Chinmaya Vishwa Vidyapeeth
Deemed to be University

INSTITUTE OF SCIENCE AND TECHNOLOGY

LAB MANUAL

COURSE NAME AND CODE: ENGINEERING PHYSICS LABORATORY/ BSL120B

YEAR AND SEM:

BRANCH:

ACADEMIC YEAR:

Chinmaya Viswa Vidyapeeth
Deemed To be University
Adi Sankara Nilayam, Veliyanad P.O., Arakunnam Via
Ernakulam Dist. Kerala, India - 682313

Course Code	Course Name	L	T	P	C
BSL 120B	**Engineering Physics Lab**	**0**	**0**	**4**	**2**

(***Effective from the academic year 2023- 24***)

Preamble

The course enables the students to gain knowledge with hands on experience on various, instrumental methods of analysis, measurements of physical parameters, and obtaining different unknown parameters using different basic physics experiments

Course Objectives

1. To familiarize the students with the basic concepts of Engineering Physics lab.
2. To train the students on how to handle the instruments.
3. To demonstrate the digital and instrumental methods of analysis.
4. To expose the students in practical aspects of the theoretical concepts.

List of Experiments

1. Determination of acceleration due to gravity using a physical pendulum
2. Determination of refractive index of the material of the prism using spectrometer
   I. Determination of angle of prism
   II. Determination of angle of minimum deviation
3. Determination of wavelengths of prominent lines of the mercury line spectra using a diffraction grating
4. Photoelectric effect; Determination of Planck's constant
5. Determination of Earth's horizontal intensity of magnetic field using circular coil
6. Deflection magnetometer; Determination of the magnetic moment of a bar magnet
7. Determination of the wavelength of sodium vapour lamp using Newton's ring experiment
8. Diffraction grating: to determine the wavelength of laser

References

1. S. Balasubramanian, M.N. Srinivasan "A Textbook of Practical Physics"- S Chand Publishers,2017
2. Physics Laboratory Experiments 7th Edition, Jerry D. Wilson, Cecilia A. Hernández-Hall, Cengage Learning, 2009
3. Laboratory Physics a Students Manual for Colleges, and Scientific Schools (Classic Reprint), Dayton Clarence Miller, Forgotten Books, 2018.
4. A Laboratory Handbook for UG Student, Dr. Ravikumar B. Shinde, Dr. Smita D. Tarale, Sankalp Publication, 2003.
5. Physics Experiments with Arduino and Smartphones (Undergraduate Texts in Physics), Giovanni Organtini, Springer, 2021

Course Outcomes

After completion of this unit the student will be able to

1. Utilize simple pendulum experiment and measure acceleration due to gravity (L3)
2. Assess the intensity of the magnetic field of circular coil carrying current with varying distance (L5)
3. Evaluate the Planck's constant value using LEDs and Plank's constant experimental set up (L5).
4. Analyse the frequency response of an electric circuit (L4)
5. Calculate of the refractive index of the material of a prism using a spectrometer(L4)
6. Determine the wavelength of light source analysing the diffraction pattern of the grating (L2)
7. Understand the characteristics of p-n junction diode and solar cell (L2).
8. Analyse the frequency spectrum of musical instrument

VISION

Chinmaya Vishwa Vidyapeeth
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"To create an academic platform that bridges Indian Knowledge Traditions (IKT) with current-day applications in every sphere in society. The university will exceed excellence in higher learning and research with the objective of exploring, conserving and sharing the contemporary relevance of Indian cultural heritage and IKT."

MISSION

Chinmaya Vishwa Vidyapeeth
Deemed to be University

"To integrate the best practices of modern pedagogical advances with the beauty of the traditional Gurukula model of learning and prepare students to address contemporary challenges, inspiring them to leave a positive impact on the world as confident and cultured contributors to society."

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Institute of Science and Technology

VISION

To be recognized as a leading centre of excellence with global standards for computer science professionals who can solve emerging issues and contribute to society through their knowledge, research, creativity, and ethical behaviour.

MISSION

To produce graduates who are well-equipped to succeed in the rapidly evolving and dynamic field of computer science, and who can make meaningful contributions to society by constant interaction with R&D organizations and industry.

