BS 192: Undergraduate Science Laboratory (Physics)

A

Laboratory Report on

NEWTON'S RINGS EXPERIMENT

BY

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Group 2

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OBJECTIVE:

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

THEORY:

An example of the phenomenon of light interference by amplitude division is Newton's rings. These are created by putting a convex or plano-convex lens with a large radius of curvature on a plane glass plate and using monochromatic light from an extended source at nearly normal incidence. There is radial symmetry about the point of contact in the air gap between the glass plate and the lower curved surface of the lens. Normal monochromatic illumination causes localised circular interference fringes, or loci of points with equal thickness, to form. The formation of these circular fringes, known as Newton's rings, can be explained by the interference of light rays reflected from the convex lens's lower surface.

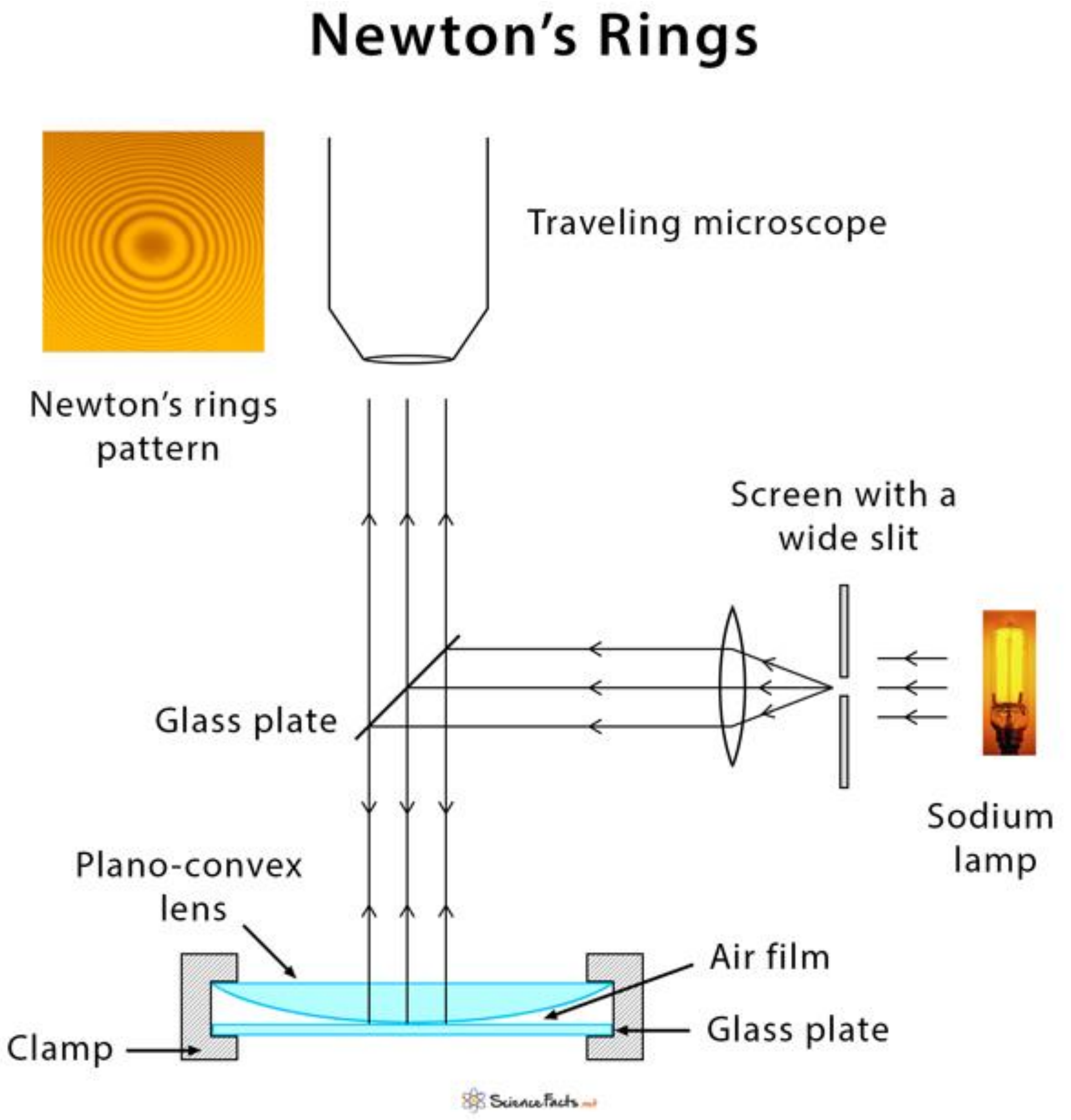

Figure 1

Conditions for the observed interference are:

