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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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

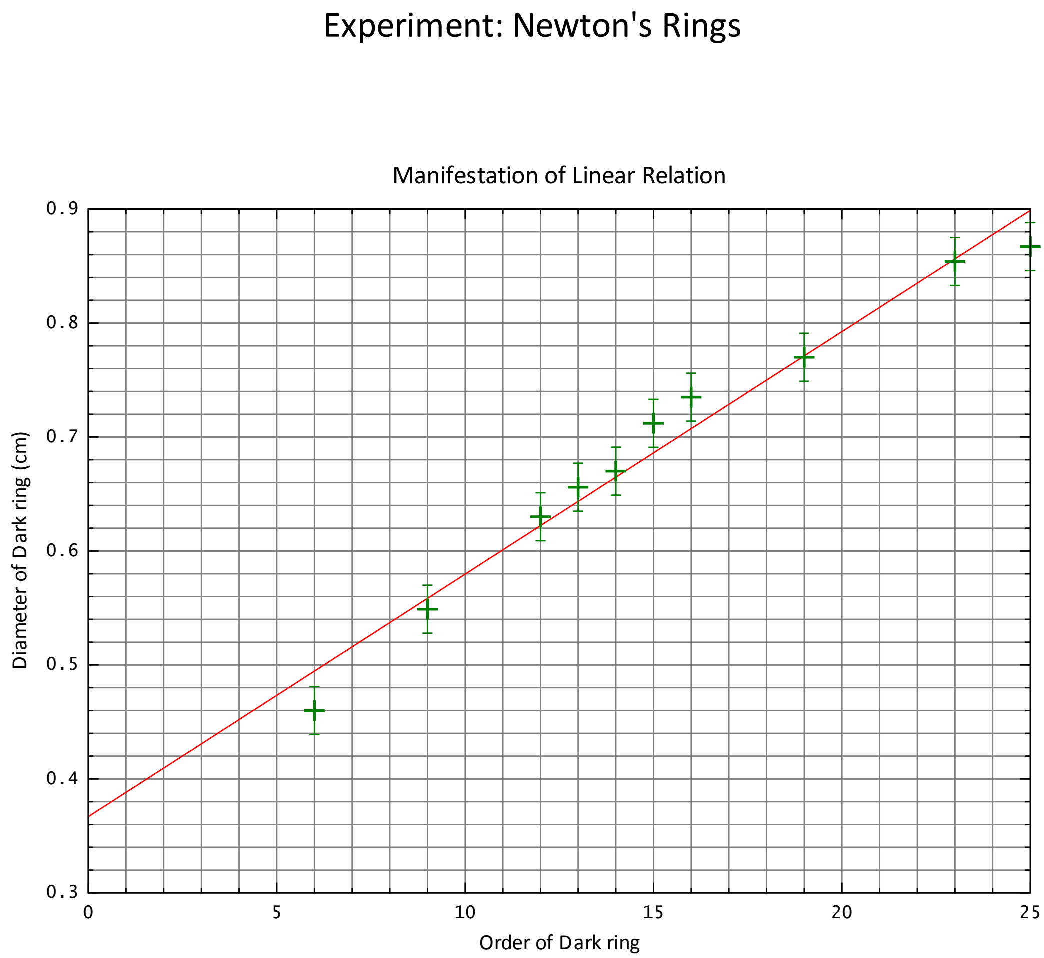
The expected wavelength of sodium vapour lamp is 589.5 nm.
Experimentally, the wavelength, λ was found to be
$598.16 \pm 3.25\%$ nm (standard deviation of the slope).
Accuracy error is 1.5%, within the precision.

