl
uniformly illuminated rings a
sodium flame with respect to
through the microscope.

5. Focus the microscop
necessary, by moving slightly
slowly until the rings are focu
to the direction of microscope

6. Move the microscope
near the centre are indistinct,
extreme distinct bright ring s
movement passes through the
from the horizontal scale and
pass off several (say, 4) interm
readings of the horizontal scale
rings. Be sure that the last brig
the centre. Next shift the micr

From the readings taken, d
microscope readings correspondi

7. Repeat the measurem
the left to the right, and determ
of the rings.

8. Plot the square of th
would be a straight line [see E
bright rings. The value of n sh

9. If time permits, repea
Find the mean R.

Experimental Results :

Vernier
... divisions scale
(Make

e air film between the lens
ys are coherent. Hence the
ght rings with the point of
n as Newton's rings.
we have

... (i)

l is the wavelength of the

... (ii)

... (iii)

the diameters and the

3.O3(ii). The combination
ded with three levelling
d provided with a screw

vertical at an angle of
of another convex lens
Alternatively, a sodium
from the plate P_1, fall
ss plate P. A travelling
system of rings which

Procedure :

1. Place a spirit level on the base of the microscope and adjust the levelling screws attached to it so that the scale along which the microscope slides is horizontal and the axis of the microscope is vertical. Focus the eye-piece on the cross-wires by moving the focussing lens in or out. Find the vernier constant of the horizontal scale.

2. Take away the lens L and the glass plate P from the case and carefully clean their surfaces by means of cotton moistened with benzene or alcohol. Mark a point on the centre of the upper surface of the glass plate and insert it within the case. Place the microscope above the plate and focus it for the marked point. Now place the lens on the plate so that its convex surface remains in contact with the marked point.

3. Produce a sodium flame by introducing an asbestos ring, soaked with a solution of common salt, into the nonluminous part of the bunsen flame. Adjust the position of the ring on the flame so that an extended bright surface of the illuminated flame is in front of the lens L_1 at a distance nearly equal to its focal length. (*Alternatively*, a sodium lamp can be used.) On looking through the microscope, alternate dark and bright rings will be seen.

4. Adjust the glass plate P_1 by rotating it about a horizontal axis until a large number of uniformly illuminated rings appear on both sides of the central dark ring. Adjust the position of the sodium flame with respect to the lens L_1 so that a maximum number of dark and bright rings is visible through the microscope.

5. Focus the microscope on the centre of the central dark ring by sliding the microscope and, if necessary, by moving slightly the case containing the combination L and P. Adjust the microscope tube slowly until the rings are focused as distinctly as possible, and set one of the cross-wires perpendicular to the direction of microscope movement.

6. Move the microscope to the left counting the number of bright rings passed. (When the rings near the centre are indistinct, count from the first distinct bright ring.). Set the microscope on the extreme distinct bright ring so that the cross-wire perpendicular to the direction of the microscope movement passes through the bright ring and is tangential to it. Take the reading of the microscope from the horizontal scale and vernier, and note the ring number. Displace the microscope to the right, pass off several (say, 4) intermediate rings, and note, for the next bright ring, the ring number and the readings of the horizontal scale and the vernier. In this way, take readings for a number (say, 5) of bright rings. Be sure that the last bright ring will not include any of the few deformed rings which form round the centre. Next shift the microscope to the right and take readings for the same rings as before.

From the readings taken, determine the diameters of the rings by taking the difference between the two microscope readings corresponding to its two positions (one in the left and another in the right) on each ring.

7. Repeat the measurements by sliding the microscope from the right to the left, and then from the left to the right, and determine the diameters of the same rings as before. Find the mean diameters of the rings.

8. Plot the square of the ring diameter (D_m^2) in metre² against the ring number m. The plot would be a straight line [see Eq. (i)]. Find, from the plot, D_m^2 and D_{m+n}^2 for the mth and the $(m+n)$th bright rings. The value of n should be as large as possible. Calculate R from Eq. (iii).

9. If time permits, repeat the whole experiment by rotating the lens combination through 90°. Find the mean R.

Experimental Results :

~~TABLE I~~

Determination of Vernier constant for the horizontal scale of the microscope

... divisions scale of vernier (say, m) = ... divisions (say, n) of main scale.

(Make a table similar to TABLE 1 of Exp. No. G1).

