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Newton's Ring

Determine the radius of curvature of a lens by Newton's rings method.

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***Abstract*—This experiment aims to determine the radius of curvature of the given plano-convex lens using Newton's Ring method. Newton's ring is a phenomenon in which an interference pattern is created by the reflection of light from two surfaces(one spherical surface and other is a flat surface). It is named after Isaac Newton, who studied it for the first time. This phenomenon explains the wave nature of light.**

***Index Terms*—Plano-convex lens, constructive interference, destructive interference, fringe pattern, RAdius of curvature.**

I. Objective

The aim of this experiment is to determine the Radius of curvature of the given plano-convex lens using Newton's Ring experiment.

II. Materials and Methods

A. Materials

Newton's ring apparatus includes a beam splitter, microscope, optical flat, plano-convex lens, and XY translational stage. Apart from this, we need a source of nearly monochromatic light (sodium vapour lamp).

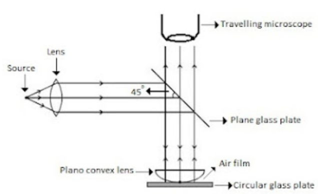


Fig. 1. Newton's Ring apparatus

B. Methods

Newton's ring experiment is an illustration of the phenomenon of interference of light by amplitude division and is formed by placing a plano-convex lens of a large radius of curvature on an optical flat(as shown in Fig.1) using an almost monochromatic source of light at near-normal incidence, as shown in Fig.1. The beams are reflected from the curved surface of the lens and the flat surface of the optical flat. This creates a path difference which leads to the formation of fringes. Since the air gap between the lens and the optical flat possesses radial symmetry about the point of contact thus, localized circular interference fringes are obtained upon normal incidence of monochromatic light.

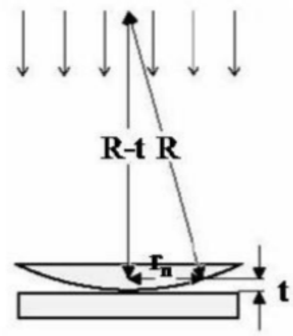


Fig. 2. Schematic of Newton's Rings experoment

If we consider a beam of light, some part of it gets reflected from the curved surface and some part is transmitted and reflected from the plane surface. Thus, the path difference is 2t.

The condition for constructive interference is given by

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

where n has integer values. Since t is positive n can be 0,1,2,3,....
By applying Pythagoras we get,

$$R^2 = r^2 + (R-t)^2 r^2 = 2Rt - t^2 \tag{2}$$

Since T is very small, thus t^2 tends to zero. Hence, neglecting t^2 we get

$$t = \frac{r^2}{4R} = \frac{d^2}{8R} \tag{3}$$

Where d is the diameter of the ring. Consider mth bright ring

$$t_m = \frac{(d_m)^2}{8R} \tag{4}$$

Considering m=m_1 and m=m_2 and subtracting the two equations so obtained we get:

$$t_{m_2} - t_{m_1} = \frac{d_{m_2}^2 - d_{m_1}^2}{8R} \tag{5}$$

also

$$2t_{m_2} - 2t_{m_1} = (m_2 - m_1\lambda \tag{6}$$

Using these equations we get:

$$R = \frac{|d_{m_2}^2 - d_{m_1}^2|}{4\lambda(m_2 - m_1)} \tag{7}$$

Similarly, this can be obtained using dark rings. Only the value $m_1 - m_2$ matters and not the individual values themselves.