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

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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

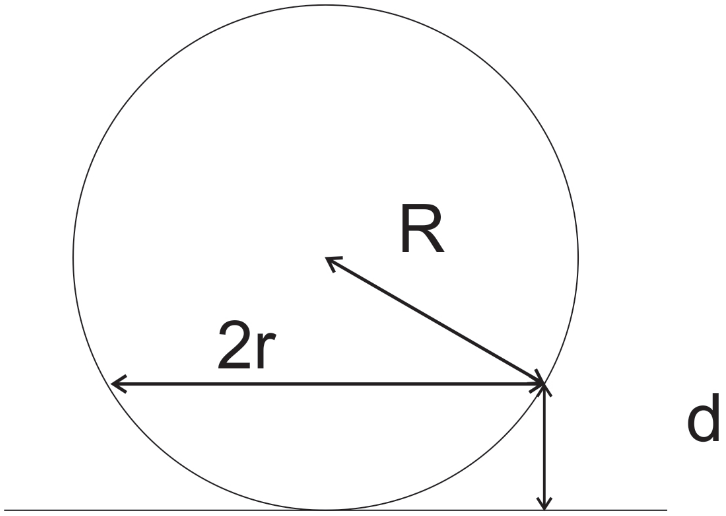


Figure 2: Spherical Lens

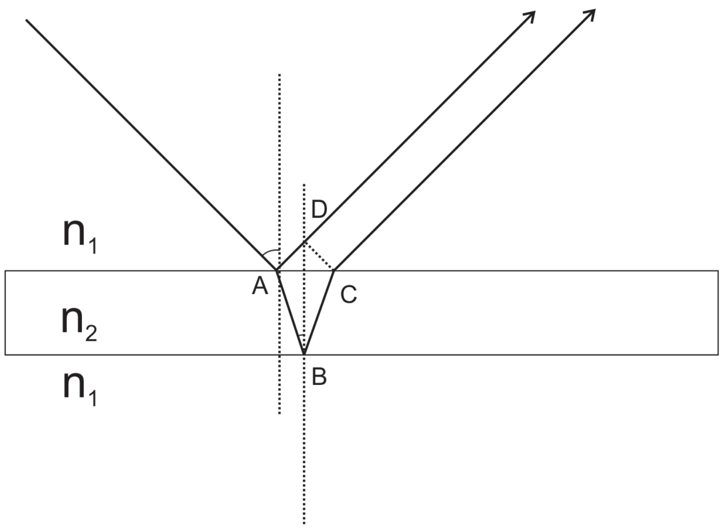


Figure 3: Thin Film Interference

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 $= 0.094mm \pm 0.00625mm$, using Table 4[1]

$D = 74.0 \pm 0.05cm$
$d_1 = 8.13 \pm 0.00625cm$ (the distance between the virtual sources in the first clear image)
$d_2 = 2.90 \pm 0.00625cm$ (the distance between the virtual sources in the second clear image)
$d =$ Geometric Mean of $(d_1, d_2) = 4.86 \pm 0.00625mm$.

2.6 RESULT

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

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.

3 SINGLE SLIT DIFFRACTION

October 9, 16 2012

3.1 AIM

To study diffraction of light due to a thin slit and due to a thin wire, using an optical bench with a laser and a photodiode.

3.2 APPARATUS

Optical Bench, Red Laser, Photodiode, multimeter, screen, adjustable slit, thin wire, wire holder and mounts

3.3 THEORY

3.3.1 *Introduction*

To start with, we assume that the meaning of geometric shadow is intuitively clear. The spreding-out of light into the geometric shadow when it passes through a narrow opening, is referred to as *diffraction* and the spatial intensity distribution on the screen is called the *diffraction pattern*. Diffraction is classified as

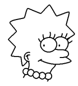
1. Fresnel diffraction
2. Fraunhofer diffraction

In the Fresnel class of diffraction, the source of light and the screen are, in general, at a finite distance form the diffracting aperture. In the Fraunhofer class of diffraction, the source and the screen at an infinite distance from the aperture. The latter can be easily achieved by using a laser (or a point source with a lens) and keeping the screen much farther compared to the dimensions of the aperture (or using a lens and a focal plane).

