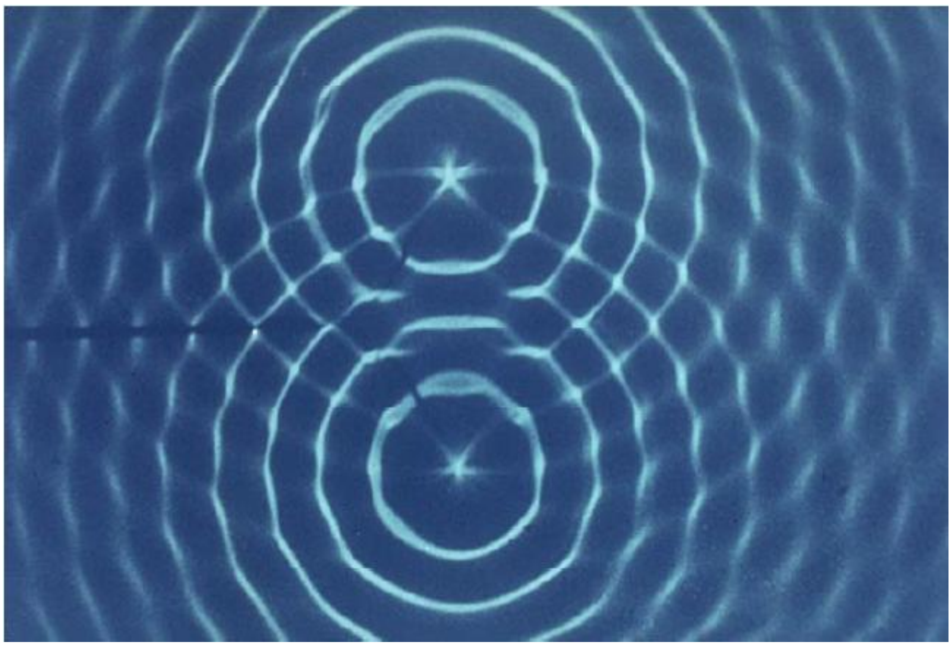
LABORATORY MANUAL
PHY247
Session: 2019-2020 (1)

WAVES AND OPTICS LABORATORY

(For private circulation only)



Name of the student……………………………………

Registration number/Roll no…………………………...

Section and Group……………………………………..

School of……………………………………………..

Transforming Education Transforming India

General guidelines for the students

Importance of lab:

Physics is an experimental science. When several physical theories compete for acceptance, the choice goes to the theory that best explains experiments. In this class you will learn some fundamental aspects of experimental physics. You will

- Observe physical phenomena in more detail than can be done in lecture.
- Work with scientific equipment.
- Learn how to compare experimental results with theoretical expectations

General guidelines:

Student must accompany lab manual while entering the lab.
Doing experiments in the laboratory without supervision is prohibited. The performance of unauthorized experiments and the use of any equipment in an unauthorized or unsafe manner are strictly forbidden.
Horseplay in the laboratory is unacceptable behavior and is cause for immediate removal from the laboratory

Safety guidelines:

- **DO NOT TOUCH ANYTHING WITH WHICH YOU ARE NOT COMPLETELY FAMILIAR**!!! It is always better to ask questions than to risk harm to yourself or damage to the equipment.
- **NEVER, EVER LOOK INTO ANY LASER BEAM**, no matter how low power or "eye
  safe" you may think it is.
- Never do unauthorized experiments.
- Never work alone in laboratory.
- Keep your lab space clean and organized.
- Do not leave an on-going experiment unattended.
- Obtain permission before operating any high voltage equipment. Maintain an unobstructed access to all electrical panels.

TABLE OF CONTENTS

Experiment 1:

To determine wavelength of (1) sodium and (2) spectral lines of the mercury light using plane diffraction grating.

Equipments to be used: A spectrometer, a spirit level, a sodium lamp, mercury lamp, an eye-piece, diffraction grating with clamping arrangement etc.

Learning Objectives:

1. The students will understand the concept of diffraction; Fresnel as well a Fraunhofer.
2. The students will learn about fringe width, diffraction patterns and diffraction gratings.
3. The students will have the idea of absent spectra.

Theory:

In optics, a diffraction grating is an optical component with a periodic structure, which splits and diffracts light into several beams travelling in different directions shown in fig.1. The directions of these beams depend on the spacing of the grating and the wavelength of the light so that the grating acts as the dispersive element. Because of this, gratings are commonly used in monochromators and spectrometers.

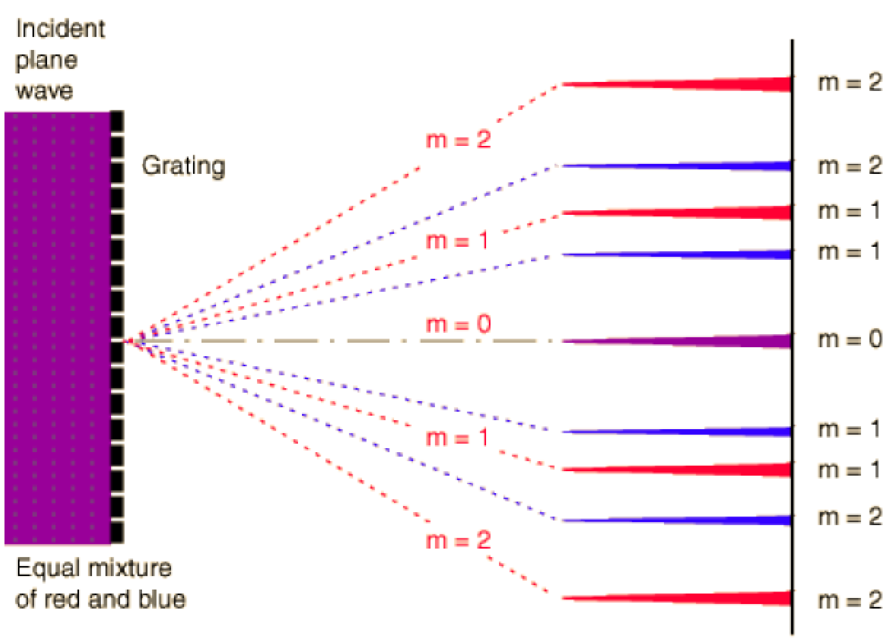


Fig.1 Diffraction pattern by Grating.

Observations: Vernier Constant =

Number of lines per inch on the grating N=

Grating element (a+b) = 2.54/ N = cm

Direct reading of telescope =

S. No	Order of Spectrum	Vernier	Telescope reading			Angle of diffraction			Grating element (a+b)
			Left	**Direct**	**right**	**Left**	**Right**	**mean**	
1	1^{st} order								
2									
1	2^{nd} order								
2									

Procedure:

1. Setting: Adjust the position of the eye-piece of the telescope so that cross-wires are clearly visible. Focus the telescope on a distant object and set it for parallel rays coming from sodium source. Level the spectrometer by the leveling screws and then the prism table with the help of a spirit level.

2. Fix the grating stand on the circular table with two screws in the holes drilled on one of the lines parallel to the line joining two of the screws meant for the purpose, say P and Q. The face of the stand to which the clamps are attached should be at the centre of

the table. Take out the grating carefully from the box, holding it from the edge and without touching its surface, fix it very carefully to the frame with its ruled surface towards the telescope.

3. Optical leveling of the grating table. Rotate the table so that the plane of the grating is approximately inclined at an angle of 45^0 to the axis of the collimator rotate the telescope to receive the reflected light from the grating surface. Rotate the table carrying the grating so that the plane of the grating is approximately perpendicular to the axis of the collimator. Look for the first order spectrum on one side of the direct image of the slit. Turn the telescope so that vertical cross-wire coincides with the first order diffracted image. If this image is not symmetrical with respect to the horizontal cross-wire, adjust it with the help of one of the screws. In this position the grating lines are parallel to the axis of the spectrometer. Now turn the telescope to the other side so that the vertical cross-wire again coincides with the first order diffracted image. If the adjustments are carefully done then the diffracted images of the slit will be symmetrical with respect to the horizontal cross-wire in all positions.

4. Setting the grating normal to the incident sodium light. Place the telescope in line with the collimator so that the vertical cross-wire falls exactly in the centre of the image of the slit. Note the scale reading. Add 90 to the reading and place the telescope at this reading to set it perpendicular to the axis of the collimator. Clamp it in this position. Rotate the grating table till the plane face of the grating is facing both the collimator and the telescope. Look through the telescope and turn the table very slowly till the centre of the slit falls exactly on the vertical cross-wire. In this position the plane of the grating is inclined at an angle of 45^0 to the incident light. Note the reading. Turn the table through 45^0 from this position so that the plane of the grating is normal to the incident light with its plane face towards the collimator. The grating is now set normal to the incident light with its rules surface away from the collimator. Clamp the table in this position. Take reading on both the venires.

6. Similarly note the reading of the verniers by setting the telescope on the second order diffracted image on either side of the direct light.

7. Repeat the above observation three times.

8. Note the number of lines per inch as marked on the grating and replace it carefully in the box with ruled surface upwards.

9. Now replace sodium source with mercury source. Rotate the telescope to the left side of direct image and adjust the different spectral lines (violet, green, blue and red etc.) turn by turn on the vertical cross wire for first order. Note down the reading of both the

verniers in each setting.

10. Rotate the telescope further to obtain the second order spectrum and again the spectral lines on the vertical cross wire and note the readings.

11. Now rotate the telescope to the right of the right of the direct image and repeat the above procedure for first order as well as for second order.

12. Find out the difference of the same kind of verniers (V1 fromV1 and V2 fromV2) for each spectral line in the first order and then in the second order. The angle is twice the angle of diffraction for that particular color. Half of it will be angle of diffraction.

