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FACULTY OF SCIENCE & TECHNOLOGY

DEPARTMENT OF PHYSICS

PHYSICS 2 LAB

Summer 2021-2022

Group: 01

LAB REPORT ON

To Determine the radius of curvature of a Plano Convex lens using Newton's rings.

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Date of Submission: Aug 01, 2022

TABLE OF CONTENTS

TOPICS	*Page no.*
I. Title Page	1
II. Table of Content	2
1. Theory	3-6
2. Apparatus	7
3. Procedure	7-8
4. Experimental Data & Calculation	9-10
5. Result	11
6. Discussion	11
7. References	11

1.1. Theory

Newton's rings are a noteworthy illustration of the interference of light waves reflected from the opposite surfaces of a thin film of variable thickness. When a plano-convex or bi-convex lens of large radius of curvature is placed on a glass plate, a thin air film of progressively increasing thickness in all directions from the point of contact between the lens and the glass is very easily formed. The air film thus possesses a radial symmetry about the point of contact. When it is illuminated normally with monochromatic light, an interference pattern consisting of a series of alternate dark and bright circular rings, concentric with the point of contact is observed (Fig-I).

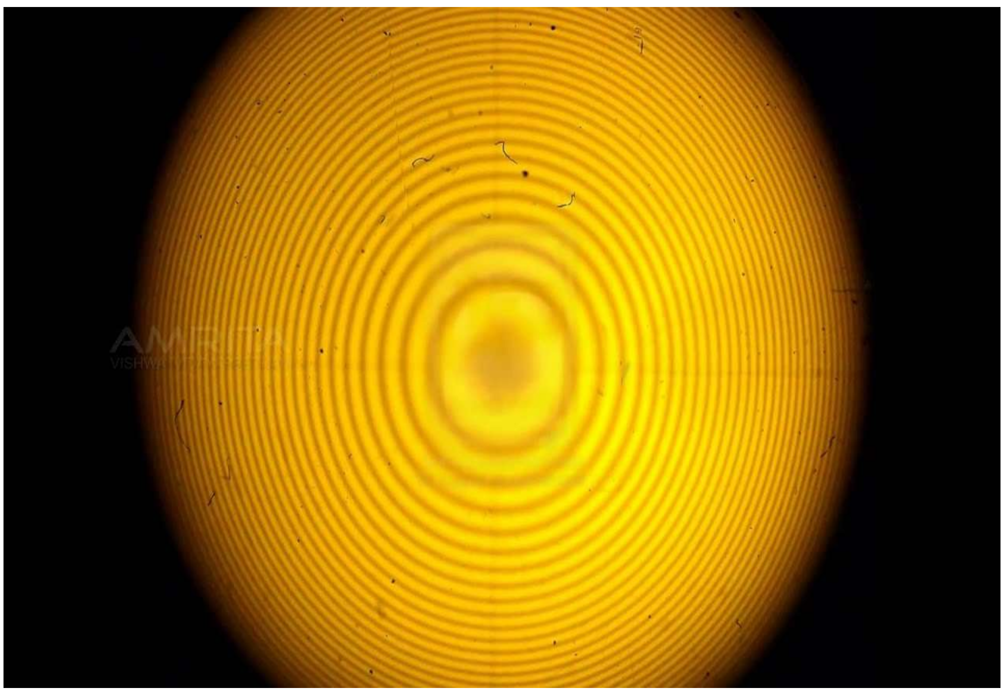


Figure-1: Newton's Ring

The fringes are the loci of points of equal optical film thickness and gradually become narrower as their radii increase until the eye or the magnifying instrument can no longer separate them. Let us consider a ray of monochromatic light AB from an extended source to be incident at the point B on the upper surface of the film (Fig-2). One portion of the ray is reflected from point B on the glass air boundary and goes upwards along BC. The other part refracts into the air film along BD. At point D, a part of light is again reflected along DEF. The two reflected waves BC and BDEF derived from the same, source. They will produce constructive or destructive interference depending on their path difference.