3.3.2 *Fraunhofer Diffraction*

Assume a narrow slit of width b as the aperture on which a parallel beam of light is incident. We further assume that the slit consists of a large number of equally spaced point sources, which behave like Huygens' secondary wavelets. Let the distance between consecutive points be Δ and number of points be n, thus we have by simple geometrical considerations,

$$b = (n-1)\Delta \tag{7}$$



All the rays make an equal angle because they're at an infinite distance from the screen; think of parallel rays being focussed at a point using a lens

Now let's consider the resultant field at a point P on the screen, where P is arbitrary and the rays received make an angle of θ with respect to the normal of the slit. Let the points A_1, A_2, ... be the said points and the path difference of say $A2$ will be $\Delta \sin\theta$ as is clear from the geometry. The corresponding phase difference, ϕ will be given by

$$\phi = \frac{2\pi}{\lambda}\Delta \sin\theta \tag{8}$$

So if the field at the point P due to the point A_1 is $a \cos\omega t$, then the field from all can be written as

$$E = a[\cos\omega + \cos[\omega - \phi] + ... + \cos[\omega - (n-1)\phi]] \tag{9}$$

where $\phi = \frac{2\pi}{\lambda}\Delta \sin\theta$. Also, Equation 9 is mathematically the same as

$$\frac{\sin n\phi/2}{\sin\phi/2} \cos[\omega t - (1/2)(n-1)\phi] \tag{10}$$

Applying the limits as $n \to \infty$ and $\Delta \to 0$ in such a way that $n\Delta \to b$, we have

$$E = A\frac{\sin\beta}{\beta} \cos(\omega t - \beta) \tag{11}$$

where $A = na$ and $\beta = \frac{\pi b \sin\theta}{\lambda}$. So the intensity follows from this to be

$$I = I_o \frac{\sin^2\beta}{\beta^2} \tag{12}$$

For the second part of the experiment, viz. measurement of thickness of a thin wire, we make a very simplified model which works to a substantial level in terms of accuracy. We assume the intensity distribution to be given by a standard Young's Double Slit Experiment. The usual calculations use

$$d \sin\theta = n\lambda \tag{13}$$

where θ is the same as before, d is the thickness we need to find, and n is an integer, while λ is the wavelength. Now we express $\sin\theta$ as a ratio and obtain

$$\Delta y = \lambda D/d \tag{14}$$

where Δy is the distance on the screen, between two minima (or maxima) and D is the distance between the screen and the wire.

3.4 PROCEDURE

1. The laser was left switched on for 15 minutes so that light intensity from laser did not flicker.
2. The slit was mounted on the bench so that the diffraction pattern could be seen on the white screen.
3. The slit size and distance from laser were varied and observations noted.
4. The photocell was mounted onto the stand between the slit and the white screen.
5. A graph between the photo-current and position of the diode was plotted.
6. The distance D between the slit and photocell was measured.
7. The distance x from the centre of diffraction pattern to the first minimum was obtained and the slit width was calculated (as explained in the theory)
8. The expected theoretical values and the observed values were compared.
9. Lastly, a wire was mounted on the optical bench. The wire and laser sources were moved until the diffraction pattern was visible through the wire. The aperture dimensions were measured by a travelling microscope and the thickness of the wire was found.

3.5 OBSERVATIONS AND CALCULATIONS

3.5.1 *Thin Slit*

The readings were taken and are appended to the experiment. The first column is relative position of the sensor with respect to the observed maximum peak, given in millimetres. The second column shows the value of current through the sensor, in $10^{-3}\,\mu A$. The last column contains the theoretically expected intensity of light (which should be proportional to the current in the previous column) calculated for each relative position in the first column. The theoretical value was evaluated using Equation 12.

It was observed that the pattern broadens as the source and slit are brought nearer and the slit is moved away from the screen. This was expected as

$$a \sin\theta = \lambda \tag{15}$$

where $\theta = x/\sqrt{x^2 + D^2}$ (using small angle approximation).

For evaluating the thickness of the slit, we have

$$\frac{ax}{x^2 + D^2} = \lambda \tag{16}$$

where $\lambda = 623.8\text{nm}$, $D = 125.0 \pm 0.1\text{cm}$, $x = 7.20 \pm 0.01\text{mm}$ which makes $a = 0.108 \pm 0.002\text{mm}$

3.5.2 *Thin Wire*

For the second experiment, we used a Young's Double Slit model and found the average of distance (on the screen) between consecutive minima and plugged it into Equation 14. We find from the graph, $\Delta y = 2.2 \pm 0.24\text{nm}$, $D = 132.9 \pm 0.1\text{cm}$, which makes d, the thickness of the wire to be $0.37 \pm 0.037\text{mm}$. The measured value (using a micrometer) was found out to be $0.36 \pm 0.01\text{mm}$.

