WAVES AND OPTICS

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Atul Singh Arora: *Waves and Optics*, Physics Lab III,

Every honest researcher I know admits he's just a professional amateur. He's doing whatever he's doing for the first time. That makes him an amateur. He has sense enough to know that he's going to have a lot of trouble, so that makes him a professional.

— Charles F. Kettering (1876-1958) (Holder of 186 patents)

ACKNOWLEDGEMENTS

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I also thank Vivek Sagar (MS11017) for his contribution to this report as my lab-partner, who made the task of performing experiments immensely comfortable and productive at the same time.

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1

NEWTON'S RING

August 14 and 21, 2012

1.1 AIM

To study the fringes of equal thickness in the Newton's ring setup and hence determine the wave-length of sodium light.

1.2 APPARATUS

Sodium vapour lamp, travelling microscope, lens assembly consisting of a plane glass plate and a planoconvex lens, spherometer, magnifying glass, vernier callipers and a tiltable glass plate assembly.

1.3 THEORY

Light when shone on a plano-convex lens in contact with a flat glass plate, produces circular successive dark and bright interference fringes, called Newton's rings. The radius of these fringes depends on both the wavelength and the radius of curvature of the lens. The objective of the experiment is to determine the wavelength of light, by experimentally determining the radius of curvature and analysing the fringes.
To derive the basic relationship, let's first consider the geometry of the problem (refer to Figure 2). For a spherical lens of radius of curvature R, consider a circle at a distance d from the bottom plane, with radius r. Invoking Pythagoras Theorem, we have

$$d = R - (R^2 - r^2)^{1/2} \tag{1}$$

Now let's consider a thin film problem (refer to Figure 3). Optical path distance can be evaluated as $n_2(AB + BC) - n_1(AD)$. Also, from geometry, we have $AB = BC = \frac{d}{\cos\theta_2}$. Plus, $AD = 2d(\tan\theta_2 \sin\theta_1)$. Therefore from Snell's Law, we can further simplify the optical path difference to $2n_2 d(\frac{1-\sin^2\theta_2}{\cos\theta_2})$ which can be rewritten as:

$$2n_2 d\cos\theta_2 = m\lambda \tag{2}$$

for constructive interference.

For newton's ring, we can approximate $\cos\theta_2$ to be 1. Thus we have $2nt = (m + \frac{1}{2})\lambda$ where $n = 1$ for air. We therefore get

$$2nt = (m + \frac{1}{2})\lambda \tag{3}$$

for the bright interference, m=0,1, etc.
We also have $r_m = (R\lambda m)^{1/2}$ from which we obtain directly a linear relation

$$(D_m)^2 = 4R\lambda m \tag{4}$$

Further, we can use the difference to evaluation λ as follows:

$$\frac{(D_{m+n})^2 - (D_m)^2}{4Rn} = \lambda \tag{5}$$

1.4 OBSERVATIONS AND CALCULATIONS

h was found out to be 0.25 mm = 0.025 cm.
l was found out to be $\frac{4.668+3.874}{2} = 4.271$ cm. (For details, refer to Table 2)
Using these, $R = \frac{l^2}{6h} + \frac{h}{2}$ turns out to be 121.6211 cm.

Observations for diameter of the ring are given in Table 1.
Slope of the graph of Diameter Squared, D_m^2 vs Order of Ring, m was found to be 0.0291 cm. (Figure 1)
Using the relation

$$(D_m)^2 = 4R\lambda m \tag{6}$$

$\lambda = 598.16 \pm 3.25\%$ nm (where the error is calculated from the standard deviation of the slope).

1.5 RESULT

The expected wavelength of sodium vapour lamp is 589.5 nm.
Experimentally, the wavelength, λ was found to be
$598.16 \pm 3.25\%$ nm (standard deviation of the slope).
Accuracy error is 1.5%, within the precision.