Let t be the thickness of the film at the point E.
Then the optical path difference between the two lays = $2\mu t cos(\theta + r)$
Where, θ= the angle which the tangent to the convex surface at the point E makes with the horizontal.
r =the angle of refraction at the point B
μ= the refractive index of the film with respect to air. t

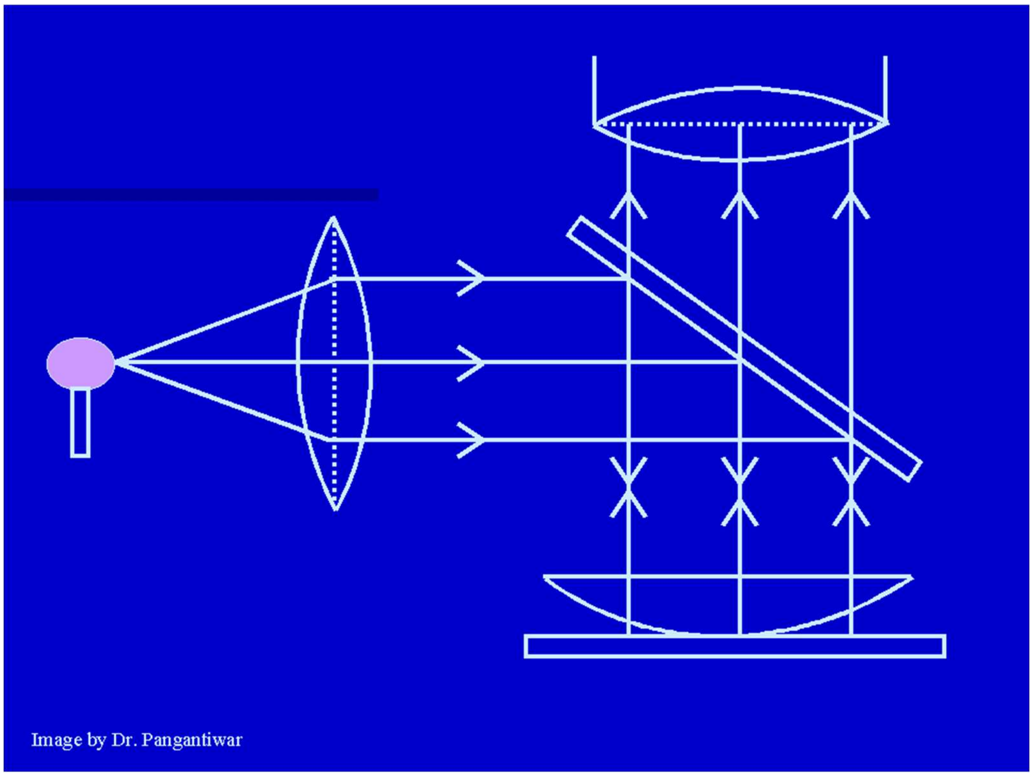


Figure-2: Formation of fringes.

From an analytical treatment by Stokes, based on the principle of optical reversibility and Lloyd's single mirror experiment, it was established that an abrupt phase change of π occurs when light is reflected from a surface backed by a denser medium, while no such phase change occurs when the point is backed by a rarer medium.
In figure 2, the point B is backed by a rarer medium (air) while the point D is backed by a denser medium (glass). Thus, there will be an additional path difference of $\frac{\lambda}{2}$ between the rays BC and BDEF corresponding to this phase difference of π.

Then the optical path difference between the two rays= $2\mu t cos(\theta + r) \pm \frac{\lambda}{2}$

The two rays will interfere constructively when,

$$2\mu t cos(\theta + r) \pm \frac{\lambda}{2} = n\,\lambda$$

$$\text{Or } 2\mu t cos(\theta + r) = (2n\text{-}1)\ \frac{\lambda}{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The minus sign has been chosen purposely since n cannot have a value of zero for bright fringes seen in reflected light.

The rays will interfere destructively when

$$2\mu t cos(\theta + r)\ ) \pm \frac{\lambda}{2} = (2n\pm1)\ \frac{\lambda}{2}$$

$$\text{Or } 2\mu t\cos(\theta + r) = n\,\lambda\ldots\ldots\ldots\ \ldots\ldots\ldots\ \ldots\ldots. (2)$$

λ is the wavelength of light in air.