3.6 RESULT

The slit width was found out to be $0.108 \pm 0.002\text{mm}$ The width of the wire was calculated to be $0.37 \pm 0.037\text{mm}$

3.7 PRECAUTIONS

1. Micrometer should be moved only in one direction to avoid errors due to backlash.
2. Ensure the table isn't disturbed while taking one particular round of measurements.
3. Be sure to use the ammeter in the right range for best results.

4 SONOMETER

October 9, 10 2012

4.1 AIM

To

1. observe standing waves in a streteched string
2. vary length and linear density of the sonometer wire and observe changes in frequency
3. find linear density of an unknown wire
4. find the fundamental modes using an AC source

4.2 APPARATUS

Sonometer, Tuning Forks, Weights, Weighing Machine, Screw Gauge, Magnetic Coil and appropriate circuitry

4.3 THEORY

This experiment is based on a single formula which is

$$f = n\frac{v}{\lambda} = n\frac{1}{2l}\sqrt{\frac{T}{m}} \tag{17}$$

where f is the frequency, n represents the mode of vibration, l is length of the wire, T is the tension on the wire and m is mass per unit length of the wire. The only caveat here is to understand that f_{ac} actually excites the string with twice the frequency because it attracts at both times, producing a $2f_{ac}$ frequency in the wire.

We keep, for the first experiment, tension and the wire constant, and find the first fundamental mode for various frequencies. We repeat this for the other wire. The slope of the frequency against fundamental length inverse graph will yield

$$m_{line} = lf = \frac{1}{2}\sqrt{\frac{T}{m}} \tag{18}$$

This was used to find the mass per unit length, since the Tension is already known.

For the next part, the frequency was taken from the AC source, and length of string was plotted against n. The slope of the graph yields

$$m_{line} = \frac{l}{n} = \frac{1}{2f}\sqrt{\frac{T}{m}} \tag{19}$$

where f and T are again known, and m was determined using the slope.

4.4 PROCEDURE

1. Tension and effective length of steel wire were varied and fundamental modes of frequencies were obtained for these values.
2. The mass per unit length of the wire was calculated as described in the theory. From the slope of best fit line for the plot of frequency f vs $1/L$, value of fL can be calculated.
3. The experiment was repeated for brass wire.
4. With the steel wire, given L, T and frequency of a magnetic vibrator, the mass per unit length can again be calculated. If the magnetic vibrator is placed above the wire and length L is gradually changed, the frequency of the wire at which it vibrated with the maximum amplitude is the frequency of the oscillator.

4.5 RESULT AND OBSERVATIONS

The observations are given in Figure 4 and for the Steel Wire are given in Figure 5. The AC source observations are given in Figure 6. In accordance with these, the mass per unit length of the brass wire was found out to be $38.4 \pm 1.9 mg/cm$. For the steel wire, using the Tuning Fork method, the value was found out to be $33.8 \pm 1.9 mg/cm$ and using the AC method, this turned out to be $552 \pm 79 mg/cm$. This may be explained by realizing that the first fundamental length was missed in the Tuning Fork experiment.

4.6 PRECAUTIONS

1. Micrometer should be moved only in one direction to avoid errors due to backlash.
2. Ensure the table isn't disturbed while taking one particular round of measurements.
3. Be sure to use the ammeter in the right range for best results.