13. Find out the angles of diffraction for other colors in first and second orders.

Required Results:

1st Order spectrum λ= (a+b) Sin θ_1 = cm

2nd Order spectrum 2λ= (a+b) Sin θ_2 =cm

Mean Wavelength λ = …cm = …m

Precautions:

1. The grating should be held from the edges and the rules surface should not be touched.
2. The telescope should be focused on the brightest image of the slit while seeing the reflected image.
3. The ruled surface should face away from the collimator.
4. The light should fall on the whole of the grating surface

Book suggested

1. B.Sc Practical Physics by C.L. Arora S.Chand Publication,19th edition(2010)

2. B.Sc Practical Physics by Harman Singh and Dr. P.S. Hemne, S.Chand Publication,1stedition(2011)

Websites: https://www.youtube.com/watch?v=SO7ZlMJv5ZM

Worksheet of the student

Date of Performance Registration Number:

To determine wavelength of (1) sodium and (2) spectral lines of the mercury light using plane diffraction grating.

Observations: Vernier Constant =

Number of lines per inch on the grating N=

Grating element (a+b) = 2.54/ N = cm

Direct reading of telescope =

Table 1
To set the unruled surface of the grating for normal incidence

Direct reading of the telescope without grating			**Telescope is rotated through 90^o and set at angle**	**Reading of the prism table when the angle of indicence is 45^o**			**Prism table is rotated through 45^oor 135^o and set at angle**
M.S. (M)	**V.S. (V)**	**Total (T=M+V)**		**M.S. (M)**	**V.S. (V)**	**Total (T=M+V)**	

Table 2 (using sodium light)

S. No.	Order of spectrum	Vernier	Telescope reading			Angle of diffraction		
			Left	Direct	Right	Left	Right	mean
1	1^{st} order							
2								
1	2^{nd} order							
2								

Table 3 (using Mercury light)

Order of Spectrum	Color of light	Vernier	Telescope reading			Angle of diffraction		
			Left	Direct	Right	Left	Right	Mean (θ)
		V1 V2						
		V1 V2						
1st order		V1 V2						
		V1 V2						
2nd order		V1 V2						
		V1 V2						

Calculation: Wavelength of sodium light as calculated from

1st Order spectrum $\lambda = (a+b) \sin \theta_1$ = cm

2nd Order spectrum $2\lambda = (a+b) \sin \theta_2$ = cm

Mean Wavelength λ = cm = m

Result and Discussion:

Color of Spectral line	**λ (Observed)**	**λ (Standard)**	**% Error**

Error Analysis:

Learning Outcomes (what I have learnt):

To be filled in by Faculty

S. No.	**Parameter**	**Marks obtained**	**Max. Marks**
1	Understanding of the student about the procedure/apparatus.		**20**
2	Observations and analysis including learning outcomes		**20**
3	Completion of experiment, Discipline and Cleanliness		**10**
	Signature of Faculty	**Total marks obtained**	

Experiment 2:
To determine the refractive index of the material of given prism using sodium light.

Equipment required:

A spectrometer, a spirit level, a source of monochromatic light (sodium lamp), a glass prism, a wooden screen with a circular aperture, an eye piece and an electric lamp.

Learning Objectives

To learn how to determine the angle of prism and the refractive index.

To acquaint oneself with the setting and alignment of spectrometer.

Theory: When a beam of light strikes on the surface of transparent material(Glass, water, quartz crystal, etc.), the portion of the light is transmitted and other portion is reflected. The transmitted light ray has small deviation of the path from the incident angle. This is called refraction.

Refraction is due to the change in speed of light while passing through the medium. It is given by Snell's Law.

$$\frac{\sin(i)}{\sin(r)} = \frac{n_2}{n_1}$$

Where i is the angle of incident and r is the angle of refraction. And n_1 is the refractive index of the first face and n_2 is the refractive index of the second face.

Procedure:

To have a demonstration on reading a vernier scale, go to the link:

http://labs.physics.dur.ac.uk/level1/ISE/ISEs.php

1. Find the least count of the spectrometer.

2. Find the angle of the prism by rotating the telescope method. Place the prism on the turn table in such a way that the refracting edge A coincides with the centre of the table and one of the refracting and polished face say AB remains perpendicular to the line joining the screws Y and Z.

3. Now rotate the prism table to bring the refracting edge A of the prism towards the collimator so that the light from the collimator falls equally on both faces AB and AC bounding the refracting angle A.

4. Rotate the telescope to the right side to receive the light reflected from the face AB and focus the crosswire on the image of the slit. Now by tangent screw the telescope is moved slowly until its

vertical cross wire coincides with the image. The reading of the two verniers of the spectrometer is taken.

5. Now rotate the telescope to the left side to receive the light reflected from the face AC and again focus the crosswire on the image of the slit by means of tangent screw. The readings of the two verniers of the spectrometer are again noted.

6. The difference of the two vernier readings of the same vernier for two positions of the telescope gives twice the refracting angle A of the prism. Thus half of this angle will give the value of angle of prism.

7. Place the prism on the prism table so that its centre coincides with the centre of the table and one of the reflecting faces say *AB* is perpendicular to the line joining the two screws *P* and *Q*. Rotate the table so that the light from the collimator is incident on the reflecting face *AB* and after refraction passes out of the face *AC* as shown in Fig.2.

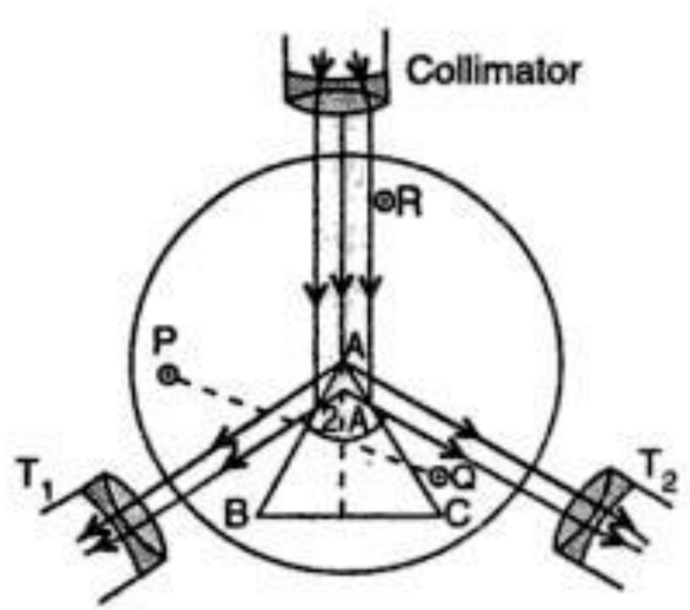


Fig.2 Setup of spectrometer of experiment.

8. Look through the face *AC* and locate the position of the refracted image with the naked eye. Bring the telescope in this position. Adjust the position till the image of the slit falls on the cross-wire. Now turn the prism table in such a direction that the telescope has to be moved towards the line of the collimator axis in order to keep the image in the centre of the field of view. As the prism table is rotated in this way the angle of deviation decreases. When the position of minimum deviation is reached the image becomes stationary and further rotation of the table makes it move in the backward direction. The direction of the telescope is finally adjusted till the image is on the cross-wire in the stationary position from which it turns back in whichever direction the prism is rotated. Clamp the telescope and the table. The minimum deviation position is correct if the image remains

stationary when the tangent screw of the table is given one rotation either way. Note the reading on both the vernier scales *V1* and *V2*.

9. Keep the table fixed and remove the prism gently. Turn the telescope and bring it in line with the collimator and clamp it. Work the tangent screw of the telescope so that the image of the slit falls exactly on the vertical cross-wire. Take the reading on both the vernier scales.

10. Repeat the experiment and take three such observations.

Scope of the result to be reported Plots & Parameters:

1. Plot a graph by taking angle of incidence 'i'along the X-axis and angle of deviation δ along the Y-axis. This graph will give the angle of minimum deviation.

2. Angle of Prism 'A' and Angle of minimum deviation Dm. Refractive Index μ can be found using the formula

$$\mu = \sin[(A + D_m)/2]/\sin A/2$$

The angle of deviation decreases with angle of incidence. For a particular angle of incidence, the angle of deviation is minimum which is known as angle of minimum deviation and which can be noted from the graph. After this point the angle of deviation again increases with angle of incidence. By measuring the angle of deviation and angle of prism, the refractive index of he material of prism can be determined.

Observations: Vernier constant=

Wavelength of light used=

Angle of Prism:

<table>
<tr><td rowspan="3">S.No.</td><td rowspan="3">Vernier</td><td colspan="6">Position of telescope for reflection from</td><td rowspan="3">Difference
(a~b =2A)</td><td rowspan="3">Mean of value 2A</td><td rowspan="3">A</td></tr>
<tr><td colspan="3">Position of Ist face
(a)</td><td colspan="3">Position of IInd face
(b)</td></tr>
<tr><td>M.S.</td><td>V.S.</td><td>Total</td><td>M.S.</td><td>V.S.</td><td>Total</td></tr>
<tr><td>1.</td><td>V_1
V_2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2.</td><td>V_1
V_2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3.</td><td>V_1
V_2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Mean value of angle of prism "A" =

Table for Angle of minimum deviation

S.No.	Vernier	Telescope reading						Difference ($a' - b'$ $= \delta m$)	Mean value of δm
		Position of minimum deviation (a')			Direct image (b')				
		M.S.	V.S.	T	M.S.	V.S.	T		
1.	V_1 V_2								
2.	V_1 V_2								
3.	V_1 V_2								

Mean value of δm =

(i) Refractive index for sodium light $\mu = \text{Sin}\,[(A+\delta m)/2]/\text{Sin}A/2$

(ii) Exact value of μ for extra dense flint glass (material of prism) =
Calculated value = ………………………….
Percentage error = [(calculated value - exact value)/exact value] x 100 = …………..%

Calculations:

1. Angle of Prism 'A' and Angle of minimum deviation Dm

2. Refractive Index μ can be found using the formula

$\boldsymbol{\mu = \sin [(A + Dm)/2]/\sin A/2}$

Cautions

1. The axis of telescope, the collimator and the plane of the prism table should be horizontal.
2. The position of the eye piece should be adjusted so that the cross-wires are clearly visible without any strain.
3. The telescope should be focused for infinity and the collimator should be adjusted to give a parallel beam of light.
4. The slit should be narrow.
5. The prism should be placed with its refracting edge at the centre of the prism table when finding the angle by rotating the telescopes.
6. The prism table should be leveled so that reflected image from both the reflecting faces lies systematically with respect to the horizontal cross-wires.