1. General Safety Guidelines:

i. **Handle equipment with care**: Ensure all equipment is returned to its proper location and stored safely after use.

ii. **Report any malfunctions**: If any equipment malfunctions or breaks, report it immediately to the lab instructor.

iii. **Know the emergency exits**: Familiarize yourself with the location of the fire extinguisher, first aid kit, and emergency exits.

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2. Before Starting an Experiment:

i. **Read the instructions**: Carefully read the lab manual and experiment procedure before starting.

ii. **Understand the theory**: Have a clear understanding of the scientific principles and calculations behind the experiment.

iii. **Check equipment**: Ensure all necessary equipment is present, functioning, and calibrated.

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3. During the Experiment:

i. **Follow the procedure**: Stick to the outlined steps in the lab manual for accurate results.

ii. **Use proper measurement techniques**: Ensure that you use the correct instruments and read measurements carefully (e.g., parallax errors in measurements).

iii. **Ask for help**: If you encounter any difficulties or have doubts, ask your instructor or lab assistant for guidance.

iv. **Be mindful of time**: Complete the experiment within the time allocated but do not rush. Quality is important.

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5. Post-Lab Procedures:

i. **Clean up the workspace**: Place the equipment to its proper place.

ii. **Submit the report on time**: Write a comprehensive lab report. Ensure the report is submitted according to the instructor's deadlines.

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7. Special Equipment Handling (if applicable):

i. **Oscilloscope, Multimeter, etc.**: Follow specific instructions for calibration and use, and always handle sensitive equipment with caution.

ii. **High-voltage systems**: Ensure that all power sources are turned off before working with electrical circuits and systems.

8. Final Reminders:

i. **Respect the lab’s schedule**: Be punctual and respect the allocated time for your experiment.

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Experiment No.1. Simple Pendulum: Determination of acceleration due to gravity

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i. Aim

Determination of the local acceleration due to gravity using a simple pendulum.

i. Apparatus

Clamp stand; a split cork; a heavy metallic (brass/iron) spherical bob with a hook; a long, fine, strong cotton thread/string (about 2.0 m); stop-watch; metre scale.

ii. Theory

The simple pendulum executes Simple Harmonic Motion (SHM) as the acceleration of the pendulum bob is directly proportional to its displacement from the mean position and is always directed towards it. The time period (T) of a simple pendulum for oscillations of small amplitude, is given by the relation

$$T = 2\pi\sqrt{\frac{L}{g}} \qquad \textit{Eq. [1.1]}$$

where 'L' is the effective length of the pendulum, and 'g' is the acceleration due to gravity at the place of experiment.

Eq. (1.1) may be rewritten as

$$T^2 = 4\pi^2\frac{L}{g} \qquad \textit{Eq. [1.2]}$$

Hence, the acceleration due to gravity, $g = 4\pi^2\frac{L}{T^2}$ *Eq. [1.3]*

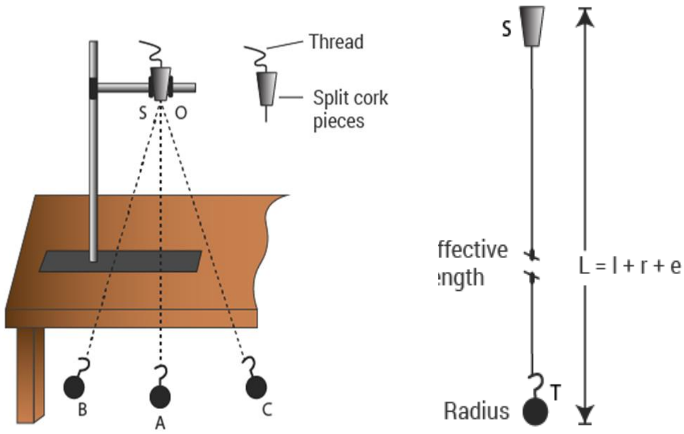
Where '$\frac{L}{T^2}$' is the slope of L-T^2 graph

iii. Procedure

i. Determine the mean diameter and hence the radius of the simple pendulum bob using the vernier calliper.
ii. Place the clamp stand on the table. Tie the hook, attached to the pendulum bob, to one end of the string of about 150 cm in length. Pass the other end of the string through two half-pieces of a split cork.