1/l	freq
6.25	256
7.352941	288
7.874016	320
8.62069	341
9.803922	384
10.86957	426
12.19512	480
13.51351	512

BRASS WIRE

Mass	2.08	Kg
Tension	20.384	N
slope	36.397	±0.918
m	0.003846788	Kg/m
	38.46787906	mg/cm
	38.4 ± 1.9	mg/cm

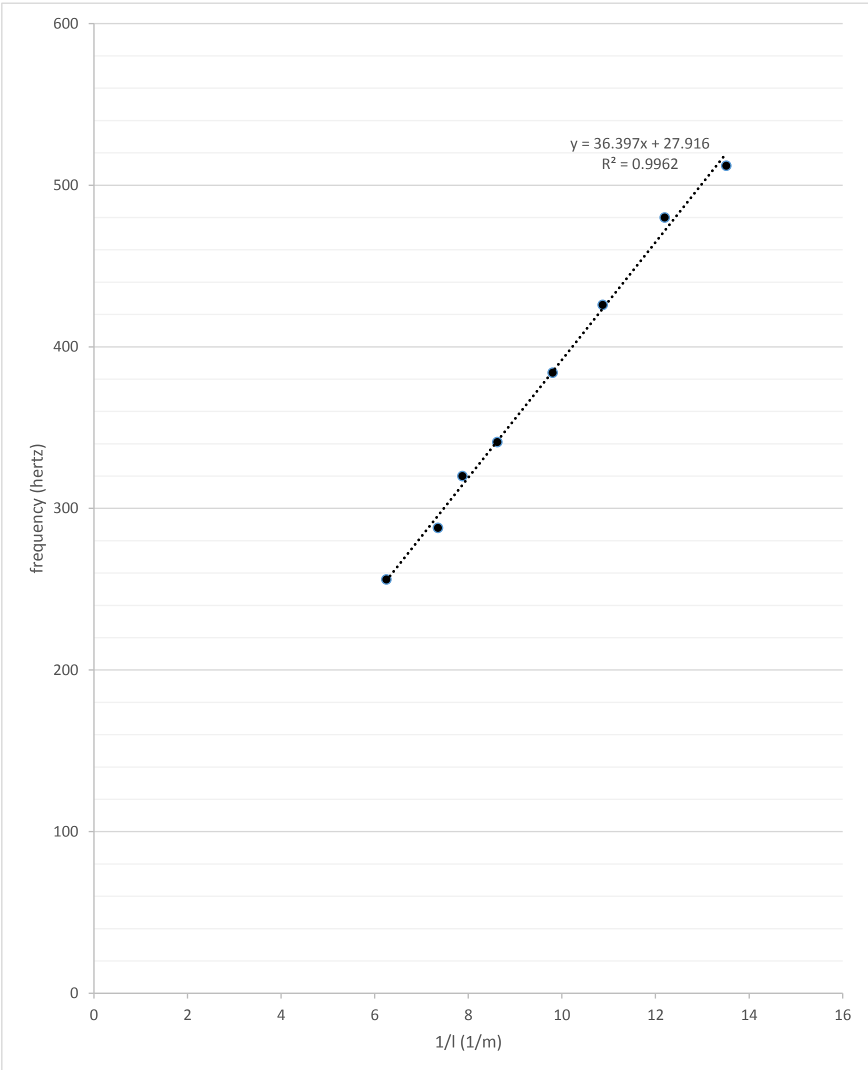


Figure 4: Brass Wire

1/l	freq
4.132231	256
4.761905	288
5.319149	320
5.882353	341
6.666667	384
7.692308	426
9.174312	480
10	512

STEEL WIRE

Mass	2.592	Kg
Tension	25.4016	N
slope	43.337	
m	0.003381	Kg/m
	33.81298	mg/cm
	33.8 ± 1.9	mg/cm