In practice, a thin lens of extremely small curvature is used to keep the film enclosed between the lens and the plate extremely thin. Consequently, the angle 0 becomes negligibly small as compared to r

Furthermore, the experimental arrangement is so designed that the light is incident almost normally on the film and is viewed from nearly normal directions by reflected light so that cos r = 1.

Accordingly, equations (1) and (2) reduce to

$$2\mu t=(2n\text{-}1)\,\frac{\lambda}{2} \ldots.\ \ldots.\ \ldots\ldots\ ..\ \text{bright}$$

$$2\mu t = n\lambda \ldots\ldots\ldots.\ldots\ldots\ldots.\ \text{dark}$$

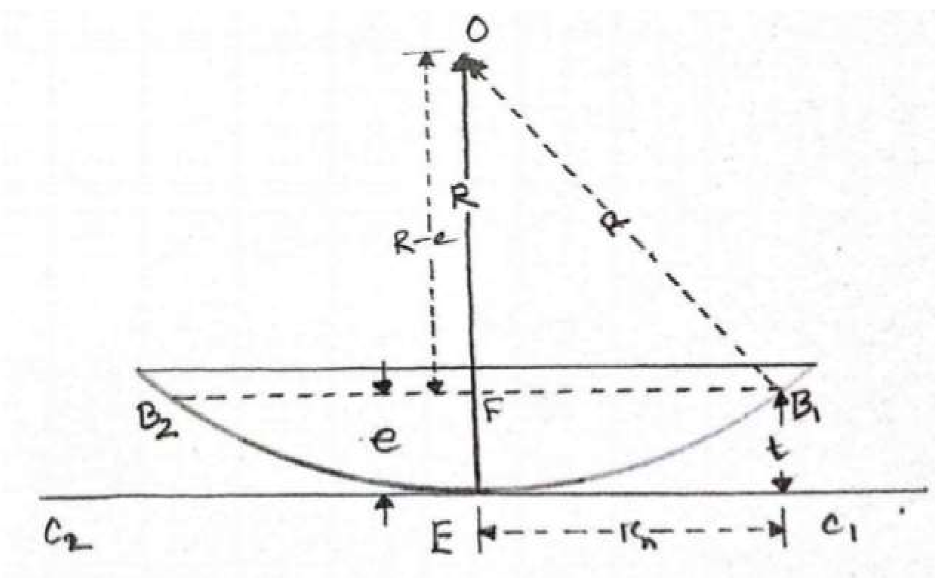


Figure-3: Derivation of radius of curvature

Let R be the radius of curvature of the convex surface which rests on the plane glass surface (Figure: 3). From the right-angled triangle OFBI we get the relation

$$R^2 = r_n^2 + (R-t)^2$$

$$\text{Or } r_n^2=2Rt-t^2$$

Where r_n is the radius of the circular ring corresponding to the constant film thickness t. As outlined above, the condition of the experiment makes t extremely small. So, to a sufficient degree of accuracy, t^2 may be neglected compared to 2Rt.

$$\text{Then, } t = \frac{rn2}{2R}$$

Substituting the value of t in the expressions for bright and dark fringes, we have

$$r_n^2 = \frac{n\lambda R}{2\mu} \text{ .... bright}$$

$$\text{And } r_n^2 = (2n+1)\,\frac{\lambda R}{\mu} \text{... ...dark}$$

The corresponding expression of the squares of the diameters are

$$D_n^2 = 2(2n-1)\,\frac{\lambda R}{\mu} \text{....... Bright}$$

$$\text{And } D_n^2 = \frac{4n\lambda R}{\mu} \text{......dark}$$

In the laboratory, the diameters newton's rings can be measured with a travelling microscope. Usually, a little away from the center, a bright (or dark) ring is chosen which Is clearly visible and its diameter is measured.

