Newton's Rings Experiment

BS192: Undergraduate Science Laboratory (Physics)

Group 7 (Lab No. 5, Experiment No. 1)

A laboratory report by

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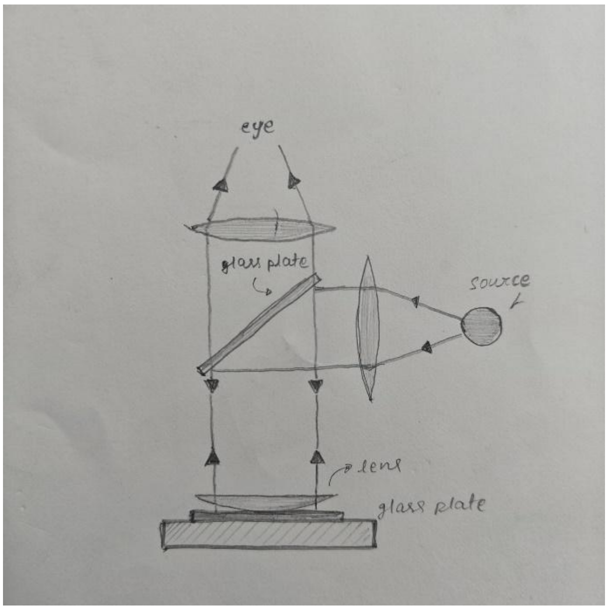
I. Aim:

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

II. Apparatus:

Microscope with XY translation stage, beam splitter inclined at 45 degree, plano-convex lens, source of nearly monochromatic light (Sodium vapor lamp) with its power supply.



III. Theory:

Newton's rings are an optical phenomenon, they occur because of the interference of light. This phenomenon can only be explained by constructive and destructive interference of monochromatic light, which requires wave theory of light. Amplitude division takes place for the formation of these rings. They can be formed by placing a convex or plano-convex lens of a large radius of curvature on a plane glass plate held with screws to accurately position the height of the

lens so that there is only one contact point between the lens and the plate. Monochromatic light is allowed to incident on the beam splitter, and the rays fall almost normally on the lens. Localized circular interference fringes are formed which are loci of points of equal thickness. These circular fringes are called Newton's
rings and their formation can be explained in terms of interference of light rays reflected from the lower surface of the convex lens and the flat upper surface of the glass plate. Optical path difference between these two rays (for a thin lens with extremely small curvature and rear normal incidence) leads to interference.

Conditions for the observed interference:

$$2t \approx 2n\ (\lambda/2)\text{: Dark fringe}$$
$$2t \approx (2n + 1)\ (\lambda/2)\text{: Bright fringe}$$

Where t is the air gap at the point of consideration.
From the figure ,we can see that if the radius of the nth bright fringe is r_n and R is the radius of curvature of the lower surface of lens, then

$$R^2 = r_n^2 + (R - t)^2$$
$$\text{Or, } t \approx t_n^2/2R \text{ (neglecting } t^2\text{)}$$

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

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

From this, the diameter of the nth bright fringe

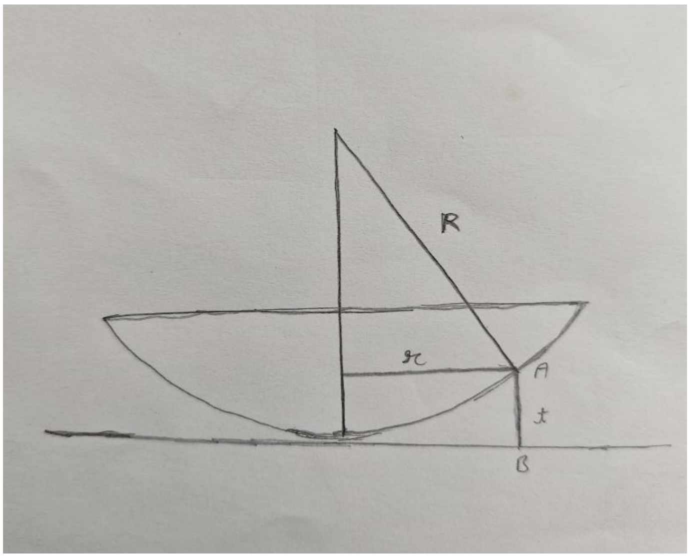
$$D_n^2 = 2\ (2n + 1)\ \lambda R$$

Similarly, the diameter of the nth dark fringe is given by,

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

Usually, due to the imperfectness of the contact between the two surfaces at the centre of the lens, the exact order of fringes cannot be ascertained. However, the difference in diameters of two bright (or dark) fringes of order n1 and n2 are related by:

$$|D_{n1}^2 - D_{n2}^2 / n_1 - n_2 = 4\lambda R|$$



IV. 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' 6 2 2 h h l R

4. Adjust the position of microscope so that it lies vertically above the center of lens L2. 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 20th 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 16th, 12th, 8th and 4th 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 4th, 8th , 16th and 20th 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 L2 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 Dn 2 along Y-axis and then number of the ring(n) along X-axis as explained in part-2 of the experiment.

