Newton's rings

Aim : 1. To determine the wavelength of sodium light by Newton's ring.
2. Plot a graph between 'n' and 'D_n^2' in the case of Newton's rings and hence find the radius of curvature of the surface of the lens

Apparatus Required :

A plano-convex lens of large radius of curvature, optical arrangement for Newton's rings, plane glass plate, sodium lamp and travelling microscope.

Formula used :

The wavelength λ of light is given by the formula:

$$\lambda = \frac{D^2_{n+m} - D^2_n}{4mR}$$

Where, D_{n+m} = diameter of (n+m)th ring,
D_n = diameter of nth ring,
m = an integer number (of the rings)
R = radius of curvature of the curved face of the plano-convex lens.

Description of apparatus :

The optical arrangement for Newton's ring is shown in fig. (1). Light from a monochromatic source (sodium lamp) is allowed to fall on the convex lens through a broad slit which renders it into a nearly parallel beam. Now it falls on a glass plate inclined at an angle 45° to the vertical, thus the parallel beam is reflected from the lower surface. Due to the air film formed by a glass plate and a plano convex lens of large radius of curvature, interference fringes are formed which are observed directly through a travelling microscope. The rings are concentric circles.

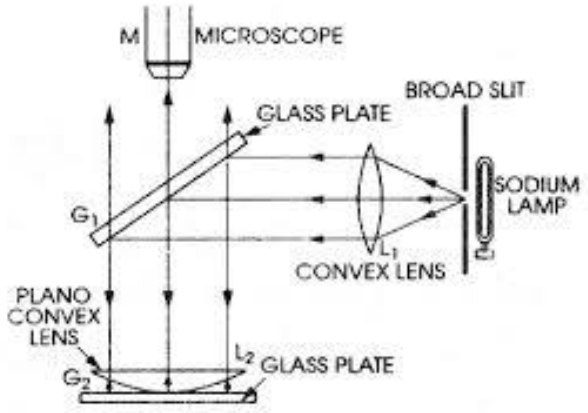


Figure 1

Theory:

A plano-convex lens is placed with its convex surface on the optically plane glass plate so as to enclose a thin film of air of varying thickness between the lens and the plate. Light from an extended monochromatic source (i.e. sodium lamp) of light is converted into a parallel beam of light by using a convex lens 'L_1' of short focal length and made to fall on an optically plane glass plate inclined at an angle of 45º to the vertical, where it gets reflected on to the plano-convex lens 'L_2' as shown in Fig.1 Interference takes place between the rays of light reflected from the upper and the lower surfaces of the wedge shaped air film enclosed between lens L_2 and glass plate P and circular interference fringes (alternate dark & bright) called Newton's rings are produced as shown in Fig.2

The center will be dark because at the center, lens is in contact with the glass plate and thickness of air film at the center is zero. By Stoke's law, a phase change of (or path difference of Fig.2) takes place due to the reflection at the lower surface of the film (Fig.3) as the ray of light passes from rarer from denser medium. As we proceed outwards from the center, the thickness of the film gradually increases being the same all along the circle with the center at the point of contact. Thus the fringes produced are concentric circles and localized in the air film. The fringes can be viewed by means of a low power travelling microscope 'M' as shown in Fig.1

The fringes are circular due to the fact that air film is symmetrical about the point of contact. The locus of all the points at same thickness is a circle i.e. all the points where the air film has a given thickness lie on a circle whose center is at 'O'

Let 'R' be the radius of curvature of the surface of plano-convex lens in contact with the glass plate P.

D_n = diameter of the n dark ring

λ = Wavelength of monochromatic source of light used

then, $\mathbf{D_n^2 = 4nR\lambda}$

It may be pointed out that surfaces of the lens and the plate may not be clean and the lens may not be perfect contact with the glass plate at the center. The center will not be dark. To eliminate the error due to this problem, the diameter of any two dark rings say, n^{th} and $(n+m)^{th}$ may be determined.