III. Procedure

1) Begin by cleaning all optical glasses using the provided isopropyl alcohol. Turn on the sodium vapor lamp to ensure it reaches maximum intensity.
2) Position the flat disk close to the depression region of the microscope and place a plano-convex lens on top, ensuring contact between them.
3) Adjust the beam-splitter to a 45-degree angle to maximize brightness in the direction of the light.
4) Use the focus knob to adjust the distance between the microscope tube and the object until a clear and sharp image with circular fringes is observed.
5) Align the crosswire intersection with the center of the circular fringes using micrometre screws.
6) Configure the microscope so that one crosswire is tangentially positioned on the rings, allowing movement through 20 rings by turning the micrometre screw in one direction only.
7) Identify a clear and larger ring (referred to as the ”mth” ring), position the crosswire at its center, and note its position (Xm) using the micrometre.
8) Turn the fine movement knob to move the microscope toward the center of the ring system. Center the crosswire at the middle of every other ring, noting down their positions $(X_{m-1}, X_{m-2}, ..., X_2, X_1)$.
9) After crossing the center of the rings, place the crosswire at the center of corresponding rings diametrically opposite from the first set. Note down their positions $(Y_1, Y_2, Y_3, ..., Y_{m-2}, Y_{m-1})$.

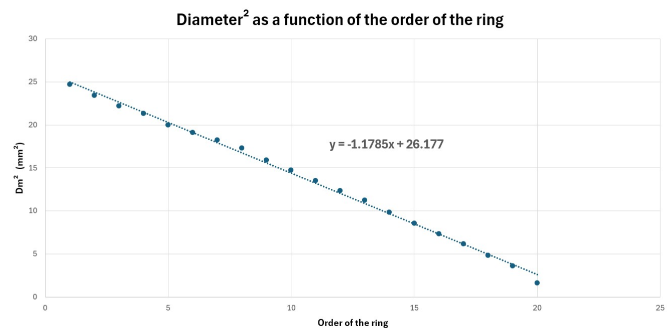
IV. Observation and Graphs

Upon centering the microscope, we begin to observe a pattern of light and dark bands. These bands are circular in shape. Upon closer inspection, we also notice that the bands get closer as the order of the rings increases, this can also be seen in the tabulated readings given below

m	X_m	Y_m	$Y_m - X_m = D_m$	D_m^2
1	10.05	15.02	4.97	24.7009
2	10.1	14.94	4.84	23.4256
3	10.15	14.86	4.71	22.1841
4	10.18	14.8	4.62	21.3444
5	10.26	14.73	4.47	19.9809
6	10.31	14.68	4.37	19.0969
7	10.35	14.62	4.27	18.2329
8	10.39	14.55	4.16	17.3056
9	10.49	14.48	3.99	15.9201
10	10.57	14.41	3.84	14.7456
11	10.64	14.32	3.68	13.5424
12	10.76	14.27	3.51	12.3201
13	10.83	14.18	3.35	11.2225
14	10.93	14.07	3.14	9.8596
15	11.05	13.98	2.93	8.5849
16	11.15	13.86	2.71	7.3441
17	11.27	13.75	2.48	6.1504
18	11.42	13.62	2.2	4.84
19	11.58	13.48	1.9	3.61
20	11.83	13.11	1.28	1.6384

TABLE I
Observations

This data can now be plotted, showing diameter square D_m^2 as a function of the order of the ring m.



The above graph used linear regression and draws a best-fitting line through all the points, giving us an accurate approximation of the real line.

$$Slope = -1.1785 = \frac{d_{m_2}^2 - d_{m_1}^2}{(m_2 - m_1)} \tag{8}$$

V. Results and Analysis

A. Discussions

Newton’s rings experiment in optics demonstrates the interference of light waves when a plano-convex surface is placed on a flat glass plate, an air film of gradually increasing thickness is formed between them, and then a monochromatic light is allowed to fall normally on the film, and when viewed in reflection mode, we observe alternate dark and bright rings. Since the locus of a constant thickness of air film about the point of contact is a circle, we see the fringes as circular.
As we go away from the point of contact, the thickness of the air gap increases, thus the difference between the radius of two consecutive rings decreases, and they get closer and closer
If we use a source of white light instead of a monochromatic one, we would have obtained circular fringes for a visible light spectrum. This is because the lights of different wavelengths would have interfered at different thickness of the air gap.
if we had use a wedge shaped prism instead of a plano-convex lens we would have obtained straight fringes instead of circular because this time the shape of air column would have been a straight line.