iii. Displace the bob to one side, not more than 15 degrees angular displacement, from the vertical position OA and then release it gently. In case you find that the stand is shaky, put some heavy object on its base. Make sure that the bob starts oscillating in a vertical plane about its rest (or mean) position OA and does not (a) spin about its own axis, or (b) move up and down while oscillating, or (c) revolve in an elliptic path around its mean position.

iv. Keep the pendulum oscillating for some time. After completion of a few oscillations, start the stop-watch/clock as the thread attached to the pendulum bob just crosses its mean position (say, from left to right). Count it as zero oscillation.



v. Keep on counting oscillations 1,2,3,..., n, every time the bob crosses the mean position OA in the same direction (from left to right). Stop the stop-watch/clock, at the count n (say, 20 or 25) of oscillations, i.e., just when n oscillations are complete. For better results, n should be chosen such that the time taken for n oscillations is 50 s or more. Read, the total time (t) taken by the bob for n oscillations. Compute the time for one oscillation, i.e., the time period T (t/n) of the pendulum.

vi. Change the length of the pendulum, by about 10 cm. Repeat the step (iv)& (v) again for finding the time (t) for about 20 oscillations or more for the new length and find the mean time period in each case.

vii. Plot a graph between 'L' and 'T^2' by taking effective length 'L' along x-axis and 'T^2' along y-axis, using the observed values from Table1.1. Choose suitable scales on these axes to represent 'L' and 'T^2'.

viii. From the graph determine the slope of the curve and hence find the acceleration due to gravity at the place using *Eq. [1.3]*.

iv. Observations

i) **To find the diameter of the bob**

One Main Scale Division = ...mm

No. of Vernier Scale divisions =......

Least count (L.C) of Vernier Calliper = $\frac{\text{One Main Scale Division}}{\text{No.of Vernier Scale divisions}}$ =…….mm

Sl. No.	Main Scale Reading (MSR)/mm	Vernier Scale Reading (VSR)	Diameter of the bob, d = MSR + (VSR× L.C)

Mean diameter of the bob, d = …….mm

Radius of the bob, r = $\frac{d}{2}$ = …….mm

ii) **To find acceleration due to gravity**

Sl. No.	**Length of the string(ℓ) /cm**	**Effective length of the pendulum(L) /cm**	**Time for 20 oscillations(t)/sec**			**Time period of the pendulum (T)/sec**	**T^2/sec^2**	**L / T^2 cm/sec^2**
			t_1	**t_2**	**t_{mean}**			

Mean value of L / T^2 = …….m/sec^2

v. Calculations

Acceleration due to gravity from the observation table,

$g = 4\pi^2 \left(\frac{L}{T^2}\right)$=…….m/sec^2

Acceleration due to gravity from L-T^2 graph,

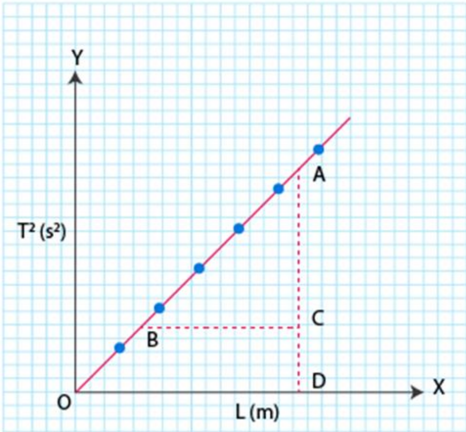
$g = 4\pi^2 \left(\frac{BC}{AC}\right)$ = ……m/sec^2

Mean value of acceleration due to gravity, g = ……. m/sec^2

Percentage error in the experimental observation = $\frac{|A-B|}{B} \times 100$ %

Where, A - observed value of acceleration due to gravity

B – Actual value of the local acceleration due to gravity



Graph of L vs T^2

vi. Results & Conclusions

Acceleration due to gravity (g) at the place

i) From the observation table = ………m/sec^2
ii) From L-T^2 graph = ……. m/sec^2
iii) Percentage error in experimentally observed value of acceleration due to gravity = ……%

Suggested additional experiments/activities

1. Studying the effect of size of the bob on the time period of the simple pendulum.
2. Studying the effect of mass of the bob on the time period of the simple pendulum.
3. Studying the effect of amplitude of oscillation on the time period of the simple pendulum.
4. Studying the effect on time period of a pendulum having a bob of varying mass (e.g. by filling the hollow bob with sand, sand being drained out in steps).