References:

1. B.Sc. Practical Physics by C. L. Arora S.Chand Publication, 20 th edition(2015).

Weblinks: http://vlab.amrita.edu/?sub=1&brch=281

Worksheet of the student:

Date of Performance: **Registration number:**

Experiment: To determine the refractive index of the material of given prism using sodium light.

Observations: Vernier constant=

Wavelength of light used=

Angle of prism

S.No.	Vernier	Position of telescope for reflection from						Difference (a~b =2A)	Mean of value 2A	A
		Position of Ist face (a)			Position of IInd face (b)					
		M.S.	V.S.	Total	M.S.	V.S.	Total			
1.	V_1 V_2									
2.	V_1 V_2									
3.	V_1 V_2									

Mean value of angle of prism “A” =

Table for Angle of minimum deviation

S.No.	Vernier	Telescope reading						Difference ($a' - b' = \delta m$)	Mean value of δm
		Position of minimum deviation (a’)			Direct image (b’)				
		M.S.	V.S.	T	M.S.	V.S.	T		
1.	V_1 V_2								
2.	V_1 V_2								
3.	V_1								

	V_2								

Calculations:

Mean value of δm =

(i) Refractive index for sodium light μ =

(ii) Exact value of μ for extra dense flint glass (material of prism) =

Calculated value = ………………………….

Percentage error = [(calculated value = exact value)/exact value] x 100

= …………..%

Learning Outcomes (what I have learnt):

To be filled in by faculty:

S.No.	Parameter	Marks obtained	Max marks
1	Understanding of the student about the procedure/apparatus		20
2	Observations and analysis including learning Outcomes		20
3	Completion of experiment , discipline and Cleanliness		10
	Signature of faculty	Total marks obtained	

Experiment 3:

To determine the dispersive power and Cauchy constants of the material of a given prism using mercury light.

Equipment required: Spectrometer, prism, prism clamp, mercury vapour lamp, lens, Magnifying glass.

Learning Objectives:

- Students will acquire proficiency in the reading of vernier scales.
- They will learn how to use a spectrometer.
  To learn how to determine the dispersive power of a prism.
- They will obtain a practical understanding of Cauchy's equation.

Theory: The phenomenon of splitting up of white light into its constituent colours is called dispersion.

The refractive index of the material of the prism can be calculated by the equation.

$$n = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Where, D is the angle of minimum deviation, here D is different for different colour **.**

Consider two colour green and violet, corresponding minimum deviation is D_G and D_V ,corresponding refractive index is

$$n_B = \frac{\sin\left(\frac{A+D_B}{2}\right)}{\sin\left(\frac{A}{2}\right)} \qquad n_V = \frac{\sin\left(\frac{A+D_V}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$n_G = \frac{\sin\left(\frac{A+D_G}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$ There for dispersive power is (i) $\omega=(n_B-n_G)/n-1$

(ii) $\omega=(n_V-n_G)/n-1$, where

$$n=\frac{(n_B+n_G)}{2} \qquad\qquad n=\frac{(n_V+n_G)}{2}$$

The most general form of Cauchy's equation is

$$n(\lambda)=A+\frac{B}{\lambda^2}+\frac{C}{\lambda^4}+..;$$

where n is the refractive index, λ is the wavelength, B, C etc., are coefficients that can be determined for a material by fitting the equation to measured refractive indices at known wavelengths.

The refractive index n of the material of the prism for a wavelength λ is given by

$$n=A+\frac{B}{\lambda^2}$$

Where A and B are called Cauchy's constants for the prism.

If the refractive indices (n's) for any known wavelengths λ's are determined by a spectrometer, the Cauchy's constants A and B can be calculated from the above equation.

Procedure:

1. Set the spectrometer using sodium lamp and find the angle of prism.
2. Replace sodium vapor lamp by mercury vapor lamp and find the angle of minimum deviation for the violet line.
3. Using mercury lamp find the angle of minimum deviation for different colors of lines e.g. violet, blue and green lines etc.
4. Calculate the refractive index corresponding to each color.
5. 4. Plot a graph between $1/\lambda^2$ and n to find out Cauchy constant.

Observations:

Vernier constant=

Wavelength of yellow light =

Wavelength of violet light =

Wavelength of blue light=

Wavelength of green light=

Angle of Prism:

S.No.	Vernier	Position of telescope for reflection from						Difference (a~b =2A)	Mean of value 2A	A
		Position of I^{st} face (a)			Position of II^{nd} face (b)					
		M.S.	V.S.	Total	M.S.	V.S.	Total			
1.	V_1 V_2									
2.	V_1 V_2									
3.	V_1 V_2									

Table for Angle of minimum deviation:

S.No.	Vernier	Telescope reading						Difference ($a'-b'=\delta m$)	Mean value of δm
		Position of minimum deviation (a')			Direct image (b')				
		M.S.	V.S.	T	M.S.	V.S.	T		
1.	V1 V2								
2.	V1 V2								
3.	V1 V2								

Refractive index for violet color n_{V} =

Refractive index for blue color n_{B} =

Refractive index for green color n_{G} =

Dispersive power (i) $\omega=(n_B-n_G)/n-1$

(ii) $\omega=(n_V-n_G)/n-1$

Graph: Plot graph taking $1/\lambda^2$ along X-axis and n along Y-axis. The graph is a straight line. Intercept of the graph in Y-axis is the Cauchy constant A and slope of the graph is B.

Scope of the Result:

With this experiment, we can find dispersive power as well as Cauchy constant A and B.

Cautions

1. The axis of telescope, the collimator and the plane of the prism table should be horizontal.
2. The position of the eye piece should be adjusted so that the cross-wires are clearly visible without any strain.
3. The telescope should be focused for infinity and the collimator should be adjusted to give a parallel beam of light.
4. The slit should be narrow.
5. The prism should be placed with its refracting edge at the centre of the prism table when finding the angle by rotating the telescopes.
6. The prism table should be leveled so that reflected image from both the reflecting faces lies systematically with respect to the horizontal cross-wires.

References:

1. B.Sc. Practical Physics by C. L. Arora S.Chand Publication, 20th edition (2015).

Weblinks: http://vlab.amrita.edu/?sub=1&brch=281

Worksheet of the student:

Date of Performance: **Registration number:**

Experiment: To determine the dispersive power and Cauchy constants of the material of a given prism using mercury light.

Observations: Vernier constant=

Wavelength of yellow light = Wavelength of violet light =

Wavelength of blue light= Wavelength of green light=

Angle of Prism:

<table>
<tr><th rowspan="3">S.No.</th><th rowspan="3">Vernier</th><th colspan="6">Position of telescope for reflection from</th><th>Difference
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<tr><td>3.</td><td>V_1
V_2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table for Angle of minimum deviation:

S.No.	Vernier	Telescope reading						Difference (a'–b' =δm)	Mean value of δm
		Position of minimum deviation (a')			Direct image (b')				
		M.S.	V.S.	T	M.S.	V.S.	T		
1.	V1 V2								
2.	V1 V2								
3.	V1 V2								

Refractive index for violet color $n_{V} =$

Refractive index for blue color $n_{B} =$

Refractive index for green color $n_{G} =$

Dispersive power (i) $\omega=(n_B-n_G)/n-1$

(ii) $\omega=(n_V-n_G)/n-1$

Color	$1/\lambda^2$	n

Value of A:

Value of B:

Graph: Plot graph taking $1/\lambda^2$ along X-axis and n along Y-axis. The graph is a straight line. Intercept of the graph in Y-axis is the Cauchy constant A and slope of the graph is B.

Learning Outcomes (what I have learnt):

To be filled in by faculty:

S.No.	Parameter	Marks obtained	Max marks
1	Understanding of the student about the procedure/apparatus		20
2	Observations and analysis including learning Outcomes		20
3	Completion of experiment , discipline and Cleanliness		10
	Signature of faculty	Total marks obtained	

Experiment 4:

To determine the dispersive power and resolving power of the plane diffraction grating.

Equipment Required: A spectrometer, a sodium lamp, an eye piece, a diffraction grating with clamping arrangement, a variable rectangular slit provided with micrometer arrangement to measure its width.