- $2t \approx 2n (\lambda / 2)$; Dark fringe
- $2t \approx (2n + 1) (\lambda / 2)$; Bright fringe

Here, 't' is the 'Air Gap' at the point of consideration and λ is the wavelength of our monochromatic light.

Let R be the radius of curvature and r_n be the radius of n^{th} bright fringe, then:

$$R^2 = r_n^2 + (R\text{-}t)^2$$

By neglecting t^2

$$t \approx r_n^2 / 2R$$

Substituting this, in the interference condition for the nth bright fringe, we get,

$$r_n^2 = (2n + 1)\, \lambda R/2$$

Here, λ represents the wavelength of monochromatic light from the sodium vapour lamp. This wavelength is given as 5893 Å. 'n' represents the n^{th} fringe in the fringe pattern.

Hence, the Diameter of the n^{th} bright fringe is given by the relation:

$$D_n^2 = 2(2n + 1)\, \lambda R$$

Also, the Diameter of the n^{th} dark fringe is given by the relation:

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

Generally, due to the imperfectness of the contact between the two surfaces at the centre of the lens, the exact order of fringes cannot be determined. However, the difference in diameters of two bright (or dark) fringes of order n and m have a relation which is shown as:

$$4\lambda R = \left|\frac{D_n^2 - D_m^2}{n-m}\right|$$

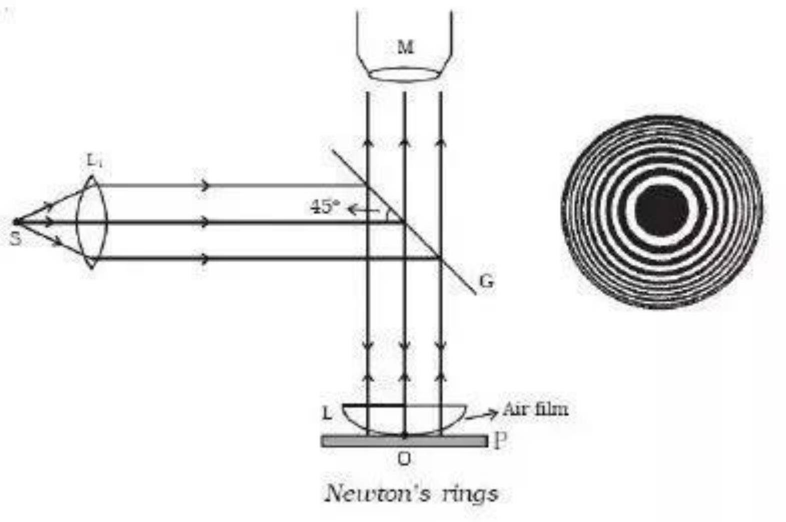

Figure 2

Experimental Details:

APPARATUS:

1) Microscope with micrometre
2) Plano-convex lens
3) Optical flat
4) Beamsplitter Procedure
5) Sodium vapour lamp
6) Power Supply for Sodium Lamp
7) Isopropyl alcohol and tissue
8) Beamsplitter Procedure