Therefore,

$$\mathbf{D_n^2 = 4nR\lambda \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)}$$

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

From equations (1) and (2), we get

$$\mathbf{\lambda = (D_n^2 - D_{n+m}^2)/4(m)R \ldots\ldots\ldots\ldots\ldots (3)}$$

since, this formula involves the difference of the squares of the diameters of two rings and is independent of the thickness of the air film at the point of contact 'O', the above error is minimized.

If the measurements are made on bright rings of the diameter of n^{th} bright ring is given by $\mathbf{D_n^2 = 2(2n+1)R}$

Therefore Diameter of the ring depends upon the wavelength of light used.

In the figure:

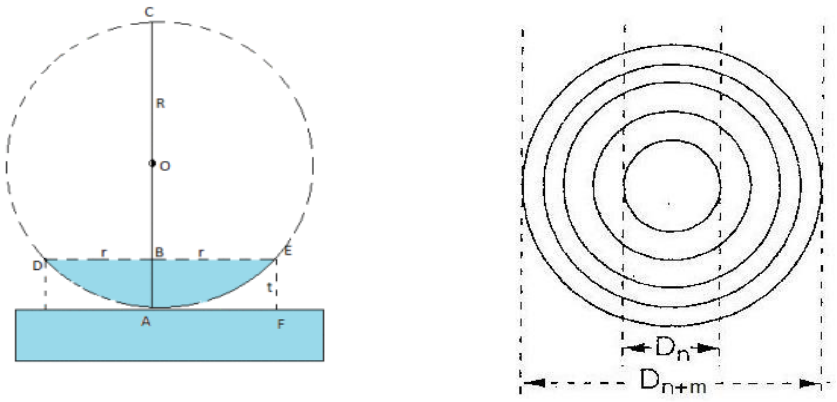


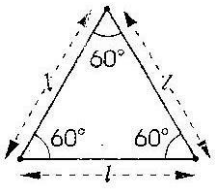
Figure 2

Here R is the radius of curvature of the lens that can be found with a spherometer using the relation

$$R = \frac{l^2}{6h} + \frac{h}{2}$$

where *l* is the distance between the two legs of the spherometer and *h* is the height or the thickness of the lens at the center.

Here, the radius of the curvature is determined by using a spherometer. In this case



$$R = \frac{l^2}{6h} + \frac{h}{2}$$

Figure 4

where *l* is the radius between the two legs of the spherometer as shown in fig. (4), *h* is the difference of the readings of the spectrometer when it is placed on the lens as well as when placed on plane surface (the thickness of the lens at the center) .

PROCEDURE:

1. Find the least count of micrometer scale.
2. Clean the surface of glass plate 'G', glass plate 'P' and the Plano-convex lens L, Put them in position as shown in Fig.1 in front of the sodium lamp.
3. Switch on the sodium lamp and see that only parallel beam of light coming from the convex lens on the glass plate 'G'

4. Adjust the position of microscope so that it lies vertically above the center of lens L_2. Focus the microscope so that alternate dark and bright rings are clearly visible.
5. Adjust the position of the microscope till the point of intersection of the cross–wires coincides with the center of the ring system and one of the vertical cross-wires is perpendicular to the horizontal scale.
6. Move the microscope to the left with the help of micrometer screw so that the vertical cross wire lies tangentially at one of the extreme ends of the 20^{th} dark ring.
7. Note the reading of the micrometer scale 'a 'of the microscope.
8. Slide the microscope backward with the help of micrometer screw and go on noting the readings when the cross wire lies tangentially at the extreme ends of horizontal diameter of 16^{th}, 12^{th}, 8^{th} and 4^{th} dark rings in column 'Left (a)' respectively.
9. Continue sliding the microscope to the right and note down the readings in column 'Right (b)' when the vertical cross wires lies tangentially at the other extreme end of the diameter of 4^{th}, 8^{th}, 16^{th} and 20^{th} dark rings respectively.
10. Now slide the microscope backwards and again note down the readings corresponding to the same rings on the right and then on the left to the center of the ring system in column 'Right(c) ' and 'Left(d)'.
11. Remove the Plano-convex lens L_2 and find the radius of curvature of its convex surface by using a spherometer.
    The radius of curvature may also be determined by plotting a graph between D_n^2 along Y-axis and then number of the ring(n) along X-axis as explained in part-2 of the experiment.