V. Results and Discussion

Order of bright fringe (m)	X_m (mm)	X'_m (mm)	$D_m = X_m - X'_m$ (mm)
1	-1.03	-2.04	1.01
2	-0.78	-2.29	1.51
3	-0.6	-2.47	1.87
4	-0.46	-2.63	2.17
5	-0.32	-2.77	2.45
6	-0.21	-2.89	2.68
7	-0.1	-3.01	2.91
8	0	-3.1	3.1
9	0.1	-3.19	3.29
10	0.18	-3.28	3.46

Here, the leftmost point on the 8th bright fringe is taken as a reference. The shifted readings after taking the rightmost point on the 10th bright fringe as reference (adding 328mm to all entries) will be

Order of bright fringe (m)	X_m (mm)	X'_m (mm)	$D_m = X_m - X'_m$ (mm)
1	2.25	1.24	1.01
2	2.5	0.99	1.51
3	2.68	0.81	1.87
4	2.82	0.65	2.17
5	2.96	0.51	2.45
6	3.07	0.39	2.68
7	3.18	0.27	2.91
8	3.28	0.18	3.1
9	3.38	0.09	3.29
10	3.46	0	3.46

Here,

X_m = Distance of the leftmost point on the 10th bright fringe

X'_m = Distance of the rightmost point on the 10th bright fringe

We can now use the formula

$$\left| \frac{D_m^2 - D_{m-2}^2}{m-(m-2)} = 4\lambda R \right|$$

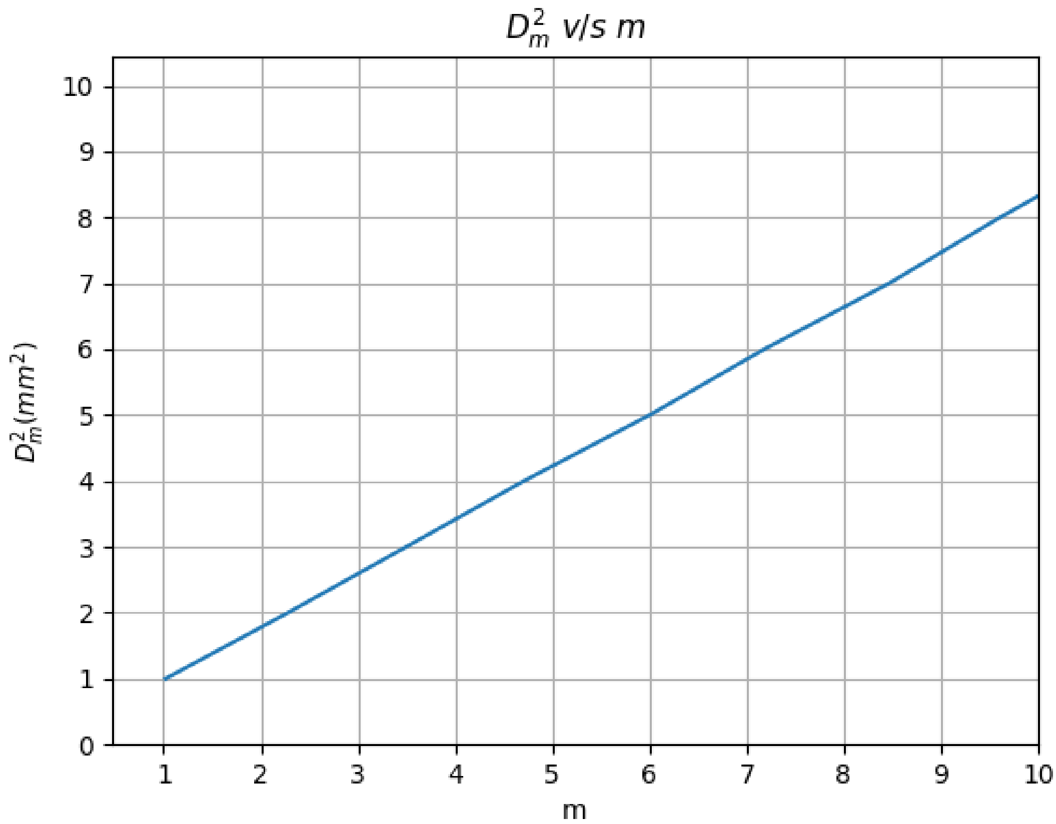
To obtain the value of R for every m = 2, 3, 4, …, 10