Let it be the n^{th} order ring. For an air film, u = 1. Then we have,

$$D_n^2 = 2(2n-1)\,\lambda R \text{ .... (3) .... Bright}$$

$$\text{And } D_n^2 = 4n\lambda R \text{ .... (4) ... Dark}$$

The wavelength of monochromatic light employed to illuminate the film can be computed from either of the above equations, provided R is known. However, in actual practice, another ring, p from this ring onwards is selected. The diameter of this $(n + p)^{th}$ ring is also measured. Then we have,

$$D_{n+p}^2 = 2(2n+2p-1)\,\lambda R \text{ .... (3) .... Bright}$$

$$\text{And } D_{n+p}^2 = 4(n+p)\,\lambda R \text{ .... (4) .... Dark}$$

Subtracting D_n^2 form D_{n+p}^2, we have,

$$D_{n+p}^2 - D_n^2 = 4p\lambda R$$

For either bright or dark ring,

$$R = \frac{Dn+p2 - Dn2}{4p\lambda} \text{ .... (6)}$$

1.2. Apparatus

- Two convex lenses one of whose radius of curvature is to be determined
- Glass plate
- Sodium lamp
- Travelling microscope

1.3. Procedure

a) We arranged the apparatus as shown in the Figure-4. Level the microscope so that the scale along which it slides is horizontal and the axis of the microscope is vertical_ Focus the eyepiece on the crosswires. Then we determined the vernier constant of the micrometer screw of the microscope.

b) After that we carefully cleaned the surfaces of the lens L and glass plate P by means of cotton moistened with benzene or alcohol. We placed the glass plate P as shown in the figure. Then we made an ink dot-mark on the glass plate and focus the microscope on this dot. Now we placed the lens L on it ip such a way that the center of the lens, which is exactly above the dot, is vertically below the microscope objective.

c) We placed the glass plate G in its position, as shown in the figure, in such a way that light from the source S, after passing through the lens C, is incident on it at an angle of approximately 45°. Now we looked onto the microscope, we saw a system of alternate dark and bright rings. Then we adjusted the glass plate number of evenly illuminated bright and dark rings appear on both sides of the central dark spot. We also adjusted the position of the lens C with respect to the flame so that a maximum number of rings are visible through the microscope. This will happen when the flame will be at the focal plane of the lens C.

d) After completing these preliminary adjustments, we focused on the microscope to view the rings as distinctly as possible and then we set one of the crosswires perpendicular to the direction along which the microscope slides. We moved out the microscope to the remotest distinct bright ring on the left side of the central dark spot. The crosswire passed through the middle of the ring and tangential to it. We noted the reading of the microscope. Moved the microscope back again. Turned the screw always in the same direction to avoid any error due to back-lash. We set the crosswire carefully on the center of each successive bright ring and observe the microscope reading. We go on moving the microscope in the same direction. After that it crossed the central dark spot and started moving to the right side of it. As before we set the crosswire on the consecutive bright rings, and we took readings. We proceeded in this way until we have reached the same remotest bright ring as in the case of left side of the dark spot. Considering a particular ring, the difference between the left side and right-side readings, gives the diameter of the ring. In this way, we determined the diameters of the various rings.

e) we tabulated the readings in the data table. While tabulating the reading we were too careful about the number of the ring so that the left side and right-side readings correspond to the same ring.

f) The whole experiment was repeated moving the microscope backwards in the opposite direction over the same set of rings

g) Then we drew a graph with the square of the diameter as ordinate and number of the ring as abscissa. The curve was a straight line.

h) From the graph, we determined the difference between the squares of the diameters of any two rings which were separated by say about 10 rings i.e., p is equal to 10. Lastly, we calculated R with the help of equation (6).