B. Calculations

We know the wavelength of the monochromatic light source used.

$$\lambda = 5893 \text{ Å}$$

From Equation (7) and Equation (8), we can say that:

$$R = \frac{\text{Slope}}{4\lambda}$$

Therefore,

$$R = \frac{\text{-1.1785} \times 10^{-6} \times 10^{10}}{4 \times 5893} = 0.499957 \times 10^{-1}\text{meters}$$

VI. Error analysis

The following are the possible sources of error

1) The glass plate may not be perfectly flat.
2) The surface of the plano- convex lens may not be the part of a perfect sphere.
3) The plate and the lens may not be perfectly clean.
4) There can be human error in taking readings from micrometer.
5) There can be inaccuracy in putting plate at 45 degree.
6) There can be alteration in monochromatic light due to other sources present in the lab.

VII. Finding Error in R mathematically

We have calculated R using the following formula:

$$R = \frac{(D_m)^2 - (D_n)^2}{4\lambda(m_1 - m_2)}$$

using the error formula we get:

$$\frac{\Delta R}{R} = 2\left(\frac{\Delta D_m}{D_m}\right) + 2\left(\frac{\Delta D_n}{D_n}\right) + \frac{\Delta\lambda}{\lambda}$$

Now lets assume that the error in the measurement of wavelength is almost zero, then $\frac{\Delta\lambda}{\lambda} \to 0$. So,

$$\frac{\Delta R}{R} = 2\frac{\Delta D_m}{D_m} + 2\frac{\Delta D_n}{D_n}$$

Since D_m and D_n were measured with a traveling microscope whose least count was $0.01\,\text{mm}$, we can assume that ΔD_m and ΔD_n are both equal to $0.01\,\text{mm}$.

So,

$$\frac{\Delta R}{R} = 2\left(\frac{0.01}{D_m}\right) + 2\left(\frac{0.01}{D_n}\right)$$

Now, here $n = m - 2$, so

$$\frac{\Delta R}{R} = \frac{0.02}{D_m} + \frac{0.02}{D_{m-2}}$$

VIII. Conclusion and Future Prospects

A. Conclusion

After conducting Newton's Ring experiment to determine the Radius of curvature of the plano-convex lens, the radius of curvature came out to be 4.999 cm.

The fringes in the experiment came out to be circular in nature because of the radial symmetry of the air gap about the point of contact of the lens and the optical flat. If we refer to theory, the relation between t and R is given by:

$$t = \frac{r^2}{8R} \tag{9}$$

The thickness of air gap is inversely proportional to the radius. As we go away from the point of contact, the thickness increases, and thus, the difference between the two consecutive portions decreases.

m	X_m	Y_m	D_m	D_m^2	D_{mean}^2	$\lvert D_{mean}^2 - D_m^2\rvert$
1	10.05	15.02	4.97	24.701	24.998	0.2971
2	10.1	14.94	4.84	23.426	23.82	0.394
3	10.15	14.86	4.71	22.184	22.641	0.457
4	10.18	14.8	4.62	21.344	21.463	0.1182
5	10.26	14.73	4.47	19.981	20.284	0.3032
6	10.31	14.68	4.37	19.097	19.106	0.0087
7	10.35	14.62	4.27	18.233	17.927	0.3057
8	10.39	14.55	4.16	17.306	16.749	0.5569
9	10.49	14.48	3.99	15.92	15.57	0.3499
10	10.57	14.41	3.84	14.746	14.392	0.3539
11	10.64	14.32	3.68	13.542	13.213	0.3292
12	10.76	14.27	3.51	12.32	12.035	0.2854
13	10.83	14.18	3.35	11.223	10.856	0.3662
14	10.93	14.07	3.14	9.8596	9.6778	0.1818
15	11.05	13.98	2.93	8.5849	8.4993	0.0856
16	11.15	13.86	2.71	7.3441	7.3208	0.0233
17	11.27	13.75	2.48	6.1504	6.1423	0.0081
18	11.42	13.62	2.2	4.84	4.9639	0.1239
19	11.58	13.48	1.9	3.61	3.7854	0.1754
20	11.83	13.11	1.28	1.6384	2.6069	0.9685
Mean Deviation						0.2845985