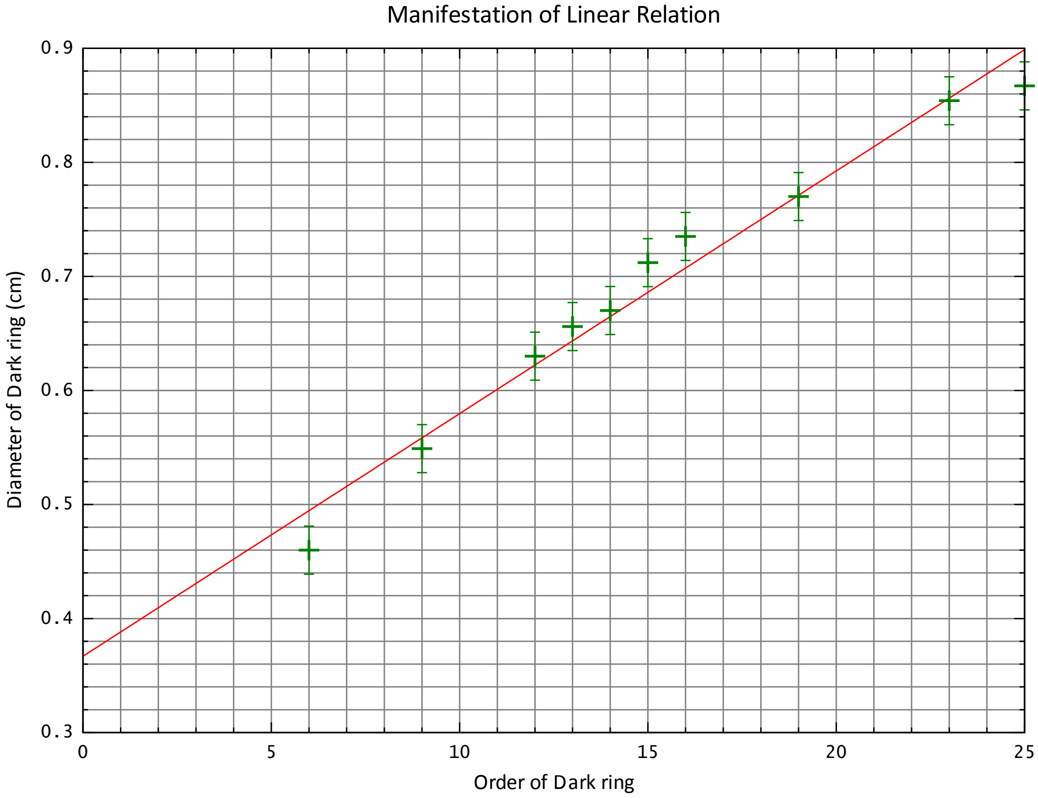
ORDER OF DARK RING m	LEFT (CM)	RIGHT (CM)
6	5.800	6.260
9	5.755	6.304
12	5.720	6.350
13	5.704	6.360
14	5.700	6.370
15	5.670	6.382
16	5.665	6.400
19	5.650	6.420
23	5.605	6.459
25	5.600	6.467

Table 1: Diameter of Newton's Ring

MAIN SCALE (CM)	VERNIER SCALE DIVISION	READING (CM)
OUTER l		
4.6	34	4.668
4.6	35	4.670
4.6	34	4.668
INNER l		
3.8	37	3.874
3.8	38	3.876
3.8	37	3.874

Table 2: Measurement of l of spherometer

Experiment: Newton's Rings

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Slope of Best Fit Line          : +0.0213
Intercept of Best Fit Line      : +0.3669
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Performed on: August 14, 2012
Performed by: Vivek Sagar and Atul Singh Arora
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Figure 1: Least Square Fit of Diameter Squared vs Order of Ring

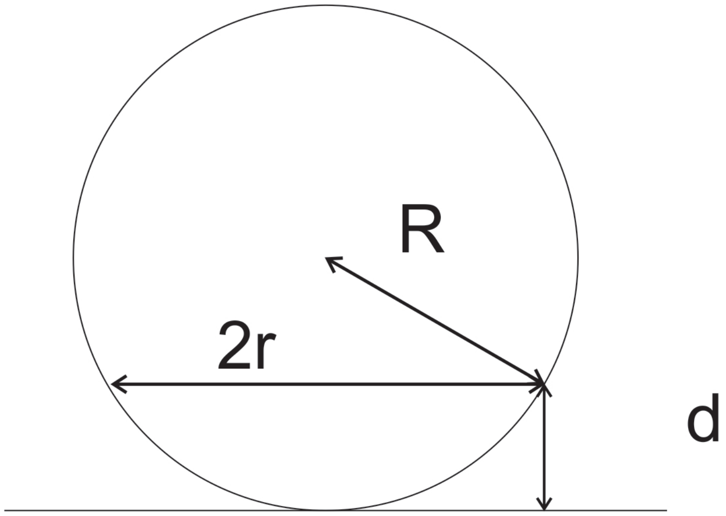

Figure 2: Spherical Lens

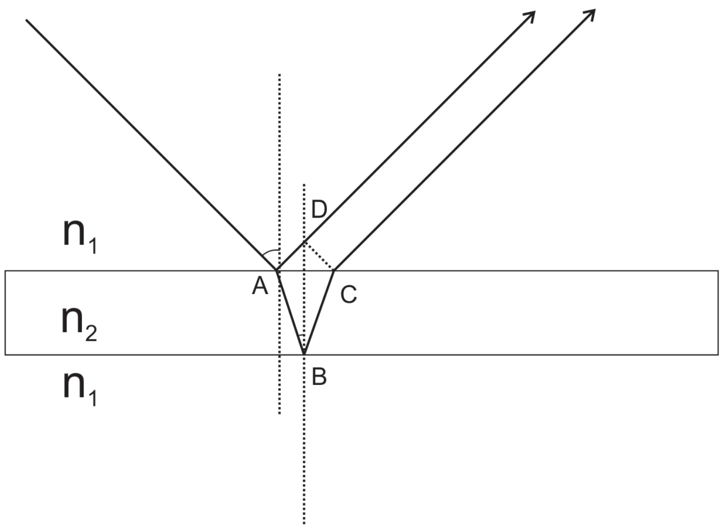

Figure 3: Thin Film Interference

2 FRENEL'S BIPRISM

September 11, 2012

2.1 AIM

To determine the wavelength of sodium light by setting up double slit type fringes using Frenel's Biprism.