Experiment No.2. Spectrometer: Determination of the Refractive index of prism

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i. **Aim**

To determine the refractive index of the material of a prism.

ii. **Apparatus**

Spectrometer, prism, prism clamp, sodium vapour lamp, lens.

iii. **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 the 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,

$$\frac{sini}{sinr} = \frac{n_2}{n_1}$$

here, i – angle of incidence
r – angle of refraction
n_1 – refractive index of first medium
n_2 – refractive index of second medium

Speed of light on both media is related by,

$$\frac{v_2}{v_1} = \frac{n_1}{n_2}$$

Refractive index of material of prism can be calculated by the equation,

$$\mu = \frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

here, δ_m – angle of minimum deviation
A – angle of prism

iv. **Procedure**

To determine the angle of prism:

i. Calibrate the spectrometer by focusing the telescope on a distant object possible.
ii. Determine the least count of the spectrometer.
iii. Place the prism on the prism table with its refracting edge at the centre and towards the collimator.
iv. The light reflected from each of the two polished faces is observed through the telescope. The image of the slit so formed is focused on the cross wire and the two positions of the telescope are noted. The

difference of the two readings gives twice the angle of the prism, i.e., 2A.

To determine the angle of minimum deviation of prism:

i. Rotate the vernier table so that the light from the collimator falling on one of the faces of the prism emerge through the other face.
ii. The telescope is turned to view the refracted image of the slit on the other face.
iii. On continuing this rotation in the same direction, a position will come where the spectral lines recede in the opposite direction. This position where the spectrum turns away is the minimum deviation position. Lock the prism table and note the readings of the vernier.
iv. Remove the prism and see the slit directly through the telescope. Set the slit on the crosswire and note the readings of the verniers.
v. The difference in minimum deviation position and direct position of the slit gives the angles of minimum deviation(δ_m) for the prism.

v. Observations

Value of one Main Scale Division, x = …….minutes
no. of div. in vernier scale, n = ……
Least count, L.C = x/n =………..minutes

Determination of angle of prism

Vernier	Telescope Readings for reflection from						Difference 2A=b-a (Degree)	Angle of Prism (A) (Degree)
	First face (a)/ Degree			Second Face (b)/ Degree				
	M.S.R	V.S.R	Total reading	M.S.R	V.S.R	Total reading		
V1								
V2								

*Total reading = M.S.R+(V.S.R × L.C)
Mean angle of prism, A = …….. Degree

Determination of angle of minimum deviation

Vernier	Telescope Readings for						Difference δ_m = b-a (Degree)
	Refracted image (a)/ Degree			Direct image (b)/ Degree			
	M.S.R	V.S.R	Total reading	M.S.R	V.S.R	Total reading	
V1							
V2							

*Total reading = M.S.R+(V.S.R × L.C)
Angle of minimum deviation, δ_m = ………degree

vi. Calculations

Refractive index of the material of prism, $\mu = \frac{\sin\left(\frac{A+\delta m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

vii. Results & Conclusions

Refractive index of the material of prism, μ = ……

Experiment No.3. Spectrometer: Determination of wavelengths of prominent lines of mercury line Spectra using diffraction grating

i. Aim

To determine the wavelengths of prominent lines of mercury by plane diffraction grating.

ii. Apparatus

A plane diffraction grating, spectrometer, mercury lamp, spirit level, reading lens.

iii. Theory

When a beam of light is partly blocked by an obstacle, some of the light is scattered around the object, light and dark bands are often seen at the edge of the shadow - this effect is known as diffraction.