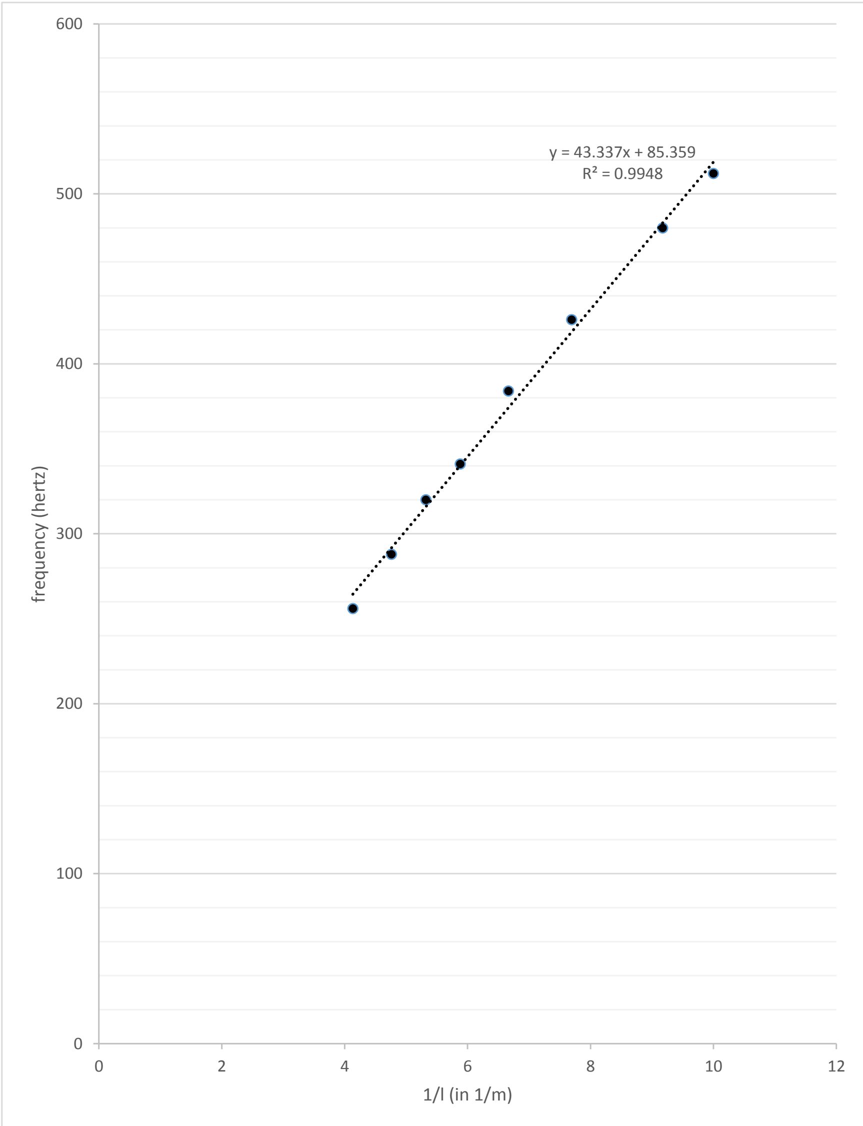


Figure 5: Brass Wire

n	L (in m)
1	0.13
2	0.174
3	0.255
4	0.395
5	0.51
6	0.7
7	0.79

STEEL WIRE (Constant frequency)

Frequency	100	Hz
Mass	3.109	Kg
Tension	30.4682	N
slope	0.1174	±0.0084
m	0.055265	Kg/m
	552.6506	mg/cm
	552 ± 79	mg/cm