Observations :

Value of one division of the main scale = …. cm

No. of divisions on the vernier scale = ….

Least count of the microscope = ….

Table: For the determination of (D^2_{n+m}-D^2_n)

No. of the rings	**Microscope reading**		**Diameter**	**Microscope reading**		**Diameter**	**Mean Diameter**
	Left (a) cm.	**Right (b) cm.**	**d_1 =(a~b)**	**Right (c) cm**	**Left (d) cm**	**d_2=(c~d)**	$D = \frac{d_1 + d_2}{2}$
20							
16							
12							
8							
4							

Using spherometer method :

L.C. of spherometer = …. cm.

S. No.	Spherometer Reading						h = (b—a) cm.	Mean h cm.
	Zero reading on plane surface			Reading on lens				
	M.S.R.	V.S.R.	Total Reading cm. (a)	M.S.R.	V.S.R.	Total Reading cm. (b)		

Distance between the two legs of spherometer *l* = …. cms.

Calculations:

Using Spherometer method:

$$R = (l^2 / 6h) + (h / 2)$$

= …. cms

The wavelength of sodium light is given by:

$$\lambda = (D^2_{n+m} - D^2_n) / 4Rm$$

= …. Angstrom

The value of $(D^2_{n+m} - D^2_n)$ can also be obtained using a graph as shown in fig.(5). The graph is plotted between the square of diameter of the ring along Y-axis and corresponding number of ring along X-axis.

Result :

The mean wavelength λ of sodium light = …. Angstrom

Standard mean wavelength λ = ….. Angstrom

Percentage error = …. %

Sources of Error and Precautions :

i) Glass plates and lens should be cleaned thoroughly.

ii) The lens used should be of large radius of curvature.

iii) The source of light used should be an extended one.

iv) Before measuring the diameter of rings, the range of the microscope should be properly adjusted.

v) Crosswire should be focused on a bright ring tangentially.

vi) Radius of curvature should be measured accurately.

Theoretical error:

In our case, $\lambda = (D^2_{n+m} - D^2_n)/ 4Rm$

Taking logarithm of both sides and differentiating

$$\frac{\delta\lambda}{\lambda} = \frac{\lambda(D^2_{n+m} + D^2_n}{D^2_{n+m} - D^2_n} + \frac{\delta R}{R}$$

$$= \frac{2\{D_{n+m}(\delta D_{n+m}) + D_n(\delta D_{n)\}}}{D^2_{n+m} - D^2_n} + \frac{\delta R}{R}$$

= …. %.

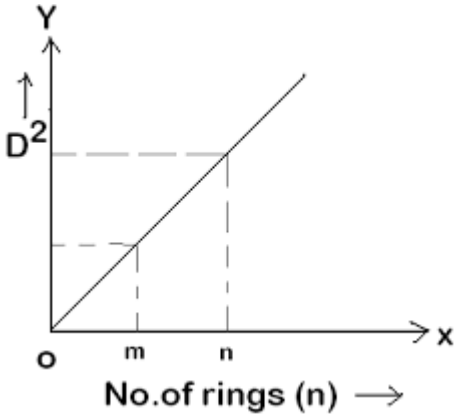


Figure 5

VIVA-VOCE QUESTIONS

1. What happens if the light rays are incident obliquely instead of normal incidence?
2. What will happen if a plane mirror is placed in place of a glass plate in Newton's rings experiment?
3. If white light is used in place of monochromatic light, how are Newton's rings affected?
4. Why the fringes obtained are circular and concentric?
5. Why is the center of circular fringes dark?
6. How are the fringes formed?
7. What will happen if a transparent liquid in Newton's rings experiment replaces air in the interspace?
8. Newton's rings are broader near the center and sharper towards the edge. Why?
9. What is the cause of formation of Newton's rings?
10. Can you get straight fringes in Newton's rings experiment?