The optical phenomena we observe here is based on the principle of Fraunhoffer diffraction through a diffraction grating. A diffraction grating has large no. of slits of equal width and separation. Let there are 'p' number of parallel slits each of width 'e' separated by opaque space 'c'. So, the grating element is (e + c) which is also denoted as 'd'.

The intensity of diffraction will be maximum when, $d\sin\theta = n\lambda$ Eq. [2.1]

Here, d – Grating element,
Θ – Diffraction angle
n – Order of diffraction
λ – wavelength of spectral line

The grating element, $d = \frac{1}{N}$

Where 'N' is the number of lines per specified unit length of the grating.
Eq. [2.1] can be rearranged to determine the wavelength of light source used,

Wavelength of the light source, $\lambda = \frac{sin\theta}{nN}$ Eq. [2.2]

iv. Procedure

i. Calibrate the spectrometer by focusing the telescope on a distant object possible.
ii. All main body of the spectrometer is leveled horizontally using the screws provided at the base with the help of a spirit level. Then prism table is leveled using the three screws which support the prism table.
iii. Adjust the slit screw to get a sharp and vertical slit.

iv. Determine the least count.

v. Mount the grating over the prism table vertically.

vi. For setting the grating for normal incidence first the direct image of the slit is seen through the telescope. Set the main scale readings at 0^0 & 180^0 by rotating the vernier table. The readings of the two verniers are noted. The telescope is rotated on either side by 90˚ and clamped. The prism table is rotated so that the reflected image of the slit is seen on the crosswire through the telescope. Take the readings of the two verniers. Now turn the prism table from this position by 45˚ or 135˚ such that the face of the grating normal to the incident beams. Unclamp the telescope. Now set up is ready for observations.

vii. Rotate the telescope to the left of the direct image to get the first order spectrum. (Direct image is the zeroth order). Clamp the telescope. Adjust the different spectral lines colourwise one by one on the crosswire and note the readings of verniers v1 and V2 for each colour. (vii). Now rotate the telescope towards the right side of the direct image. Again get 1st order spectrum of same colours and note the readings of verniers v1 and V2 for each colour as shown in Fig.3.

viii. Find out the difference of readings of same verniers for various colours for 1st orders, half of the angle so obtained is the angle of diffraction for that particular colour and particular order.

ix. Determine the various wavelengths using Eq. [2.2]

v. Observations

Value of the smallest division on the main scale (d) = …..minutes
Number of divisions on the vernier scale (n) = …….
Least Count of the instrument (LC=d/n) = ……minutes
Number of lines on the grating (=15000 per inch)*: N

(*Convert N to either per metre or per nanometre or per angstrom unit so that your final answer λ will be in metre/nanometre/angstrom unit accordingly)

i) **Readings for the spectrum on the LEFT SIDE**

	Vernier 1			**Vernier 2**		
	M.S.R (degree)	**V.S.R**	**Total reading LV1 (degree)**	**M.S.R (degree)**	**V.S.R**	**Total reading LV2 (degree)**
Colour 1						
Colour 2						
Colour 3						

*Total reading = M.S.R+(V.S.R × L.C)

ii) **Readings for the spectrum on the RIGHT SIDE**

	Vernier 1			**Vernier 2**		
	M.S.R (degree)	**V.S.R**	**Total reading LV1 (degree)**	**M.S.R (degree)**	**V.S.R**	**Total reading LV2 (degree)**
Colour 1						
Colour 2						
Colour 3						

*Total reading = M.S.R+(V.S.R × L.C)

vi. Calculations

Angle 2θ for colour 1: (1/2) {(LV1 - RV1)+(LV2-RV2)} =…….degree

Angle 2θ for colour 2: (1/2) {(LV1 - RV1)+(LV2-RV2)} =…….degree

Angle 2θ for colour 3: (1/2) {(LV1 - RV1)+(LV2-RV2)} =…….degree

Wavelength of colour 1: $\lambda_1 = \frac{sin\theta 1}{nN}$ =……..nm

Wavelength of colour 2: $\lambda_2 = \frac{sin\theta 2}{nN}$ =……..nm

Wavelength of colour 3: $\lambda_3 = \frac{sin\theta 3}{nN}$ =……..nm

vii. Results & Conclusions

Wavelength of prominent lines in mercury spectra are obtained to be,

λ_1 = ………nm

λ_1 = ………nm

λ_1 = ………nm

Experiment No.4. Photoelectric effect: Determination of Planck's constant

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i. Aim

i. To determine Planck's Constant and work function using photo electric effect.