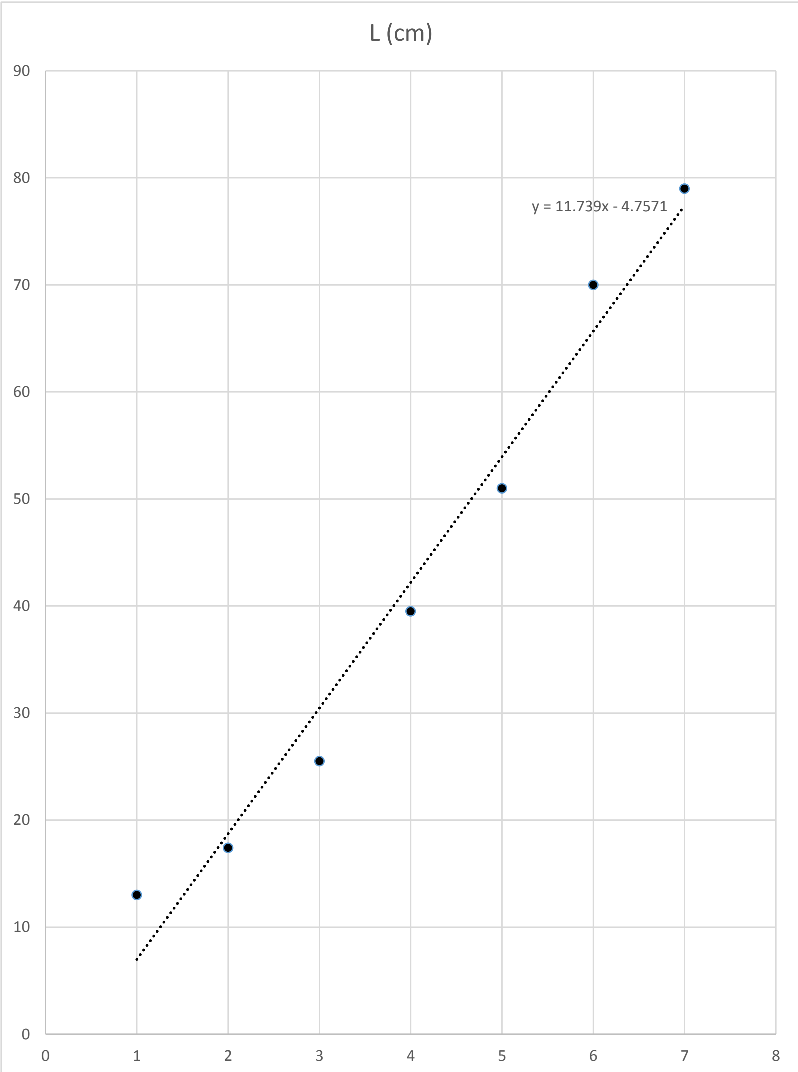


Figure 6: Steel Wire (constant AC)

5 MICHELSON INTERFEROMETER

November 16, 17 2012

5.1 AIM

To

1. observe circular fringes for a monochromatic light source (sodium lamp)
2. obtain the wavelength of sodium D-lines
3. obtain the separation of the sodium D-lines

5.2 APPARATUS

Michelson interferometer setup, which consists of a sodium lamp source, diffusing glass, beam splitter, moveable and fixed mirror with measurement gauges, compensator

5.3 THEORY

5.3.1 *Introduction*

Michelson interferometer is a rather simple and elegant experiment, where a beam is split into two and then made to meet after travelling different distances.

5.3.2 *Determining Wavelength*

The easiest place to begin the analysis of this apparatus would be to ignore the thickness of the beam splitter and the compensator (which is anyway not needed for this experiment, as is explained later) and assume the observations are made at the centre of a far away screen (although in the experiment we've used a lens to focus at infinity). Now at this point, the path difference in the two beams of light would be essentially because of twice the distance between the fixed mirror and the image of the movable mirror. Let this be given by $2d$, where d is the distance between the said mirrors. Now imagine a point other than than the centre at the screen. The angle this makes with the principal axis, let that be θ. The distance light will travel for this point, which can cause phase difference will be $2d\cos\theta$. Keeping in mind the fact that there's an abrupt phase change of π because of reflection at the beam splitter, we have for destructive interference

$$2d\cos\theta = m\lambda \tag{20}$$

and similarly, for constructive interference we'll have

$$2d\cos\theta = (m + 1/2)\lambda \tag{21}$$

It is easy to put in a few numbers [1] and conclude that reducing the distance causes fringes to collapse to the centre (while the spacing between fringes increases). Say for a given configuration, the centre's dark;

$$2d = m\lambda \tag{22}$$

and say for a distance d_o the same is achieved, and N fringes have collapsed to the centre in the process. Then we have

$$2(d + d_o) = (m - N)/\lambda \tag{23}$$

Subtracting these, gives us a simple method of finding the 'average' wavelength of the sodium source

$$\lambda = 2d_o/N \tag{24}$$

5.3.3 *Resolving the D-Lines*

That was the basic theory behind the experiment. Using a little more naiive Math, we can even find the small difference in the Sodium D-lines. Here's how we go about it. First 'd' is made 0. Then the mirror is moved away (or towards) through a distance d. In general, the fringe patterns will overlap in some fashion. Assume a d is such that,