2.2 APPARATUS

Sodium vapour lamp, Aperture, Moveable Adjustable Slit, Moveable Eye Piece with a micrometer, Frenel Biprism

2.3 THEORY

The idea here is to setup interference using a biprims. Light emerges from a near point source and hits the biprism, one of whose angles is approximately 180^0, and others $30''$. The beam splits into two and these seem to appear from two sources ('seem to', thus virtual sources). Since the light was split from a common source, it's phase locked (coharent). The light is also monochromatic as its coming from the sodium lamp. Thus, interference patterns of dark and light band are obtained. The shape is attributed to the geometry of the prism.

The fringe width $\beta = D\lambda/d$, where D is the distance between the slit and the eye-piece, d is the distance between the two virtual sources and λ = wavelength of the source. Here β and D can be readily observed, directly. For measurement of d we use a method which is not immediately obvious.

2.4 PROCEDURE

1. Sodium lamp was turned on, since it usually takes some time to produce a bright enough light.
2. The micrometer was calibrated by measuring the lateral displacement in effect with the rotation.
3. The aperture, the biprism, the slit and the eye peice were all vertically aligned, by shifting all of them very close.
4. The Biprism was rotated using the tangential screws, to make it parallel to the slit.

ROTATIONS OF THE MICROMETER SCREW	LATERAL DISPLACEMENT (mm)
4	2.5
8	5.0
12	7.5
16	10.0

Table 3: Calibration of the Micrometer

5. While looking through the eye peice, the source of light, the distances were suitably increased.

6. Fringe width was measured for 20 consecutive fringes using the micrometer, which was calibrated in item 2

7. Distance between the eye piece and the slit was measured for the configuration, using the marks on the 'track'

8. Without disturbing the configuration, a convex lens was placed between the biprism and the eye-piece. The lens was moved to obtain a sharp image, which ideally should be obtained at two locations. The distance between the beams was noted using the micrometer for both cases and their geometric mean taken.

2.5 OBSERVATIONS AND CALCULATIONS

One rotation of the screw of the micrometer was found equivalent to $\frac{10}{16}$ mm lateral displacement, in accordance with .

Least count of the micrometer $= \frac{2.5}{400}$ mm since 4 rotations are equivalent to 2.5 mm and each revolution can be resolved into 100 parts.

The mean width $= 2.87$ rotations $= 0.094\text{mm} \pm 0.00625\text{mm}$, using Table 4[1]

$D = 74.0 \pm 0.05\text{cm}$

$d_1 = 8.13 \pm 0.00625\text{cm}$ (the distance between the virtual sources in the first clear image)

$d_2 = 2.90 \pm 0.00625\text{cm}$ (the distance between the virtual sources in the second clear image)

$d =$ Geometric Mean of $(d_1, d_2) = 4.86 \pm 0.00625\text{mm}$.

2.6 RESULT

Wavelength of Sodium light (λ) was experimentally found to be $(d\beta/D)$ $= 617.3\text{nm} \pm 0.85\% = 617.3 \pm 5.2\text{nm}$

1 Numbers given are rotations of the screw of the Micrometer of the eye-piece, where 1 corresponds to 180^0 rotation.

SERIAL	INITIAL SCREW POSITION	FINAL SCREW POSITION	FRINGE WIDTH
1	0.17	0.32	0.15
2	0.32	0.32	0.15
3	0.47	0.63	0.16
4	0.63	0.84	0.21
5	0.84	0.97	0.13
6	0.97	1.15	0.18
7	1.15	1.29	0.14
8	1.29	1.42	0.13
9	1.42	1.60	0.18
10	1.60	1.71	0.11
11	1.71	1.80	0.09
12	1.80	2.02	0.22
13	2.02	2.16	0.14
14	2.16	2.31	0.15
15	2.31	2.43	0.12
16	2.43	2.57	0.14
17	2.57	2.71	0.14
18	2.71	2.89	0.18
19	2.89	3.04	0.15

Table 4: Fringe Width Observations

2.7 PRECAUTIONS

1. The surfaces of the optical parts should be wiped properly to obtain clear images with good contrast.
2. Micrometer should be moved only in one direction to avoid errors due to backlash.
3. The brightness of the source and width of the mean can be adjusted separately using aperture and slit width
4. Do not make the distance between the lens and slit too high, else the two positions of sharp images using the lens will not be obtained.

Part II

THE SHOWCASE

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COLOPHON

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