From these values, the following results can be obtained

$D_m^2 (mm^2)$	$D_m - D_{m-2} (mm^2)$	$S = \frac{D_m^2 - D_{m-2}^2}{m-(m-2)} (mm^2)$	$R = \frac{S}{4\lambda} (m)$
1.02			
2.28			
3.5	2.48	1.24	0.53
4.71	2.43	1.21	0.52
6	2.51	1.25	0.53
7.18	2.47	1.24	0.52
8.47	2.47	1.23	0.52
9.61	2.43	1.21	0.51
10.82	2.36	1.18	0.5
11.97	2.36	1.18	0.5

To get the radius of curvature of the lens used, we take the average of the obtained values of R. We get

$$R = 0.52\, m$$



VI. Error Analysis

Radius of curvature (R) (m)	$x_i - \mu$	$(x_i - \mu)^2$
0.53	8.4×10^{-3}	7.2×10^{-5}
0.52	-1.7×10^{-3}	3.0×10^{-6}
0.53	15×10^{-3}	2.1×10^{-4}
0.52	7.8×10^{-3}	6.0×10^{-5}
0.52	6.1×10^{-3}	3.7×10^{-5}
0.51	-2×10^{-3}	4.0×10^{-6}
0.5	-17×10^{-3}	3.0×10^{-4}
0.5	-15×10^{-3}	2.5×10^{-4}

$$\mu = \frac{\Sigma R_i}{N} = 0.52\ m$$

$$\sigma = \sqrt{\frac{(\Sigma R_i - \mu)^2}{N-1}} = 0.01\ m$$

We can also calculate the relative errors between 2 consecutive slopes and then take their average to obtain ΔS, which we can then use to obtain ΔR

$S(mm^2)$	$\Delta S = \left\lvert \frac{S_n - S_{n-1}}{2} \right\rvert$
1.24	
1.21	0.01
1.25	0.02
1.24	0.01
1.23	0
1.21	0.01
1.18	0.02
1.18	0

From here, we get the average value of ΔS to be $0.01mm^2$. We know,

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

Differentiating on both sides, we get the error as

$$\frac{\Delta R}{R} = \frac{\Delta S}{S} + \frac{\Delta \lambda}{\lambda}$$

Since, $\Delta\lambda = 0$ (wavelength is known),

$$\Delta R = R \times \frac{\Delta S}{S}$$

$$\Delta R = 0.04\ m$$

So the final value of R is

$$R = 0.52 \pm 0.04\ m$$

Percentage error:

$$Error\ \% = \frac{\Delta R}{R} \times 100\%$$

$$Error\ \% \ = \ 7.69\ \%$$

Possible sources of error:

- Positioning of the monochromatic light source could be imperfect, resulting in the formation of fringes of the other light sources. This could make it difficult to estimate the tangent of the ring.
- The levers of the microscope were very loose; even a small disturbance might have resulted in inaccuracy in the results.
- Since the fringes were wide, it was difficult to estimate the brightest, central part.

VII. Conclusion

We conducted this experiment to determine the radius of curvature of a plano-convex lens, which comes out to be $R\ =\ 0.52\ \pm 0.04\ m$. We observed the dark and bright circular fringes formed when a plano-convex lens is placed in contact with a glass plate due to the varying thickness of the air column between the two and the symmetry around the centre. We could try this experiment in a multichromatic light, observe multi-coloured fringes in the microscope, and find out the radius of curvature using them.

VIII. Author Contributions

Name	Roll number	Contribution	Signature
Aksh Kishor Solanki	24110023	Creation of pre-report	
Akshat Vishal Wandalkar	24110024	Error analysis and possible sources of errors	
Akshay	24110025	Proofreading of reports and elimination of errors, drawing diagrams	
Akshit Chhabra	24110026	Results and discussion in the lap report, operation of equipment	
Akul Gupta	24110027	Documenting data during the experiment, sketching of graphs	