Newton's rings

Aim : To determine the wavelength of sodium light by Newton's ring.

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.

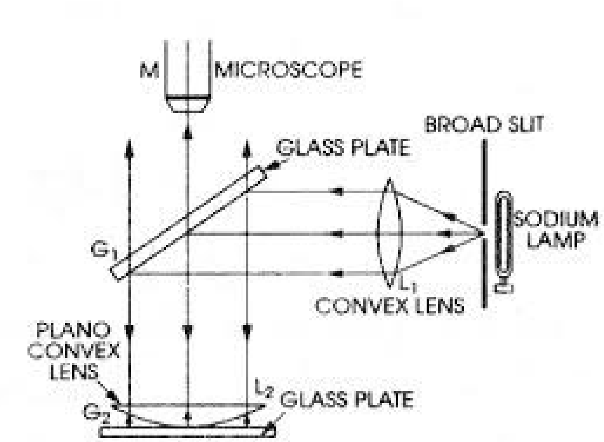


Figure 1

Theory:

Consider a ring of radius ‘r‘ due to thickness ‘t‘ of air film as shown in the figure (2) given below:

In the figure:

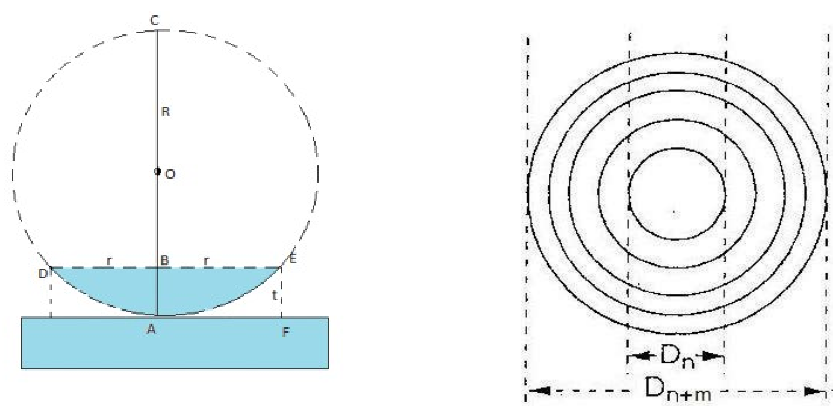


Figure 2

R is the radius of the circle, **O** is the center of the circle, **AC** is the diameter, **DE** is the chord, **r** is the distance between D and E, **t** is the height between the chord of the circle and the plane glass plate (AB). According to geometrical theorem, the product of intercepts of intersecting chord is equal to the product of sections of diameter then,

$$DB \times BE = AB \times BC$$

$$r \times r = t \times (2R - t)$$

$$r^2 = t \times (2R - t)$$

As ‘t’ is very small then t^2 will be so small which may be neglected, then,

$$r^2 = 2Rt$$

$$t = r^2/2R \;\ldots\ldots\ldots\ldots(1)$$

$$2t = (D/2)^2/R$$

where D is the diameter of the ring.

The path difference between the two rays one reflected from E and the other from F (from figure) is

$$2 \times \mu \times t \times \cos(\theta)$$

where θ is the angle of refraction in the air film.

For an air film (μ = 1) between the lens and the glass plate.

The path difference is

$$2 \times t \times \cos(\theta)$$

The ray reflected from F suffers an additional phase change of π or a further increase in the path difference by λ/2 . Hence the total path difference between the two rays, reflected from E and F is.

$$2 \times t \times \cos(\theta) = \lambda/2$$

Since the rays are incident normally, θ is zero and hence Cos (θ) =1 .

For the points D and E to lie on a bright fringe

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

or $2\times t=(2\times n-1)\times\lambda/2$

Substituting the value of $2\times t$

$$D^2/4R=(2\times n-1)\times\lambda/2$$

Let $D=D_n$ as the diameter of the n^{th} bright fringe

$$D_n^2=2(2\times n-1)\times R\times\lambda$$

Also for the n^{th} dark fringe

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

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

Using any of the two relations, we can find the wavelength of the monochromatic light used.
Thus if D_n and D_{n+m} denotes the diameters of n^{th} and $(n+m)^{th}$ dark fringes then we have ,

$$D_n^2/4R=n\times\lambda \quad \text{and} \quad D_{n+m}^2/4R=(n+m)\times\lambda$$

Subtracting we get

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

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

An alternative and better method is to plot n (the no. of fringes) along x-axis and D^2_n on y-axis. Then the slope of the straight line, $\tan(\phi)$ will give the wavelength as

$$\lambda=\tan(\phi)/4R$$

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.