Learning Objectives:

To learn how the resolving power is changing in plane grating

To acquaint oneself with the setting and alignment of spectrometer

Theory: resolving power of a diffraction grating is defined as its ability to show the two neighboring lines in a spectrum as separate. It is measured as $\lambda/d\lambda$ where $d\lambda$ is the smallest difference in wavelength of the two lines. According to Rayleigh's criterion the two lines of wavelengths λ and $\lambda+d\lambda$ are said to be resolved in a certain order grating spectrum if the principal maximum of one falls on the first secondary minimum of the other. For the nth order principal maximum for a wavelength λ for normal incidence and a grating element (a+b) , we have

$$\mathbf{(a+b)\sin\theta = n\lambda}$$

If the angle of diffraction θ changes by a small amount $d\theta$ corresponding to a change in wavelength $d\lambda$, then differentiating , we have

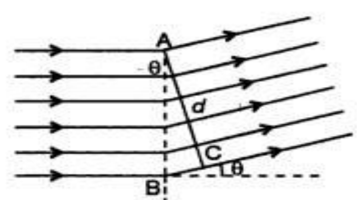


Fig.3. Bending of light in diffraction

Plane diffraction grating

$$(a+b)\cos\theta . d\theta = n d\lambda$$

Or $d\theta = nd\lambda/(a+b)\cos\theta$ ………..(1)

if light after diffraction enters the objective of a telescope of diameter d, then the smallest angel $d\theta'$ that it can resove for a wavelength λ is given by

$d\theta' = \lambda/d$

thus the principal maxima in a certain order spectrum corresponding to wavelength λ and $(\lambda+d\lambda)$ having angular separation of $d\theta$ will be just resolved by the telescope, if

$d\theta = d\theta'$

or $nd\lambda/(a+b)\cos\theta = \lambda/d$ ………………(2)

resolving power $(\lambda/d\lambda) = n.d/(a+b)\cos\theta$

if the total width of the grating AB has N lines then $AB = N(a+b)$

Now diameter of the objective of the telescope $AC = D = AB\cos\theta = N(a+b)\cos\theta$

Hence from equation (2), we have

Resolving power $(\lambda/d\lambda) = [nN(a+b)\cos\theta]/(a+b)\cos\theta = nN$,
N being the number of rulings per inch of the grating

Dispersive power (Angular dispersion of the grating) $= nN/(2.54\cos\theta)$

In practice it is difficult to find two spectral lines in a grating spectrum which just fulfill this requirement. Moreover it is essential that the entire grating surface should be illuminated uniformly hence to find the resolving power of the grating, the smallest portion of the grating is found out with an adjustable slit which just resolves the two neighboring lines of the wavelength λ and $(\lambda+d\lambda)$ and then the maximum resolving power of the grating is calculated.

Procedure: 1. Set the spectrometer , mount the grating on the turn table and after doing the optical leveling set the grating normal to the incident light.

For normal setting of grating:

Setting the grating normal to the incident sodium light. Place the telescope in line with the collimator so that the vertical cross-wire falls exactly in the centre of the image of the slit. Note the scale reading. Add 90 to the reading and place the telescope at this reading to set it perpendicular to the axis of the collimator. Clamp it in this position. Rotate the grating table till the plane face of the grating is facing both the collimator and the telescope. Look through the telescope and turn the table very slowly till the centre of the slit falls exactly on the vertical cross-wire. In this position the plane of the grating is inclined at an angle of 45^0 to the incident light. Note the reading. Turn the table through 45^0 from this position so that the plane of the grating is normal to the incident light with its plane face towards the collimator. The grating is now set normal to the incident light with its rules surface away from the collimator. Clamp the table in this position. Take reading on both the venires.

2. Illuminate the slit with sodium light and turn the telescope from the normal position to one side to obtain the first order spectrum in which the two D lines of sodium of wavelengths $5890A^o$ and $5896A^o$ are seen. Clamp the telescope so that the vertical cross wire coincides with the middle of the two lines. Find the angle of diffraction θ1 in the first order.

3. Mount an adjustable slit on to the objective of the telescope and adjust its width. The two lines will be found to approach each other. Continue reducing the width of the slit to reduce the part of grating producing the spectrum, until the two lines just cease to be resolved.

4. To measure the width of the slit note the reading on the micrometer scale. Carefully remove the slit and turn the screw slowly till the slit just closes and no light is visible. Note the reading of the micrometer screw slowly till the slit just closes and hence the portion of the grating which just resolves the tow wavelengths of the D lines of Na in the first order. Make several trials and repeat the experiment for the first order on the other side of the direct image.

5. Measure the full width of the grating and the diameter of the objectives of the collimator as

Observations:

Vernier costant of the spectrometer =

Number of lines on the grating (per inch) N =

Grating constant (a+b) = 2.54/N

Wavelength of D_1 line of sodium = $5896x\ 10^{-10}$ m

Wavelength of D1 line of sodium = 5890x 10^{-10} m

Mean wavelength λ = 5893×10^{-10} m

Difference in wavelength dλ = 6×10^{-10} m

Least count of the micrometer screw = cm

Full width of the grating = cm

Diameter of the collimator lens = cm

Diameter of the objective of telescope = cm

(a) Reading of the angle of diffraction

S. No.	**Order of spectrum**	**Vernier**	**Telescope reading**			**Angle of diffraction**		
			Left	**Direct**	**Right**	**Left**	**Right**	**Mean (θ)**
1	1st order							
2								
1	2nd order							
2								

(b) Reading of width of slit when lines are just resolved

			Reading of micrometer			Mean width (d)
			Lines just resolved (p)	Slit closed (q)	Width of slit p-q	
1st order	Left	(i) (ii) (iii)				
	Right	(i) (ii) (iii)				
2nd order	Left	(i) (ii) (iii)				
	Right	(i) (ii) (iii)				

Scope of Result:

Vernier costant of the spectrometer =

Number of lines on the grating (per inch) N =

Grating constant (a+b) = 2.54/N

Least count of the micrometer screw	=	cm
Full width of the grating	=	cm
Diameter of the collimator lens	=	cm
Diameter of the objective of telescope	=	cm

Calculations:

First order

Width of the grating used AB = $d/\cos\theta_1$ =

Number of lines in width AB of grating = AB/(a+b) = N'
Resolving power r = nN' =

Theoretical resolving power = nN = Actual
resolving power $\lambda/d\lambda$ = 5893/6 =982

Dispersive power (Angular dispersion of the grating) = $nN/(2.54\cos\theta)$

Second order : Make similar calculations taking the corresponding value of θ and d.

Cautions :

1. The width of the slit should be adjusted so that the wo lines are just resolved.

2. The screw should be turned only in one direction while adjusting the width of the slit , to avoid backlash error.
3. The final reading of the micrometer should be taken when the two jaws of the slit are just in contact.
4. The adjustment for the width of the slit should be done a number of times and the mean thus obtained should be used in calculations.

References:

1. B.Sc. Practical Physics by C. L. Arora S. Chand Publication, 20 th edition (2015).

Weblinkshttp: http://www.montefiore.ulg.ac.be/services/acous/STSI/file/IAVT_2014_Chap2.pdf

Worksheet of the student:

Date of Performance: **Registration number:**

Experiment: To determine the dispersive power and resolving power of the plane diffraction grating.

Observations:

Vernier costant of the spectrometer =

Number of lines on the grating (per inch) N =

Grating constant (a+b) = 2.54/N

Wavelength of D1 line of sodium = 5896x 10^{-10} m

Wavelength of D2 line of sodium = 5890x 10^{-10} m

Mean wavelength λ = 5893x 10^{-10} m

Difference wavelength indλ = 6x 10^{-10} m

Least count of the micrometer screw = cm

Full width of the grating = cm

Diameter of the collimator lens = cm

Diameter of the objective of telescope = cm

Table 1

To set the unruled surface of the grating for normal incidence

<table>
<tr><th colspan="3">Direct reading of the telescope without grating</th><th rowspan="2">Telescope is rotated through 90^o and set at angle</th><th colspan="3">Reading of the prism table when the angle of indicence is 45^o</th><th rowspan="2">Prism table is rotated through 45^{o}or 135^o and set at angle</th></tr>
<tr><th>M.S. (M)</th><th>V.S. (V)</th><th>Total (T=M+V)</th><th>M.S. (M)</th><th>V.S. (V)</th><th>Total (T=M+V)</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

(a) Reading of the angle of diffraction

<table>
<tr><th rowspan="2">S. No.</th><th rowspan="2">Order of spectrum</th><th rowspan="2">Vernier</th><th colspan="3">Telescope reading</th><th colspan="3">Angle of diffraction</th></tr>
<tr><th>Left</th><th>Direct</th><th>Right</th><th>Left</th><th>Right</th><th>Mean (θ)</th></tr>
<tr><td>1</td><td rowspan="2">1st order</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1</td><td rowspan="2">2nd order</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

(b) Reading of width of slit when lines are just resolved

			Reading of micrometer			Mean width (d)
			Lines just resolved (p)	Slit closed (q)	Width of slit p-q	
1st order	Left	(i) (ii) (iii)				
	Right	(i) (ii) (iii)				
2nd order	Left	(i) (ii) (iii)				
	Right	(i) (ii) (iii)				

Calculations:

First order

Width of the grating used AB = $d/\cos\theta_1$ =

Number of lines in width AB of grating = AB/(a+b) = N'
Resolving power r = nN' =

Theoretical resolving power = nN = Actual resolving power $\lambda/d\lambda$ = 5893/6 =982

Dispersive power (Angular dispersion of the grating) = $nN/(2.54\cos\theta)$

Second order : Make similar calculations taking the corresponding value of θ and d.

Learning Outcomes (what I have learnt):

S.No.	Parameter	Marks obtained	Max marks
1	Understanding of the student about the procedure/apparatus		20
2	Observations and analysis including learning Outcomes		20
3	Completion of experiment , discipline and Cleanliness		10
	Signature of faculty	Total marks obtained	

Experiment 5:

To determine the wavelength of sodium light using Newton's ring set or Fresnel biprism set.

Equipment Required: Newton ring apparatus, sodium lamp, eye-piece, spherometer, traveling microscope etc.

Learning Objectives:

1. Formation of interference pattern (~1-2 mm) on the lens-glass plate assembly.
2. Measure the diameter of bright/dark fringes using micrometer attached in the traveling microscope.
2. Calculate the wavelength of light.