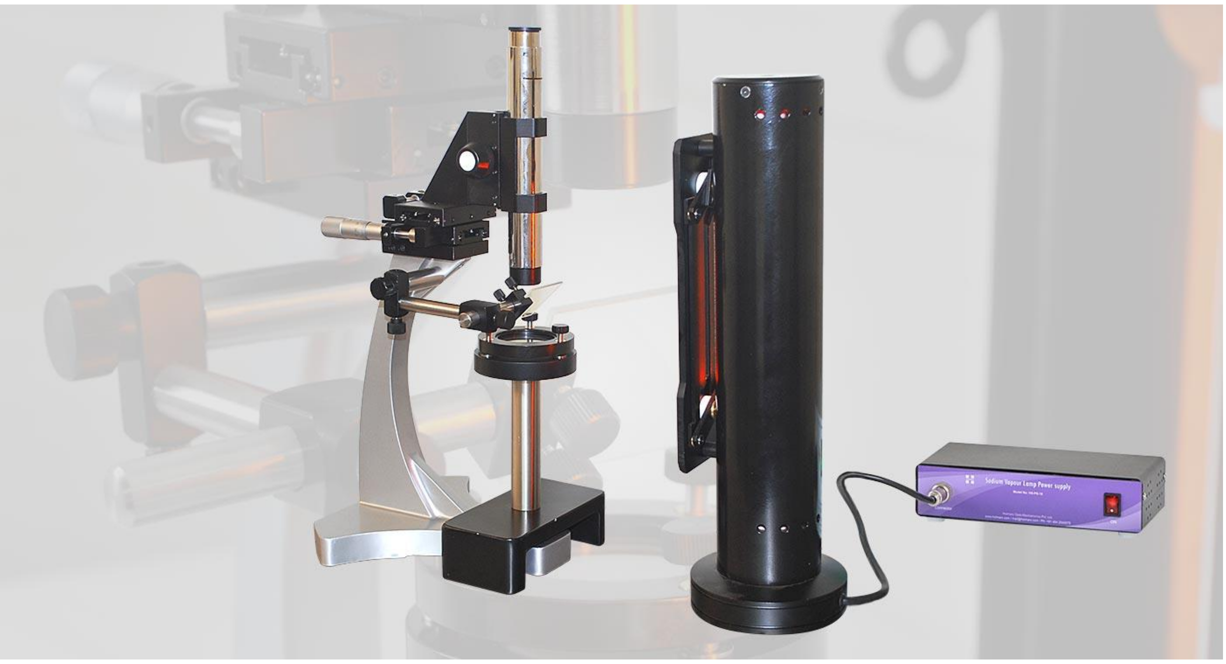

Figure 3

PROCEDURE:

1. We cleaned the optic lens with isopropyl alcohol.
2. Then, an optically flat disk in the region of depression was placed near the objective of the microscope.
3. Then we placed a plano-convex lens on top of the optically flat disk with a single point of contact.
4. After this, we inserted the beam splitter into the holder and adjusted its declination to 45° for maximum intensity.
5. Then, we switched on the Sodium vapour lamp and waited for it to reach maximum intensity with the lamp's position in front of the microscope.
6. The image obtained was focused by adjusting the distance of the microscope tube from the object using the focusing knob.
7. Then, we ensured that the crosswire in the view was oriented along the direction of motion of the traveling microscope.
8. With the fringe system in view, we used micrometre screws to coincide the intersection of the crosswire system with the centre of the fringe pattern.
9. Positioning the microscope so that one crosswire tangentially touches the rings, we carefully noted down all the readings.
10. Following this, we measured the distance towards the left from the centre, noting positions X_{m-1}, X_{m-2}, ..., X_2, X_1, and then right as Y_1, Y_2, ..., Y_{m-2}, Y_{m-1}.

Results and discussion:

Observations:

For noting down the readings, the position of the crosswire can be obtained as:

$$X_m = \text{Main Scale Reading} + (\text{Least Count}) \times \text{Circular Scale Reading}$$

As we know, Least Count can be calculated with the following relation:

$$\text{L.C.} = \frac{Pitch}{Number\ of\ Divisions}$$

$$\therefore \text{L.C.} = \frac{0.5\ mm}{50}$$

$$\therefore \text{L.C.} = 0.01 \text{ mm}$$

Therefore, Least Count of our measuring system is equal to 0.01 mm.

Newton's Ring Experiment

m	X_m	Y_m	$D_m (X_m - Y_m)$
20	17.46	12.48	4.98
19	17.40	12.51	4.89
18	17.33	12.54	4.79
17	17.26	12.64	4.62
16	17.19	12.71	4.48
15	17.12	12.77	4.35
14	17.06	12.86	4.20
13	16.99	12.93	4.06
12	16.90	13.00	3.90
11	16.83	13.02	3.81
10	16.74	13.14	3.60
9	16.64	13.22	3.42
8	16.58	13.32	3.26
7	16.52	13.44	3.08
6	16.41	13.53	2.88
5	16.28	13.63	2.65
4	16.16	13.76	2.40
3	16.01	13.89	2.12
2	15.87	14.05	1.82
1	15.67	14.23	1.44