Procedure :

i) If a point source is used only then we require a convex lens otherwise using an extended source, the convex lens L_1 is not required.

ii) Before starting the experiment, the glass plates G_1 and G_2 and the plano convex lens should be thoroughly cleaned.

iii) The centre of lens L_2 is well illuminated by adjusting the inclination of glass plate G_1 at 45°.

iv) Focus the eyepiece on the cross-wire and move the microscope in the vertical plane by means of rack and pinion arrangement till the rings are quite distinct. Clamp the microscope in the vertical side.

v) According to the theory, the centre of the interference fringes should be dark but sometime the centre appears white. This is due to the presence of dust particles between glass plate G_2 and plano-convex lens L_2. In this case the lens should be again cleaned.

vi) Move the microscope in a horizontal direction to one side of the fringes. Fix up the crosswire tangential to the ring and note the reading. Again the microscope is moved in the horizontal plane and the cross wire is fixed tangentially to the successive bright fringes noting the vernier readings till the other side is reached. This is shown in fig. (2).

vii) The radius of curvature of plano-convex lens is determined by Boy's method as discussed below:
If an object is placed at the principal focus of convex lens placed over a plane mirror, its image is formed at same point and the distance from the lens is equal to the focal length f of the lens as shown in fig. (3i).
If the mirror is removed and the object is moved along the axis, a position will come where the image of the object formed by the lens coincides with object as shown in fig. (3ii). If the direction of a ray starting from O is such that it is incident normally on the spherical surface, the ray returns to its previous path and forms the image at the same point. Since the refracted ray is normally incident on the surface, it appears to come from the centre of curvature C.
Hence in this $TO = v = R$ we have

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

$$\frac{1}{R} - \frac{1}{u} = -\frac{1}{f}$$

or $$\frac{1}{R} = \frac{1}{u} - \frac{1}{f} = \frac{f-u}{uf}$$

$$\therefore \quad R = \frac{uf}{f-u}$$

Knowing the value of u, the value of R can be calculated because the value of f is already known with the help of fig. (3i).

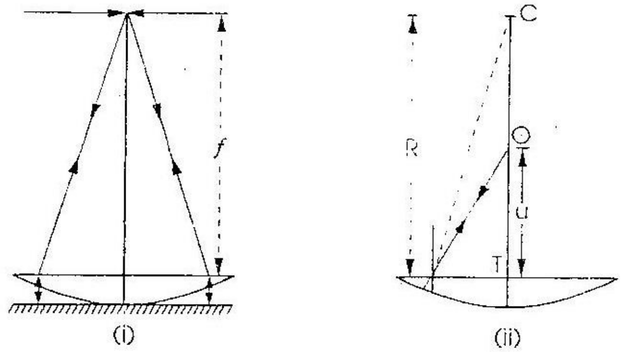
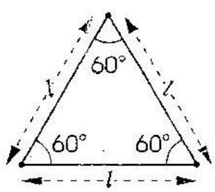


Figure 3

The radius of the curvature can also be 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.

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	Micrometer reading		Diameter D (a —b) cm.	D^2 $(a-b)^2$ cm^2	$D^2_{n+m}-D^2_n$	Mean cm^2	m
	Left end a cm.	Right end b cm.					

20							
19							
18							
17							
16							
15							
14							
13							
12							
11							
10							
9							
8							
7							
6							
5							

Table: For the determination of R :

(Either use Boy's method or spherometer method)
Using Boy's method:

S. No.	Position of object	Position of lens placed on plane mirror	f cm.	Position of lens placed on plane mirror	u	$R = \frac{uf}{f-u}$cm

Table – 2: Determination of R
Using spherometer method :
L.C. of spherometer = …. cm.

<table>
<tr><td rowspan="3">S. No.</td><td colspan="6">Spherometer Reading</td><td rowspan="3">h = (b—a) cm.</td><td rowspan="3">Mean h cm.</td></tr>
<tr><td colspan="3">Zero reading on plane surface</td><td colspan="3">Reading on lens</td></tr>
<tr><td>M.S.</td><td>V.S.</td><td>Total cm. (a)</td><td>M.S.</td><td>V.S.</td><td>Total cm. (b)</td></tr>
</table>

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

Calculations:

Using Boy's method:

$$R = uf/(f-u)$$
$$= \ldots \text{cms}$$

Using Spherometer method:

$$R = (l^2/6h) + (h/2)$$
$$= \ldots \text{cms}$$

The wavelength of sodium light is given by:

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

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 = …. A.U.
Standard mean wavelength λ = …. A.U.
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.

<u>Theoretical error:</u>

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

Taking logarithm of both sides and differentiating

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

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

= …. %.

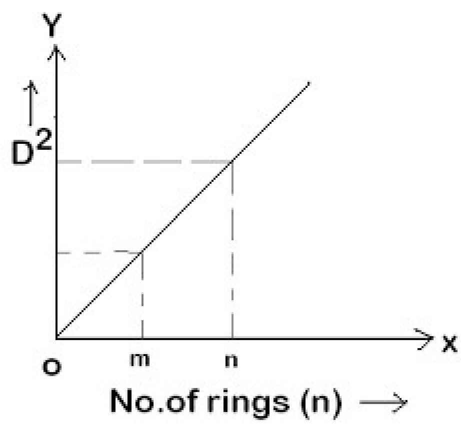


Figure 5