Theory :

Circular interference fringes produced by enclosing a thin air film of varying thickness between the surface of a convex lens of large radius of curvature and a plane glass plate are known as Newton's rings. The wavelength of monochromatic light which produces these rings is given by

$$\lambda = (D_n^2 - D_m^2)/4(n-m)R$$

where R is the radius of curvature of the surface of the lens in contact with the glass plate and Dn and Dm the diameters of the n^{th} and m^{th} dark or bright fringes.

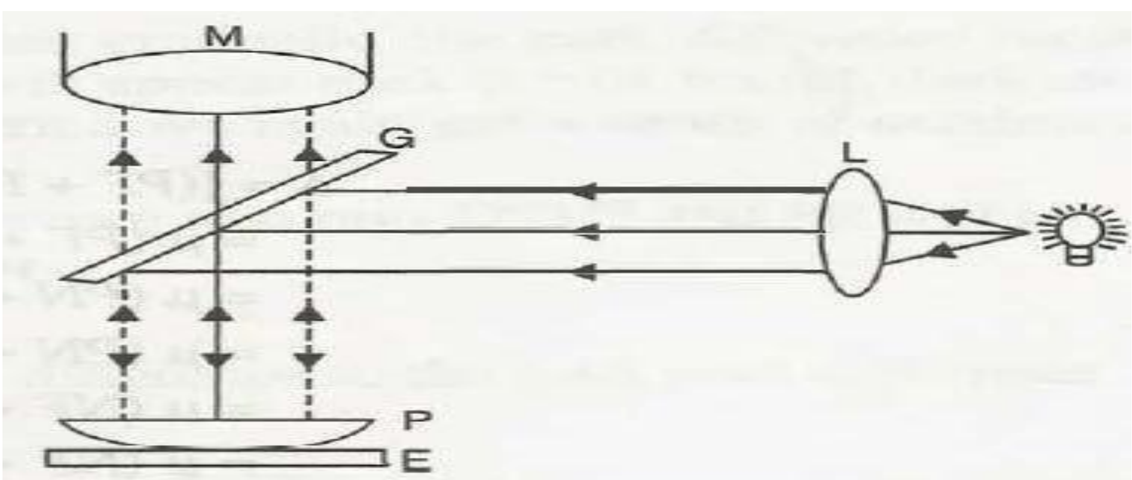


Fig.4. Ray diagram of experimental setup of Newton's ring experiment.

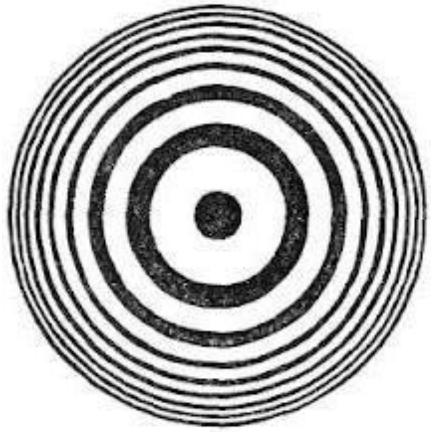


Fig. 5. Newoton’s rings with dark center.

Outline of Procedure:

1. Clean the glass and lens surfaces. Place the curved side of the lens on the glass plate. Place this assembly in the frame supplied and slightly tighten the screws provided in the frame.

2. Hold the lens- glass plate assembly horizontal while standing below any light source and observe the formation of very small (~1-2 mm) interference pattern formation. Try to bring the pattern at the center of the glass plate-lens assembly by rotating the screws of the frame.

3. Place the lens-glass plate assembly in the Newton’s ring apparatus so that the interference pattern is placed just below the microscope. Fringes are then focused by using microscope. The central fringe should be dark and to obtain the maximum contrast, move the entire apparatus in front of the lamp till the complete pattern is observed.

4. Use the micrometer attached in the apparatus to move the microscope in the horizontal direction and check that whether more than 25 dark fringes on either sides from the center can be marked over cross-wire.

5. Counting carefully from the center move out till the cross-wire reaches 21st dark fringe or 22nd bright fringe. Now rotate the micrometer to note the position of 19th dark fringe or 20th bright fringe. Repeat this for 18th, 16th, 14th etc. bright fringe or otherwise for dark fringes. It is important to use micrometer in one direction for taking micrometer reading, to avoid any backlash error.

6. Remove the plano-convex lens and plate from the frame and lay the lens with the flat surface pointing downwards. Raise the central screw of the spherometer and place the spherometer on the convex surface of the lens. Rotate the screw till the tip just touch

the lens surface and note the reading. Now without disturbing the reading lift the spherometer and place it on the glass plate. Again lower the screw till it touches the plate and note the new reading. Repeat this 2-3 times to obtain the mean value of the difference in the two reading.

7. In order to measure the distance between any two legs of the spherometer, press the spherometer down on the plain paper, so that the three legs make mark on it and the distance between the two legs can be calculated.

Observations:

Vernier constant = …………………………cm

Ring No.	Microscope reading						D	Microscope reading						D	Mean D	
	Left			Right				Right			Left				cm	m
	MS	VS	T	MS	VS	T		MS	VS	T	MS	VS	T			
20																
16																
12																
8																
4																

Pitch of the spherometer screw = ……………… mm Number of divisions on circular scale = ……….

Least count = ………………… mm

Distance between the two legs = 1……………….= 2……………….. = 3……………… Mean l = ……………….cm

No.	Spherometer reading on		h
	Convex surface	Plane surface	
1			
2			
3			

Mean h = ……………….cm

Radius of curvature of convex surface R = $(l^2/6h) + (h/2)$ = …………cm = …………….m

Wavelength $\lambda = (D_n^{\,2} - D_m^{\,2})/4(n-m)R$

Find the value of λ By taking the various combinations of n and m as for example, (20,12),

(16,8),(12,4). λ = …………..1. ………………………2. ……………………………..3.

mean wavelength of sodium light λ= ……………………… m

Scope of results:

Least count of micrometer on microscope =

Pitch (least count of main scale) of spherometer =

Least count of vernier (circular) scale of spherometer =

The wavelength of the light comes out to be = Ǻ

Cautions:

1. Make sure that the glass plate and lens are properly cleaned and free from any greasy material.
2. Micrometer reading should be taken in one direction to avoid any backlash error.

3. Spherometer should be used only by touch-rotate method or by shadow method only.
4. The contrast of light used for the illumination of the interferences pattern should be used accurately.

References:

1. B.Sc. Practical Physics by C. L. Arora S.Chand Publication, 20 th edition(2015).

Weblinks:

http://vlab.amrita.edu/?sub=1&brch=281

Worksheet of the student:

Date of Performance: **Registration number:**

Experiment: To determine the wavelength of sodium light using Newton’s ring set or Fresnel biprism set..

Observations:

Vernier constant of microscope =

Observations:

Vernier constant = ……………………….cm

Ring No.	Microscope reading						Dia-meter	Microscope reading						Dia-meter	Mean diameter	
	Left			Right				Right			Left				cm	m
	MS	VS	T	MS	VS	T		MS	VS	T	MS	VS	T			
20																
16																
12																
8																
4																

Pitch of the spherometer screw = ………………mm

Number of divisions on circular scale = ……….

Least count =………………… mm

Distance between the two legs = 1……………….= 2……………….. = 3................

Mean l = ……………….cm

No.	Spherometer reading on		h
	Convex surface	Plane surface	
1			
2			
3			

Mean h = ……………….cm

Radius of curvature of convex surface R = $(l^2/6h) + (h/2)$

= ………..cm = …………….m

Wavelength $\lambda = (D_n{}^2 - D_m{}^2)/4(n-m)R$

by taking the various combinations of n and m as for example, (20,12), (16,8),(12,4).

$\lambda 1$ = ……………………

$\lambda 2$ = ………………………

$\lambda 3$ = ...

mean wavelength of sodium light λ= ……………………… m

Scope of results:

Least count of micrometer on microscope =

Pitch (least count of main scale) of spherometer =

Least count of vernier (circular) scale of spherometer =

The wavelength of the light comes out to be = λ

Learning Outcomes (what I have learnt):

To be filled in by faculty:

S.No.	Parameter	Marks obtained	Max marks
1	Understanding of the student about the procedure/apparatus		20
2	Observations and analysis including learning outcomes		20
3	Completion of experiment , discipline and cleanliness		10
	Signature of faculty	Total marks obtained	

Experiment 6:

To determine the wavelength of laser light using Michelson interferometer.

Equipment Required: A Michelson interferometer, He-Ne Laser, collimating lens, Screen, magnifying lens.

Learning objectives:

- To determine the wavelength of monochromatic light (He-Ne Laser).
- To study the phenomena of interference of light.

Theory :

The interferometer is adjusted to obtain circular fringes in the field of view of the telescope. the mirror M1 and M2 are equidistant from the glass plate G1 , the field of view will be perfectly dark. The position of the mirror M1 is adjusted till a particular bright fringe appears in the field of view of the telescope with its centre coincide with the cross-wire. When the mirror M1 is moved backward or forward , each fringe in the focal plane of the telescope is displaced parallel to half. When the mirror M1 is moved through a distance $\lambda/2$, the path difference changes by λ and the position of a particular bright fringe is taken by the next bright fringe. If n is the number of fringes that more across the field of view when the mirror is displaced through a distance L then ..