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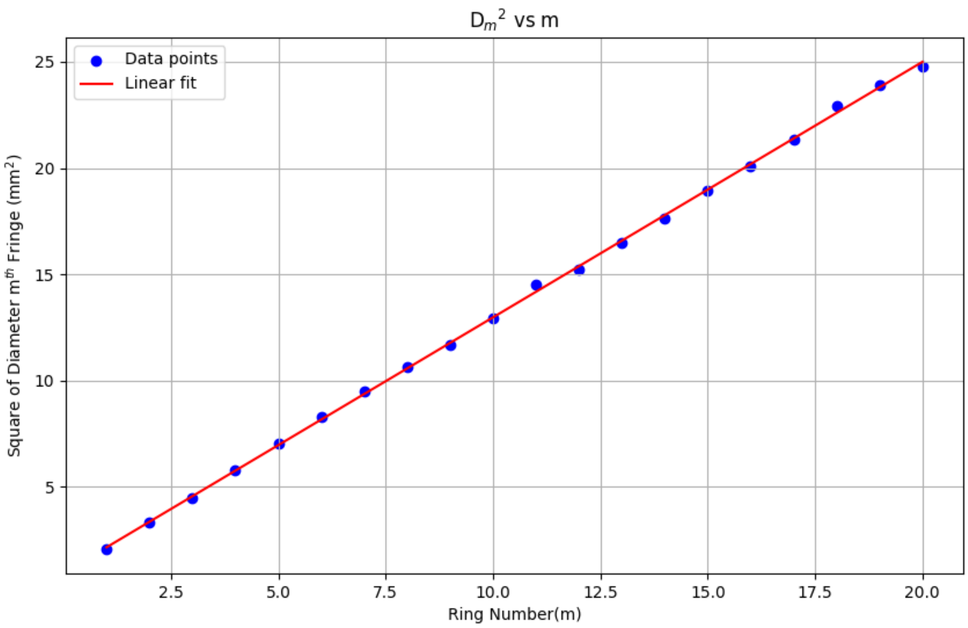
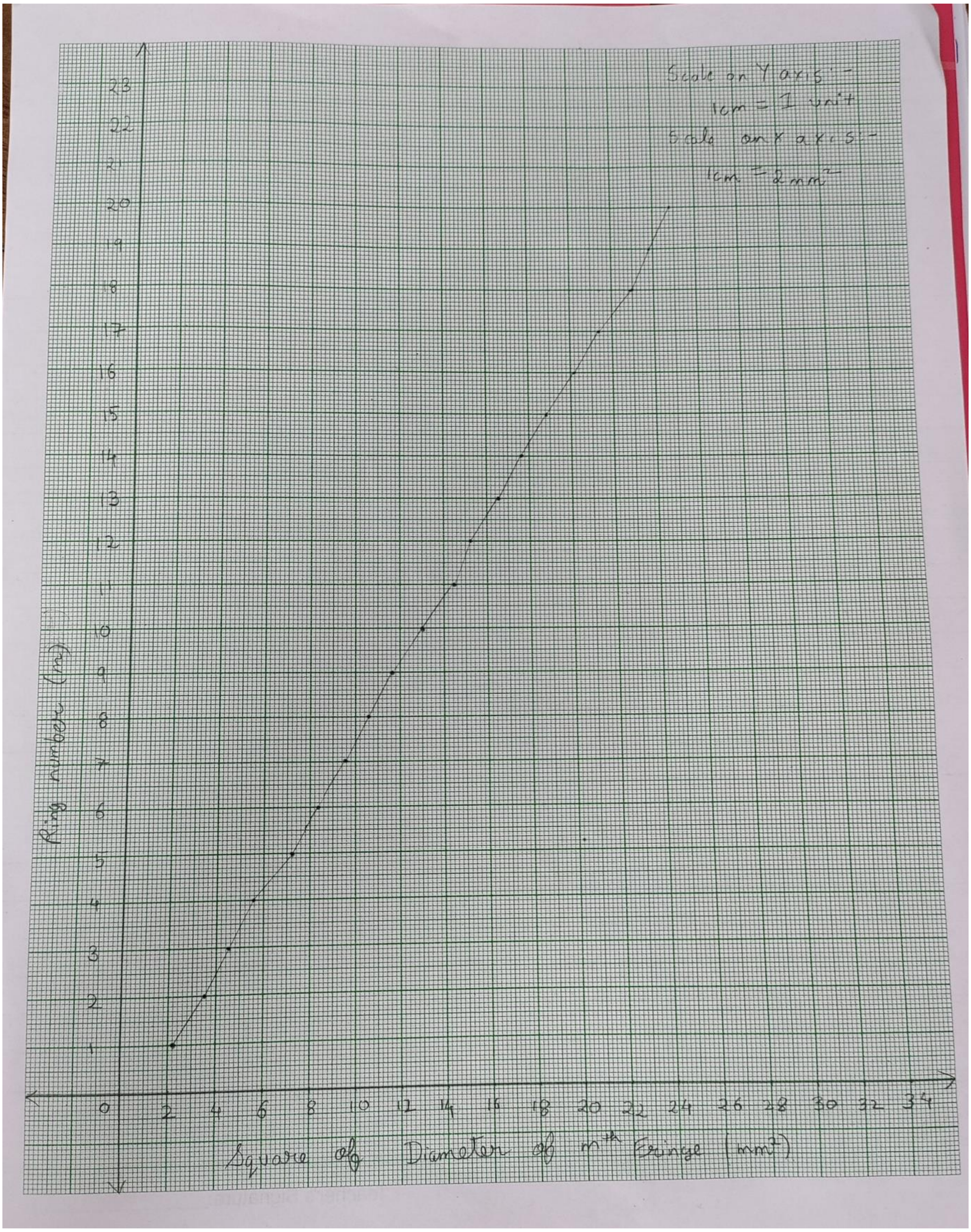
Ring Number m	Position of the left edge of m^{th} ring X_m (mm)	Position of the right edge of m^{th} ring Y_m (mm)	$D_m = X_m - Y_m$ (mm)	D_m^2 (mm^2)
20	17.46	12.48	4.98	24.8
19	17.40	12.51	4.89	23.9
18	17.33	12.54	4.79	22.9
17	17.26	12.64	4.62	21.3
16	17.19	12.71	4.48	20.1
15	17.12	12.77	4.35	18.9
14	17.06	12.86	4.20	17.6
13	16.99	12.93	4.06	16.5
12	16.9	13.00	3.90	15.2
11	16.83	13.02	3.81	14.5
10	16.74	13.14	3.60	13.0
9	16.64	13.22	3.42	11.7
8	16.58	13.32	3.26	10.6
7	16.52	13.44	3.08	9.49
6	16.41	13.53	2.88	8.29
5	16.28	13.63	2.65	7.02
4	16.16	13.76	2.40	5.76
3	16.01	13.89	2.12	4.49
2	15.87	14.05	1.82	3.31
1	15.67	14.23	1.44	2.07