TABLE II
Mean deviation

m	D_m	$\frac{\Delta R}{R}$
1	4.97	
2	4.84	
3	4.71	0.00827
4	4.62	0.008461
5	4.47	0.008721
6	4.37	0.008906
7	4.27	0.009158
8	4.16	0.009384
9	3.99	0.009696
10	3.84	0.010016
11	3.68	0.010447
12	3.51	0.010906
13	3.35	0.011405
14	3.14	0.012067
15	2.93	0.012796
16	2.71	0.01375
17	2.48	0.01489
18	2.2	0.016471
19	1.9	0.018591
20	1.28	0.024716
Mean $\frac{\Delta R}{R}$		0.012147
ΔR		6.073317

TABLE III
Error in R

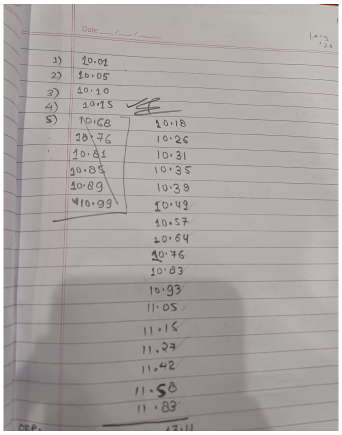
B. Future prospects

- We can make this experiment better by using new tools like digital image processing and advanced sensors. This will help us measure things more accurately.
- Although the sodium lamp produces monochromatic light, it has a small spectrum of different wavelengths. This thing can be resolved using better sources that produce a sharper spectrum.
- In open exposure, it is possible that the experiment is affected by environmental factors such as humidity, temperature, and pressure. This thing can be improved by doing the experiment in a vacuum or any other suitable

environment.

- Poor polishing of the instruments used in the experiment also causes deviation from the accurate results. This thing can be avoided by using polished and better instruments.

IX. READING IMAGES


Date __/__/__
1) 10.01
2) 10.05
3) 10.10
4) 10.15
5) 10.68 10.18
10.76 10.26
10.81 10.31
10.85 10.35
10.89 10.39
10.99 10.49
10.57
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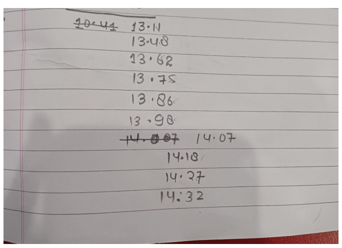
11.58
11.83


~~10.41~~ 13.11
13.48
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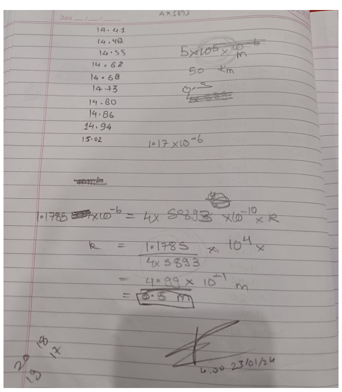
Date __/__/__
14.41
14.48
14.55 $5 \times 10^5 \times 10^{-6}$ m
14.62
14.68 50 km
14.73
14.80
14.86
14.94
15.02 1.17×10^{-6}

$1.1785 \times 10^{-6} = 4 \times 5893 \times 10^{-10} \times R$

$R = \frac{1.1785}{4 \times 5893} \times 10^4$

$= 4.99 \times 10^{-1}$ m

$= \boxed{0.5 \text{ m}}$

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X. AUTHOR CONTRIBUTIONS

Name	Roll number	Contribution	Signature
Faayza Vora	23110109	Abstract, Objective, Material and Methods, Procedure, Taking readings in lab	
Goraksh Bendale	23110118	Lab readings/equipment handling, Observations, Graphs, Results	
Dishant Tanmay	23110100	Error analysis, Discussion, Compilation, Taking Readings in the lab	
Haravath Saroja	23110127	Conclusion and future prospects	

TABLE IV
AUTHOR'S CONTRIBUTION