$n(\lambda/2) = L$ wavelength

$\lambda = (2L/n)$

Diagram:

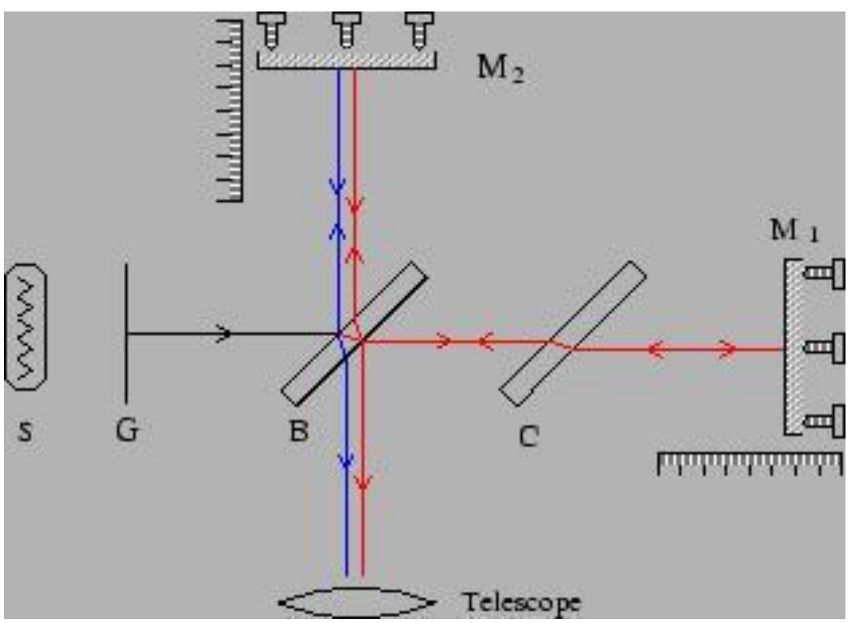


Fig.6.Ray diagram of Michelson Interferometer to measuring wavelength of He-Ne LASER light.

Outline of the procedure:

1. First put the interferometer on a rigid table and level the instrument with three leveling screws provided at the base.
2. Put the Helium-Neon laser, about 50 to 60 cm away from the instrument such that its beam passes through the pin hole fitted in front of the instrument. Make sure that the laser beam falls at the middle of the Mirrors M1 and M2 after getting split from beam splitter plate G1.
3. The beam after the reflections will make four spots on the wall or on a screen. One pair is formed due to partial reflections at the unsilvered surface of G1 and reflections at M1 and M2 respectively. While the other pair is formed due to partial reflections at M1 and M2 respectively. Out of these one pair is brighter than the other.
4. Now mirrors M1 and M2 are tilted carefully such that the two brighter images coincide.
5. Now the instrument is aligned and the fringes are formed on the wall or screen.
6. The mirror M2 is kept fixed and the mirror M1 is moved with the help of the fine movement screw and the number of fringes that cross the field of view is counted.

Scope of the results: The student will be able to find the wavelength of He-Ne laser with the help of interference phenomena and will come to know about the role of path difference in interference of light.

Observations:

Least reading on the main (linear scale) = ………………… mm = ……………………… cm Least count of rough micrometer screw (R.M.S.) = ………...mm = ……………………… cm Least count of fine micrometer screw (F.M.S.)= ……… ....mm=………...……….…… cm

S.No.	No. of fringes shifted	Position of mirror M_1				Difference for100 fringes
1	0	Main scale reading (cm)	R.M.S. reading (cm)	F.M.S. reading (cm)	Total cm	
2	25					
3	50					
4	75					
5	100					
6	125					
7	150					
8	175					
9	200					
10	225					

Mean difference for 100 fringes L= ………………………….cm

Wavelength of light λ = (2l/n) = …………………cm = ………………………… A^{o}

Parameter and Plots:

Take any value of n≥20 and note down the value of distance (d) through which the mirror is moved and apply theory of interference of light to find wavelength of light. [Report data in tabular or systematic manner]

Caution:

1. Do not use the telescope.
2. Do not see directly into the laser beam.
3. Make sure that the distances of mirror M1 and M2 are almost equal from beam splitter G1.
4. Make sure that centre of the circular fringes are properly adjusted.

References:

1. B.Sc. Practical Physics by C. L. Arora S.Chand Publication, 20 th edition(2015).

Weblinks:

http://vlab.amrita.edu/?sub=1&brch=281

Worksheet of the student:

Date of Performance: **Registration number:**

Experiment : **To determine the wavelength of laser light using Michelson interferometer.**

Observations:

Least reading on the main (linear scale) =………………… mm =…………… cm

Least count of rough micrometer screw (R.M.S.)= …...........mm=……....…… cm

Least count of fine micrometer screw (F.M.S.) = ………..mm=…………… cm

S.No.	No. of fringes shifted	Position of mirror M_1				Difference for100 fringes
1	0	M. S. scale reading (cm)	R.M.S. reading (cm)	F.M.S. reading (cm)	Total cm	
2	25					
3	50					
4	75					
5	100					
6	125					
7	150					
8	175					
9	200					
10	225					

Mean difference for 100 fringes =……………. L=…………….cm

Wavelengthoflightλ=(2l/n)=…………………cm=……………………………… A^o

Learning Outcomes (what I have learnt):

To be filled in by faculty:

S.No.	Parameter	Marks obtained	Max marks
1	Understanding of the student about the procedure/apparatus		20
2	Observations and analysis including learning outcomes		20
3	Completion of experiment , discipline and cleanliness		10

Experiment 7:

To determine the angle of prism of the given material using hollow prism and spectrometer.

Equipment required:

a) Mercury lamp (as source of white light),
b) Spectrometer
c) Hollow Prism
d) Spirit level
e) Magnifying Lens
f) Torch

Leaning Objectives:

1. To study the spectrum of white light using Hollow prism.
2. To find out angle of prism of given material.
3. To acquaint oneself with the setting and alignment of spectrometer.

Outline of Procedure:

(1) First the telescope has to be focused distant objects i.e. infinity and this has to be maintained until the experiment is over, so as not to refocus again. Then, the cross-wires should be focussed by moving the eye-piece of the telescope.

(2) Adjust the collimator such that the image seen in the telescope is sharp of the slit without the prism.

(3) Measuring the Angle of Prism A: Place the hollow prism on the Prism Table and lock the prism table in the position so the incident beam falls on one of the edges of the hollow prism. Now, move the telescope and locate the images (for a particular color) of the slit and note down the angles. The difference between both the angles is 2A. Hence, half of the difference will give us A.

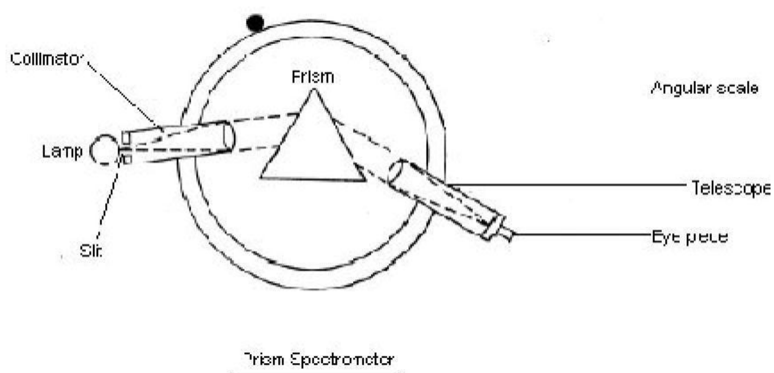


Fig.7. Setup of collimator and telescope.

(4) Remove the hollow prism and turn the telescope so that the direct light is received and the image of slit falls on the vertical cross wire. Note the reading of both the vernier scales.

(5) After that repeat the procedure for other colors of light.

Observation table: **Determination of angle of Prism**

<table>
<tr><td rowspan="3">Color of light</td><td rowspan="3">Vernier</td><td colspan="6">Position of telescope for reflection from</td><td>Difference

(a~b =2A)</td><td rowspan="3">Mean of

value
2A</td><td rowspan="3">A</td></tr>
<tr><td colspan="3">Position of Ist face

(a)</td><td colspan="3">Position of IInd face

(b)</td><td rowspan="2"></td></tr>
<tr><td>M.S.</td><td>V.S.</td><td>Total</td><td>M.S.</td><td>V.S.</td><td>Total</td></tr>
<tr><td></td><td>V_1
V_2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>V_1
V_2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>V_1
V_2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Precautions:

1. It must be ensured that the light rays coming out of collimator are parallel. Hence, the collimator must be focused properly before the experiment.

2. The plane on which the prism rests must be horizontal

3. The slit must be as thin as possible in order to avoid diffraction effects.

Suggested Literature: 1. B.Sc. Practical Physics by Arora, C.L., S Chand & Company Ltd., New Delhi, 19th Edition (2010).

2. An advanced course in practical physics D. Chattopadhyay and P.C. Rakshit, New central book agency(P) Ltd. Kolkota 8th Edition, (2007)

Weblinks: http://amrita.vlab.co.in/? sub=l&brch=189&sim=851&cnt=1

Worksheet for the student

Date of performance **Registration number**

Aim: **To determine the angle of prism of the given material using hollow prism and spectrometer.**

Observation table: **Determination angle of Prism**

S.No.	Vernier	Position of telescope for reflection from						Difference (a~b =2A)	Mean of value 2A	A
		Position of I^st face (a)			Position of II^nd face (b)					
		M.S.	V.S.	Total	M.S.	V.S.	Total			
1.	V_1 V_2									
2.	V_1 V_2									
3.	V_1 V_2									

Calculations:

Learning outcomes:

To be filled by the faculty

S.No.	Parameter	Marks Obtained	Maximum Marks
1	Understanding of the student about the procedure/apparatus.		20
2	Observations and analysis including learning outcomes		20
3	Completion of experiment, discipline and cleanliness		10
	Signature of faculty	**Total marks obtained**	

Experiment 8:

To study the characteristics of loudspeaker and microphone.