D_m^2 v/s m graph drawn on graph paper

$$S = (D_m^2 - D_{m-2}^2) / (m - (m-2))$$

Where S = 4λR, where λ is the wavelength, and R is the radius of curvature of the convex lens.

m	m-2	D_m^2 (mm^2)	D_{m-2}^2 (mm^2)	**Slope** $S = \frac{D_m^2 - D_{m-2}^2}{m-(m-2)}$ (mm^2)	**Error in Slope** $\lvert S_i - \bar{S} \rvert$ (mm^2)
20	18	24.8	22.9	0.93	0.272
19	17	23.9	21.3	1.28	0.084
18	16	22.9	20.1	1.44	0.237
17	15	21.3	18.9	1.21	0.0109
16	14	20.1	17.6	1.22	0.0152
15	13	18.9	16.5	1.22	0.0195
14	12	17.6	15.2	1.22	0.0150
13	11	16.5	14.5	0.98	0.2163
12	10	15.2	13.0	1.13	0.0750
11	9	14.5	11.7	1.41	0.2098
10	8	13.0	10.6	1.17	0.0338
9	7	11.7	9.49	1.11	0.0950
8	6	10.6	8.29	1.17	0.0334
7	5	9.49	7.02	1.23	0.0319
6	4	8.29	5.76	1.27	0.0672
5	3	7.02	4.49	1.26	0.0640
4	2	5.76	3.31	1.22	0.0238
3	1	4.49	2.07	1.21	0.0104
2	-	3.31	-	-	-
1	-	2.07	-	-	-