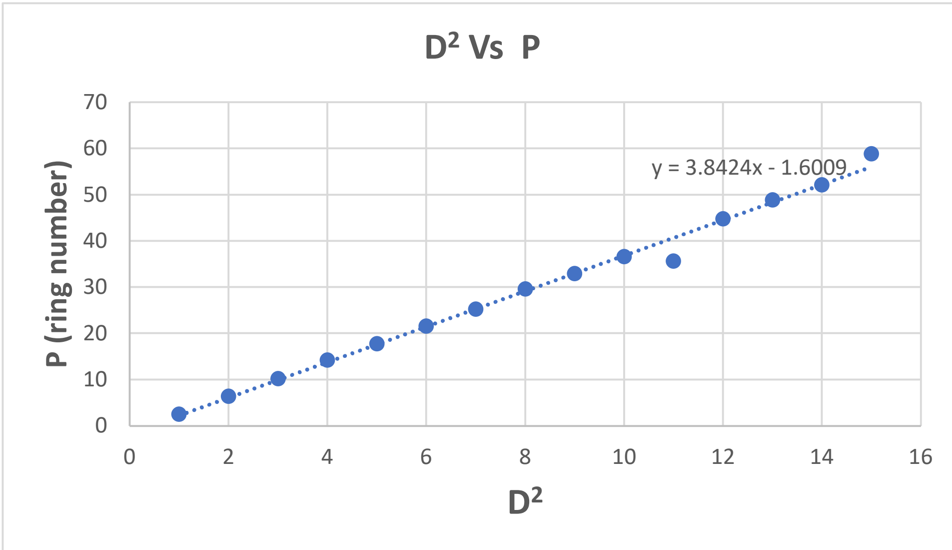
1.4. Experimental Data & Calculation

Least count of the micrometer screw L.C = $\frac{1}{100}$ = 0.01 mm

Table -1: Reading for ring diameter

Rings Number	Reading of the microscope						Diameter of the Ring [D=L-R] mm	D^2 mm^2
	Left Side(L)			Right Side(L)				
	Main Scale Reading (MSR) mm	Vernier Scale Reading (VSR)= Ver. Division x L.C mm	Total Reading L= MSR+VSR mm	Main Scale Reading (MSR) mm	Vernier Scale Reading (VSR)= Ver. Division x L.C mm	Total Reading L= MSR+VSR mm		
1	48	0.41	48.41	46	0.83	46.83	1.58	2.50
2	48	0.92	48.92	46	0.39	46.39	2.53	6.40
3	49	0.25	49.25	46	0.06	46.06	3.19	10.17
4	49	0.53	49.53	45	0.76	45.76	3.11	14.21
5	49	0.75	49.75	45	0.54	45.54	4.21	17.72
6	49	0.97	49.97	45	0.33	45.33	4.64	21.53
7	50	0.16	50.16	45	0.14	45.14	5.02	25.2
8	50	0.39	50.39	44	0.95	44.95	5.44	29.59
9	50	0.51	50.51	44	0.77	44.77	5.74	32.95
10	50	0.65	50.65	44	0.60	44.60	6.05	36.60
11	50	0.82	50.82	44	0.45	44.45	5.97	35.64
12	50	0.99	50.99	44	0.30	44.30	6.69	44.76
13	51	0.16	51.16	44	0.17	44.17	6.99	48.86
14	51	0.25	51.25	44	0.03	44.03	7.22	52.12
15	51	0.58	51.58	43	0.91	43.91	7.67	58.82

Graph:



Calculation:

The mean wavelength of the Sodium light, λ = 5893×10^{-8} cm

From the graph.

$$\text{Slope, R} = \frac{D_{n+p}^2 - D_n^2}{p}\, mm^2$$
$$= 3.842\ mm^2$$
$$= 3.842\ \times 10^{-2}\ \text{cm}^2$$

Thus, the radius of curvature of the lower surface of the given lens is,

$$\text{R} = \frac{D_{n+p}^2 - D_n^2}{4p\lambda}$$
$$= \frac{Slope}{4p\lambda}$$
$$= \frac{3.842\ \times 10^{-2}}{4\lambda}$$
$$= 162.99\ \text{cm}^2$$

1.5. Result

The value of the radius of curvature = 162.99 cm^2

1.6. Discussion

- Glass plates and lens should be cleaned thoroughly.
- The Plano-convex lens should be of large radius of curvature.
- The sources of light used should be an extended one.
- The range of the microscope should be properly adjusted before measuring the diameters.
- Crosswire should be focused on a dark ring tangentially.
- The center of the ring system should be a dark spot.
- The microscope is always moved in the same direction to avoid back lash error.
- Radius of curvature should be measured accurately.

1.7. References

- Lab Manual
- **Fundamentals of Physics**: Transverse and Longitudinal waves (Chapter 16, page, 445) Waves on a stretched string (Chapter 16, Page- 452), Standing wave and resonance (Chapter 16, page- 465)