Equipment required: Moving coil microphone, Audio tone generator, high frequency milli voltmeter, Cone type audio loudspeaker, audio signal generator, sound dB meter.

Learning objectives:

1. To study the frequency response of a loudspeaker and microphone

2. To find the bandwidth of a loudspeaker and microphone.

Theory:

(I) For Microphone:

A moving coil microphone works on the principle of electromagnetic induction (Faradays law). The sound pressure variations move a coil in a magnetic field. An emf is induced in the coil of the microphone.

A microphone should have linear response in the complete audio range from 16 Hz to 20 kHz. This is necessary to ensure that there is no distortion in the output. An ideal microphone should have flat frequency response (±1dB) of the output at 1000 Hz. This is shown in the figure.

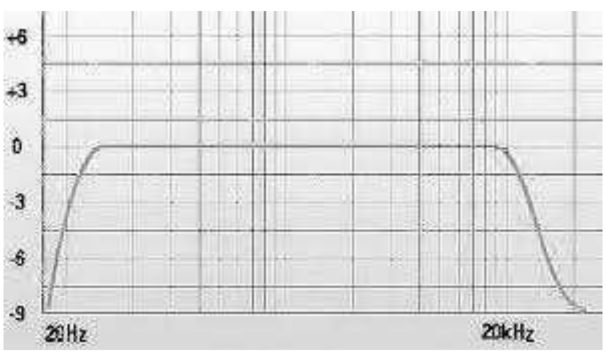


Fig.8. Frequency response of an ideal microphone.

(II) For Loudspeaker:

A loudspeaker should give linear (or flat) response over the entire frequency range. An ideal loudspeaker's frequency response is ±1dB. However due to a number of moving parts, high frequencies tend to get attenuated. Moreover the low frequencies are also attenuated. For a good loudspeaker, the attenuations should be as small as possible. The frequency response is similar to that of a microphone.

Outline of the procedure:

(I) For Microphone:

Keeping the microphone diaphragm at a distance of 20 cm from the output of the audio tone generator, set the audio tone generator frequency at 1000 Hz and this intensity at a suitable value so that the voltage output of
microphone is measured by the milli voltmeter. Note down the voltmeter reading. Repeat for 8-10 other frequencies in the range of 16 Hz to 20 kHz. Keep the intensity level of audio tone generator and distance between audio tone generator and microphone at a fixed value. From the milli voltmeter readings, find the frequency response in dB as below:

Response in dB = $20 \log_{10} (V_2/V_1)$

Since the reference frequency is 1000 Hz, V_2 denotes reading of milli voltmeter for reference audio tone and V_1 is the reading of milli voltmeter for the frequency at which response is required.

(ii) For Loudspeakers:

Set the audio signal generator frequency at 1000 Hz and output voltage at such a value so that the dB meter gives a suitable reading. Note down the reading of dB meter. Repeat for 8-10 other frequencies of audio range. Two of these frequencies should be less than 100 Hz and other another two should be 5 kHz. Note down the dB meter readings and plot the frequency response.

Required Results:

1. The bandwidth of the given microphone is …….

2. The bandwidth of the given loudspeaker is ………

Parameters:

1. The output voltage is noted from milli voltmeter.

2. The frequency response is calculated from the output of milli voltmeter.

3. The response is noted from dB meter in case of loudspeaker.

4. The bandwidth is calculated from graph.

Relationships:

Response in dB = 20 $\log_{10}(V_2/V_1)$

Where V_2 denotes reading of milli voltmeter for reference audio tone and V_1 is the reading of milli voltmeter for the frequency at which response is required.

Cautions:

1. All readings must be taken within audible range.
2. Be sure to turn off the microphone when it is not in use. The battery runs down quickly.

2. All electronic devices must be handled properly and with care.

3. The distance between loudspeakers and dB meter must be kept 1cm.

4. The distance between microphone diaphragm and audio tone generator should be kept 20cm.

Suggested for further reading:

1. http://www.montefiore.ulg.ac.be/services/acous/STSI/file/IAVT_2014_Chap2.pdf
2. Consumer electronics by Deepak Arora Eagle Publication, 4th ed. (2012).

Worksheet of the student

Date of Performance   Registration Number:

Aim: To study the characteristics of loudspeaker and microphone.

Observations:

(I) For microphone:

Distance between microphone diaphragm and output of a audio tone generator = 20 cm
Reference frequency = 1000 Hz

Milli voltmeter reading for reference audio tone (V_2) =

S. No.	**Frequency**	**Reading of milli voltmeter**	**Response in dB**

(II) For loudspeakers

Distance between loudspeakers and sound dB meter = 1 m

Reference frequency = 1000 Hz

dB meter reading =

S. No.	Frequency	Sound dB meter reading

Calculations:

Result and discussions:

Error Analysis:

Learning Outcomes (what I have learnt):

To be filled in by Faculty

S. No.	**Parameter**	**Marks obtained**	**Max. Marks**
1	Understanding of the student about the procedure/apparatus.		**20**
2	Observations and analysis including learning outcomes		**20**
3	Completion of experiment, Discipline and Cleanliness		**10**
	Signature of Faculty	**Total marks obtained**	

Experiment 9: To determine the frequency of an electrically maintained tuning fork by Meldes experiment.

Equipment Required: Electrically maintained tuning fork, Clamp stand, pan, weight box, rheostat, key, connecting wire, meter rod.

Material Required: Thread

Learning Objectives: To understand the formation of standing waves in transverse and longitudinal waves and also study laws of string.

Formulae:-
Frequency of the tuning fork in the transverse mode of vibration

$$\eta = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

Where ' l ' is the length of each loop. 'T' is the Tension applied as $T = (m_1+m_2)\, g$
where 'm_1' is the mass of the pan and 'm_2' is the load added to the pan and 'g' is acceleration due to gravity in cm/sec^2 . 'm' is the linear density of the thread.
where 'M' is mass of the thread and 'L' is the total length of the thread.

Frequency of the tuning fork in the longitudinal mode of vibration

$$\eta = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

Where ' l ' is the length of each loop. 'T' is the Tension applied as $T = (m_1+m_2)g$
where 'm_1' is the mass of the pan and 'm_2' is the load added to the pan and 'g' is acceleration due to gravity in cm/sec^2,'m' is the linear density of the thread and 'M' is mass of the thread and 'L' is the total length of the thread.

Theory

Speed of waves in a stretched string*:* A string means a wire or a fiber which has a uniform diameter and is perfectly flexible. The speed of a wave in a flexible stretched string depends upon the tension in the string and mass per unit length of the string.

$$v = \sqrt{\frac{T}{m}}$$

Where m= M/L as M is the mass of the string and L is the total length of the string.

Vibrations of a stretched string: When the wire is clamped to a rigid support, the transverse progressive waves travel towards each end of the wire. By the superposition of incident and reflected waves, transverse stationary waves are set up in the wire. Since ends of the wire are clamped, there is node N at each end and anti-node A in the middle as shown in Fig: 1.

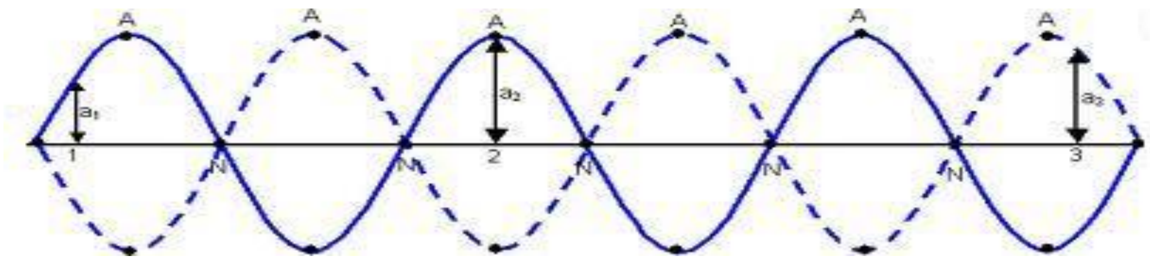


Fig:8. Pattern of nodes and antinodes in vibrating string.

The points of the medium which have no displacements called ***nodes*** and there are some points which vibrate with maximum amplitude called ***antinodes.***

The distance between two consecutive nodes is λ/2, (λ - wavelength). Because l is half a wavelength in the equations, $l = \lambda/2$, η is frequency of vibration of wire

$$\eta = \frac{v}{2l}$$

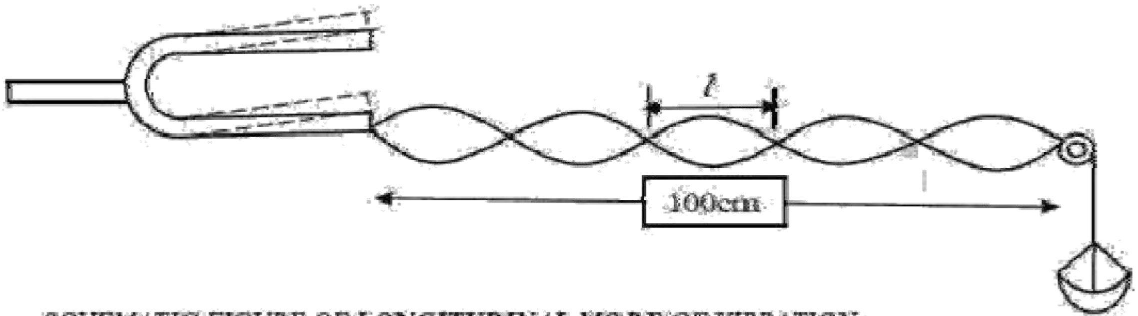
Substituting the value of ' v ' in equation

$$\eta = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

Outline of the Procedure:

- A string can be set into vibrations by means of an electrically maintained tuning fork, thereby producing stationary waves due to reflection of waves at the pulley. The standing wave is formed between the pulley and the end of the string.