From the above data, the slope of the graph comes out to be:

$$\bar{S} = \frac{\sum S_m}{Number\ of\ Readings}$$

$$\bar{S} = 1.20\ mm^2 = 1.20 \times 10^{-6}\ m^2$$

For the given experiment, we were asked to take the wavelength of the λ as:

$$\lambda = 5893\ Å = 5.893 \times 10^{-7}\ m$$

Now, we can calculate the Radius of curvature of the given lens using the following relation:

$$\bar{S} = \frac{D_m^2 - D_{m-2}^2}{m-(m-2)}$$

$$\bar{S} = 4\lambda R$$

$$R = \frac{\bar{S}}{4\lambda}$$

Substituting the values in the above equation, we get:

$$R = \frac{1.20 \times 10^{-6}}{4 \times 5.893 \times 10^{-7}}\ m$$

$$R = 0.509\ m$$

Error Analysis:

$$\text{Average error in slope } (\Delta S) = \frac{\sum |S_i - \bar{S}|}{Number\ of\ Readings}$$

$$\Delta S = 0.0841 \text{ mm}^2$$

$$\text{Relative error in slope} = \frac{\Delta S}{S} = 0.0701$$

Relative error of radius of curvature will be:

$$R\frac{\Delta S}{S} = 0.0701 \times 0.509 \text{ m}$$

$$\therefore R\frac{\Delta S}{S} = 0.036 \text{ m}$$

The final value of radius of curvature of the plano-convex lens can be written as:

$$R_f = R \pm \Delta R$$

$$R_f = 0.509 \pm 0.036 \text{ m}$$

$$R_f = 509 \pm 36 \text{ mm}$$

Final Precise Results:

Radius of curvature of plano convex lens **= 0.509 ± 0.036 m = 509 ± 36 mm**

Source of Errors in the experiment:

1. Readings may be affected by dust on the glass plate, lens, beam-splitter, or microscope.
2. We obtained an approximative relationship for the lens's radius of curvature. The air gap thickness t's second-degree term had been disregarded. There would be some mistakes as a result.
3. In this experiment, human error is a major cause of errors as well. The ability of the observer to focus, see, and understand information is important.
4. Errors in the proper measurement of the ring diameter can arise from vibrations in the fringes during knob rotation or vibrations in the setup.

CONCLUSION:

We can investigate light interference and related phenomena with this experiment. Through the observation of both constructive and destructive interference's brilliant and dark fringes, we determine the correlation between interference pattern thickness and wavelength. This experiment also provides strong evidence for the wave form of light.

We calculated the radius of curvature of the plano-convex lens using this experiment to be:

R = 509 ± 36 mm

A distinct monochromatic light source can be used to repeat the experiment and see how the fringe pattern changes. If a liquid with a refractive index of (mu) is used in place of the air gap, the experiment can be repeated, and the fringe pattern can be seen to vary.

The future scope for this experiment can be conducted by varying the source of light, changing the material used for the lens, etc.

Learning Outcomes:

1. Understood the concept of interference due to division of amplitude using Newton' rings experiment.
2. Determined how the interference pattern depends on the wavelength of the incident monochromatic light.

Author Contributions:

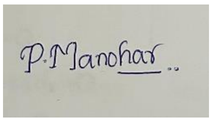
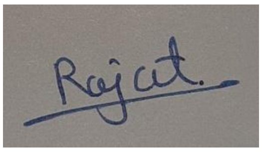
Name	Roll Number	Contribution	Signature
Prachand Aditya Prashant	23110250	• Conclusion • Learning Outcomes • Author Contributions	
Pulakurthi Manohar	23110259	• Apparatus • Theory • Safety Precautions	
Rajat Kabra	23110268	• Introduction • Mechanism • Procedure	
Rishank Soni	23110277	• Observation Table • Results • Calculations • Graphs	

Image Sources:

- https://qph.cf2.quoracdn.net/main-qimg-cf33bd241c030e05004876f3fca2de56.webp
- https://www.sciencefacts.net/wp-content/uploads/2020/07/Newtons-Rings.jpg
- https://www.holmarc.com/images/newtons_rings_appa1.1.jpg

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