TABLE 1

Measurements of the diameters of the rings

[The specific values of the ring number are for illustration only]

Ring No. (m)	Direction of microscope movement	Microscope readings (cm) on the Left (R_1) Main scale	Left (R_1) Vernier	Left (R_1) Total	Right (R_2) Main scale	Right (R_2) Vernier	Right (R_2) Total	Diameter, $D_m = R_1 \sim R_2$ (cm)	Mean D_m (m)	D_m^2 (m^2)
	Left to Right	...	...	...	...	...	...	...		
p + 30	Right to Left	...	...	...	...	...	...	...	...	...
	Left to Right	...	...	...	...	...	...	...		
	Left to Right	...	...	...	...	...	...	...		
p + 25	Right to Left	...	...	...	...	...	...	...	...	...
	Left to Right	...	...	...	...	...	...	...		
p + 20										
p + 15										
p + 10										

Plot D_m^2 versus m.

Two sets of readings l → r r → l must be taken. If time permits take the 3rd set.

10

Plot D_m^2 versus m.

TABLE 3

Calculation of the radius of curvature, R

D_m^2 (m^2) (from graph)	D_{m+n}^2 (m^2) (from graph)	n	λ (m) (given*)	$R = \frac{D_{m+n}^2 - D_m^2}{4n\lambda}$ (m)
...	...	...	...	...

* For sodium light, take $\lambda = 5893Å = 5893 \times 10^{-10}$ m.

Determine of value from graph

Computation of Percentage Error :

The radius of curvature is calculated from Eq. (iii), viz.

$$R = \frac{D_{m+n}^2 - D_m^2}{4n\lambda}$$

Since D_{m+n} and D_m are only measured, the maximum proportional error in R is given by

$$\frac{\delta R}{R} = \frac{\delta\left(D_{m+n}^2 - D_m^2\right)}{D_{m+n}^2 - D_m^2} = \frac{2(D_{m+n} + D_m)\delta D}{D_{m+n}^2 - D_m^2} = \frac{2\delta D}{D_{m+n} - D_m}.$$

Since D_m or D_{m+n} is measured by taking the difference between the two readings of a scale provided with a vernier, the maximum error in measuring each of these quantities is twice the vernier constwant, i.e., $\delta D = 2 \times$ v.c.

The maximum percentage error in determining R is

$$\frac{\delta R}{R} \times 100 = \frac{4 \times \text{v.c.}}{\text{typical measured value of } (D_{m+n} - D_m)} \times 100.$$

Discussions :

1. The Newton's ring experiment can also be used to find the wavelength of a monochromatic light. In this case, the radius of curvature of the convex surface of the given lens is supplied or is determined otherwise. By employing sodium light whose mean wavelength is 589.3 nm, R can be determined from Eq. (iii), as in the present experiment. Then the same equation can be used to find the wavelength λ of any other given monochromatic light.

2. R is calculated from Eq. (iii) and not from Eq. (i). An error in the actual ring number m does not, therefore, affect the result.

3. Since the first few rings near the centre are deformed, they must be avoided while taking readings for the rings.

4. Care must be taken not to disturb the lens and glass plate combination in any way during the experiment.

5. Here the fringes (rings) are localized, being formed in the air film between the lens and the glass plate by division of amplitude. These rings are observed after refraction through the lens. The resulting error is small, if the lens is thin.

Aids to the Viva Voce

1. In the Newton's ring experiment, how does interference occur?

   Hint : See 'Theory' of this experiment.

2. Why are the interference fringes circular in this case?

   Ans. Here the film is of varying thickness and a locus of constant illumination over the face of the film is a locus of constant path difference which is a circle with the point of contact of the lens and the plate as centre. Hence the fringes are circular.

3. Why is an extended source used in this experiment?

   Ans. An extended source is used so that the whole surface of the lens is illuminated. This is necessary for the interference fringes to become circular rings.

4. What will happen if a point source or an illuminated slit is used instead of the extended source?

   Ans. With a point source only alternate dark and bright points will be seen. With an illuminated slit only a portion of the rings will be observed.

5. Why is the central spot dark?

   Ans. Although the path difference between the reflected rays from the centre (the point of contact of the convex surface of the lens and the glass plate) is zero, there is a phase-change of π due to reflection from the denser medium, i.e., from the glass plate. Because of this phase change, the central spot becomes dark.