$$2d\cos\theta = m\lambda_1 \qquad 2d\cos\theta = (m + 1/2)\lambda_2 \tag{25}$$

For small θ, we can easily obtain

$$2d/\lambda_1 - 2d/\lambda_2 = 1/2 \tag{26}$$

Observe here what has happened. The maxima of one pattern falls on the minima of the other and vice versa. This means that what we obtain is all bright! Consequently, the pattern disappears in this situation. Making this general, if

$$2d/\lambda_1 - 2d/\lambda_2 = 1/2, 3/2, 5/2.. \tag{27}$$

then the fringe pattern will disappear and for 1, 2, 3 .. it will reappear. Now let us move another step further. ay for an experiment, I find the distance between occurrence of two blank patterns, we have

$$2d_1(1/\lambda_1 - 1/\lambda_2) = 1/2 \tag{28}$$

1 refer to page 15.23 of Ajoy Ghatak, Optics, 4th Edition for details

$$2d_2(1/\lambda_1 - 1/\lambda_2) = 3/2 \tag{29}$$

$$2\Delta d(\Delta\lambda/\lambda^2) = 1 \tag{30}$$

$$\Rightarrow \Delta\lambda = \lambda^2/2\Delta d \tag{31}$$

5.4 PROCEDURE

1. The sodium light source was switched on, allowed to heat up and kept at a distance of about 50 cm from the interferometer.
2. Measured the position of fixed mirror w.r.t. beam splitter with a ruler and brought the movable mirror to the same distance from the beam splitter.
3. The pinhole was brought in front of the sodium light source. Two sets of images of the pinhole were visible through the telescope. The two sets were brought to coincidence with the screws on the fixed and movable mirrors.
4. Pinhole was removed and ground glass was placed in front of the light. No fringes were obtained so the positions of movable mirror and compensator were changed.
5. The steps 3 and 4 were repeated many times so as to obtain the fringes.
6. The fringes were observed through the telescope and position of movable mirror was altered with the help of the drum.
7. When the mirror was moved the fringes seemed to collapse towards the center of the pattern. Micrometer readings were taken after 10 fringes passed through the cross of the telescope.
8. Average wavelength was calculated as $10\lambda = 2(d_0 - d_{10})$.

5.5 OBSERVATIONS AND CALCULATIONS

The average separation ΔD was found to be equal to $0.00283 \pm 0.00014mm$ using the values given in Table 5. Using Equation 24 we get the average wavelength to be $566 \pm 29nm$. For the separation in D-lines, the experiment couldn't be setup.

DISTANCE (MM)	DIFFERENCE (MM)
0.6228	0.0028
0.6255	0.0027
0.6284	0.0029
0.631	0.0026
0.6339	0.0029
0.6367	0.0028
0.6397	0.0030
0.6428	0.0031
0.6455	0.0027
0.6455	

Table 5: Average Wavelength of Sodium

5.6 RESULT

The average wavelength of Sodium was found to be $566 \pm 29nm = 566 \pm 5\%$. The actual wavelength falls within the error range.

5.7 REMARKS

This experiment doesn't quite require the compensator since the source is monochromatic.

5.8 PRECAUTIONS

1. TODO: Talk to vivek

Part II

THE SHOWCASE

You can put some informational part preamble text here. Illo principalmente su nos. Non message *occidental* anglo-romanic da. Debitas effortio simplificate sia se, auxiliar summarios da que, se avantiate publicationes via. Pan in terra summarios, capital interlingua se que. Al via multo esser specimen, campo responder que da. Le usate medical addresses pro, europa origine sanctificate nos se.

COLOPHON

This document was typeset using the typographical look-and-feel `classicthesis` developed by André Miede, for LaTeX.
The style was inspired by Robert Bringhurst's seminal book on typography "*The Elements of Typographic Style*".

The latest version of this document is available online at:

https://github.com/toAtulArora/IISER_repo