SCHEMATIC FIGURE OF **TRANSVERSE MODE** OF VIBRATION:



SCHEMATIC FIGURE OF **LONGITUDINAL MODE** OF VIBRATION:

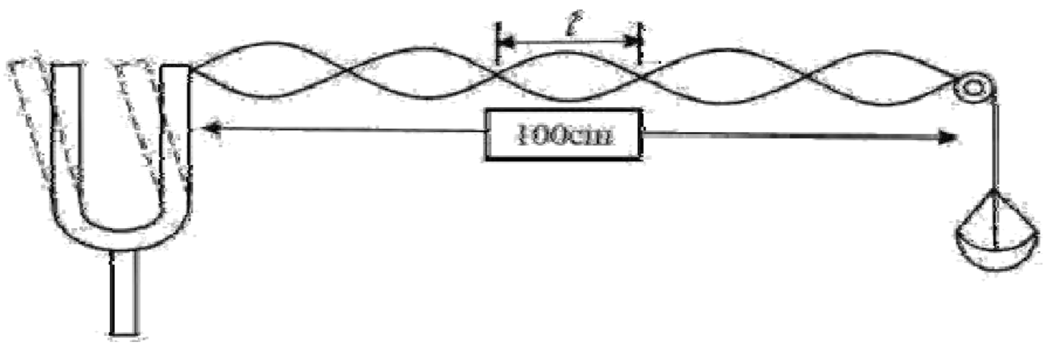


Fig.10. Different modes of vibration

- Find the weight of pan P and arrange the apparatus as shown in figure. Place a load of 4 To 5 gm in the pan attached to the end of the string passing over the pulley. Excite the tuning fork by switching on the power supply. Adjust the position of the pulley so that the string is set into resonant vibrations and well defined loops are obtained. If necessary, adjust the tensions by adding weights in the pan slowly and gradually. For finer adjustment, add milligram weight so that nodes are reduced to points.
- Measure the length of n loops formed in the middle part of the string. If ‘L’ is the distance in which n loops are formed, then distance between two consecutive nodes is L/n. Note down the weight placed in the pan and calculate the tension T.

  T= (wt. in the pan + wt. of pan) g.

- Repeat the experiment twine by changing the weight in the pan in steps of one gram and altering the position of the pulley each time to get well defined loops. Measure one meter length of the thread and find its mass to find the value of m, the mass per unit length.

Required Results: Find the frequency of tuning fork in transverse mode and also in longitudinal mode. Observe and discuss the difference between these arrangements.

Cautions:

The thread should be uniform and inextensible. Well defined loops should be obtained by adjusting the tension with milligram weights. The loops in the central part of the thread should be counted for measurement. The nodes at the tip of the prong and at the pulley should be neglected. Frictions in the pulley should be least possible.

Book suggested

1. B.Sc Practical Physics by C.L. Arora S.Chand Publication,19th edition(2010)

2. B.Sc Practical Physics by Harman Singh and Dr. P.S. Hemne, S.Chand Publication,1st edition(2011)

Websites: http://vlab.amrita.edu/?sub=1&brch=201&sim=882&cnt=1

Worksheet of the student

Date of Performance Registration Number:

Aim: : To determine the frequency of an electrically maintained tuning fork by Meldes experiment.

Observations:

Mass of Pan =

Mass of Thread =

Length of Thread =

Mass per unit Length of Thread (m) =

Mode of vibration	**Sr. No.**	**No. Of loops (p)**	**Distance between extreme nodes (L)**	**Length of each loop L/p=l**	**Mass in the pan W**	**Tension T= (W+w)g**	**Frequency n**
Transverse mode (A)	**1**						
	2						
	3						
	4						
Longitudinal mode (B)	**1**						
	2						
	3						
	4						

Calculations:

Result and Discussion:

Error Analysis

Learning Outcomes (what I have learnt):

To be filled in by Faculty

S. No.	**Parameter**	**Marks obtained**	**Max. Marks**
1	Understanding of the student about the procedure/apparatus.		**20**
2	Observations and analysis including learning outcomes		**20**
3	Completion of experiment, Discipline and Cleanliness		**10**
	Signature of Faculty	**Total marks obtained**	

Experiment 10:

To study Lissajous figures.

Apparatus Required: A standard 1000 Hz audio oscillator, a variable frequency audiooscillator and CRO.

Learning Objectives: Students will be able to understand the Lissajous figures and their variation with frequency.

Theory: When a particle is acted upon simultaneously by two simple harmonic motions at right angle to each other the resultant path traced out by the particle is called a Lissajous figure.

Procedure:

1. Connect the standard frequency oscillator (1000 Hz) to the "vertical input" terminals of an oscilloscope. Connect the audio-oscillator whose frequencies are to be compared with the standard oscillator to the 'horizontal input' terminals. Connect together the ground terminals of both the oscillators.
2. Set the C.R.O, to obtain the sharp, bright spot is obtained in the centre of the screen. Turn the sweep control to off position by setting it to ext. input position. Set the audio-oscillator frequency to the marked value of 1000 cycles/-sec.
3. Switch on both the oscillators and adjust the gain controls of the two oscillators as well as the horizontal and vertical gains of the oscilloscope so that a good size ellipse (a 1 : 1 Lissajous figure) appears on the screen. Adjust the necessary controls to stop the ellipse. The actual oscillator frequency is now 1000 Hz. Record the dial reading. (It will, in general, have a slightly different value, say 990 Hz).
4. By switching off the audio oscillator allow the ellipse to change phase and note various shapes that appear on the screen. By phase change and amplitude try to obtain a circular trace.
5. Set the oscillator frequency to the marked value of 500 and adjust slowly so that a 1 : 2 Lissajous figure as shown in Figure 1 is obtained. If possible, adjust the controls to lock the figure. Read the dial reading.
6. Similarly obtain (1 : 3, 3 : 1), (2 : 3, 3 :2) Lissajous figures and so on upto (1 : 5, 5 : 1)

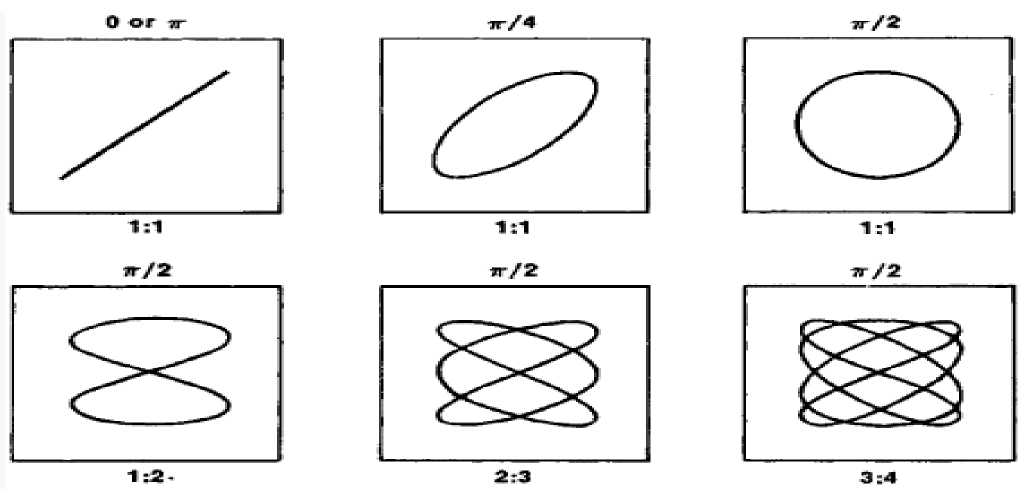


Figure 1. Shape of Lissajous figures for various ratios of periods (1:1, 1:2, and so on) and phase differences

Fig.11. Different pattern of **Lissajous figures.**

Observations : Vertical input standard frequency = 1000 Hz

Horizontal input marked dial freq.	Shape of Figure.	No. of tangency points		Vert Freq./Hor. Freq	Actual Hor. Freq.
		on X-axis	on Y-axis		
990		1	1	2	1000/1=1000
495		2	1	2/1	1000/2= 500
1980		1	2	1/2	1000*2=2000

Precautions :

1. The vertical and the horizontal gain controls of the oscilloscope should be adjusted to obtain a proper size of lissajous figures.
2. The frequency of the audio oscillator should be slowly adjusted so as to lock the pattern.

Books Suggested :

1. B.Sc Practical Physics, by C. L. Arora, S.Chand Publication,19th edition (2010)
2. An Advance course in practical physics by D. Chattopadhyay and P.C. Rakshit, 8th edition (2013).

Weblinks:

http://physics.kenyon.edu/EarlyApparatus/Oscillations_and_Waves/Lissajous_Figures/Lissajous_Figures.html

Worksheet of the student

Date of Performance Registration No.

Aim: To study Lissajous figures.

Observations : Vertical input standard frequency = 1000 Hz

Horizontal input marked dial freq.	Shape of Figure.	No. of tangency points		Vert Freq./Hor. Freq	Actual Hor. Freq.
		on X-axis	on Y-axis		
990		1	1	2	1000/1=1000
495		2	1	2/1	1000/2= 500
1980		1	2	1/2	1000*2=2000

Learning Outcomes (what I have learnt):

To be filled by faculty

S.No.	**Parameters**	**Marks obtained**	**Max Marks**
1	Understanding of the student about the procedure/apparatus		20
2	Observation and analysis including learning outcome		20
3	Completion of experiment, Discipline and Cleanliness		10
	Signature of the faculty	**Total marks obtained**	