6. When the rings are observed with transmitted light, is the central spot bright or dark?

   Ans. Bright.

7. What happens with the central spot when a liquid of refractive index μ greater than that of the lens and less than that of the glass plate is introduced between the lens and the glass plate?

   Ans. The central spot becomes bright, because in this case, the rays reflected from the lower surface of the lens (backed by denser medium) and that reflected from the upper surface of the glass plate will both suffer a phase change of π due to reflection.

8. Is it possible to determine the refractive index of the liquid by this experiment?

   Ans. Yes. By employing the relation $\mu = \dfrac{(D_{m+n}^2 - D_m^2)_{\text{air}}}{(D_{m+n}^2 - D_m^2)_{\text{liquid}}}$, the refractive index μ of the liquid can be calculated.

9. What would happen if white light is used instead of sodium light?

   Ans. A smaller number of coloured rings will be seen.

10. What are the differences between the biprism fringes and Newton's rings?

    Ans. Biprism fringes are straight and are formed by division of wavefront. Newton's rings are circular and are formed by division of amplitude. Biprism fringes are produced by a narrow source, but Newton's rings are produced by an extended source. Biprism fringes are nonlocalized, but Newton's rings are localized.

11. Where are the rings formed?

    Ans. The rings are formed on the air film between the lens and the glass plate.

12. On which factors

    Ans. The diameter
    (l) of light, order nu

13. What would happen if

    Ans. The rings will disa

14. Is it desirable to measu
    way?

    Ans. No. The radius c
    central screw of the sp
    the radius of curvature
    be measured accurate

15. What would happen to
    of refractive index μ?

    Ans. The rings will cc

16. When rings are forme

    Ans. No, there is a re

TO DETERMINI
LI(

Theory :

[Write the 'Theory' of E
Equations (i) and (ii) gi

λ

The radius of curvatu
spherometer using the form

R

where d is the average dist
displacement of the screw w

By measuring the diam
be found from Eq. (iii).

Apparatus :

[The same as in Expt.

illumination over the face of
ith the point of contact of the

e lens is illuminated. This is

stead of the extended source?

be seen. With an illuminated

e centre (the point of contact
is a phase-change of π due
cause of this phase change,

pot bright or dark?

ex μ greater than that of the
lens and the glass plate?

ys reflected from the lower
om the upper surface of the

experiment?

e index μ of the liquid can

ings?

efront. Newton's rings are
re produced by a narrow
n fringes are nonlocalized,

glass plate.

12. On which factors does the diameter of a ring depend?

    Ans. The diameter (D) of a ring depends on the radius of curvature (R) of the lens, wavelength (l) of light, order number (n) of the ring, and the refractive index (m) of the medium.

13. What would happen if the glass plate is replaced by a plane mirror?

    Ans. The rings will disappear and a uniform illumination will be observed due to strong reflection.

14. Is it desirable to measure the radius of curvature of the given lens by a spherometer in the usual way?

    Ans. No. The radius of curvature in this case is very large and therefore, the elevation of the central screw of the spherometer will be very small causing a large error in the measurement. If the radius of curvature is small, the rings will be too closely spaced and their diameters cannot be measured accurately.

15. What would happen to the rings if the space between the lens and the plate is filled with a liquid of refractive index μ?

    Ans. The rings will contract in the ratio of $\frac{1}{\sqrt{\mu}}$.

16. When rings are formed, is the light energy changed?

    Ans. No, there is a redistribution of energy.

Experiment No. O3A

TO DETERMINE THE WAVELENGTH OF A MONOCHROMATIC LIGHT BY NEWTON'S RING METHOD

Theory :

[Write the 'Theory' of Expt. No. O3 up to Eq. (ii) and then add the following.]

Equations (i) and (ii) give

$$\lambda = \frac{D_{m+n}^2 - D_m^2}{4nR} \qquad \text{... (iii)}$$

The radius of curvature R of the convex surface of the plano-convex lens is measured by a spherometer using the formula

$$R = \frac{d^2}{6h} + \frac{h}{2}, \qquad \text{... (iv)}$$

where d is the average distance between any two successive legs of the spherometer and h is the displacement of the screw when it touches successively the convex surface and a plane surface.

By measuring the diameters D_m and D_{m+n}, and determining R from Eq. (iv), the wavelength λ can be found from Eq. (iii).

Apparatus :

[The same as in Expt. No. O3.]