ii. Apparatus

Experimental set up for measurement of Planck's constant, filters of different colours.

iii. Theory

It was observed as early as 1905 that most metals under influence of radiation, emit electrons. This phenomenon was termed as photoelectric emission. The detailed study of it has shown:

i. That the emission process depends strongly on frequency of radiation
ii. For each metal there exists a critical frequency such that light of lower frequency is unable to liberate electrons, while light of higher frequency always does.
iii. The emission of electron occurs within a very short time interval after arrival of the radiation and number of electrons is strictly proportional to the intensity of this radiation.

The experimental facts given above are among the strongest evidence that the electromagnetic field is quantified and the field consists of quanta of energy $E = h\nu$ where is 'ν' the frequency of the radiation and 'h' is the Planck's constant. These quanta are called photons.

Further it is assumed that electrons are bound inside the metal surface with an energy '$\phi = h\nu_0$', where 'ϕ' is called the work function. It then follows that if the frequency of the light is such that $h\nu > \phi$, it will be possible to eject photoelectron, while if $h\nu < \phi$, it would be impossible.

In the former case, the excess energy of photon appears as kinetic energy of the electron,

$$\frac{1}{2}mV^2 = h\nu - \phi \qquad \text{Eq. [1]}$$

which is the famous photoelectric equation formulated by Einstein in 1905. If we apply a retarding potential 'V' so as to stop the photo electrons completely, it is known as stopping potential V_s. At that instant,

$$\frac{1}{2}mV^2 = eV_s$$

Hence, Eq. [1]] becomes,

$$eV_s = h\nu - \phi$$

$$V_s = \frac{h}{e}\nu - \frac{\phi}{e} \qquad \text{Eq. [2]}$$

when we plot a graph V_s as a function of υ, the slope of the straight-line yields $\frac{h}{e}$ and the intercept of extrapolated point at ν =0 gives work function $\frac{\phi}{e}$. from there determine the work-function of the given material.

iv. Procedure

i. Adjust to de-accelerating voltage to 0 V and insert the red color filter (635nm).
ii. set light intensity switch to maximum.
iii. Adjust the reverse voltage (or de-accelerating voltage) such that the ammeter reads zero.
iv. Take that voltage as the stopping potential.
v. Repeat the same procedure for other filters as well.
vi. Plot the $V_s - \nu$ graph, from which you find out the Planck's constant and work-function of the material.

v. Observations

Sl. No.	**Filters**	**Frequency,** ν (Hz)	**Stopping potential,** V_s (V)

vi. Calculations

From $V_s - \upsilon$ graph,
Planck's constant, h = e × Slope of the graph = ………J-sec
Work function, ϕ = e × y- intercept = …….J

vii. Results & Conclusions

i. Planck's constant 'h' is found to be work function h = ……..J-sec
ii. Work function, ϕ = …….J

Experiment No.5. Circular coil: Determination of Earth's Horizontal intensity of Magnetic Field using circular coil

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i. Aim

i) Determination of Earth's Horizontal intensity of Magnetic Field using circular coil

ii) To study the variation of magnetic field with distance along the axis of a circular coil carrying current.

ii. Apparatus

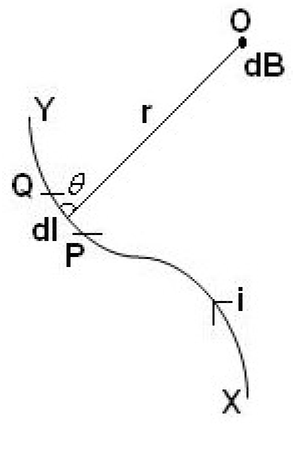
Circular coil, compass box, ammeter, rheostat, commutator, cell, key, connection wires, etc.

(The purpose of the commutator is to allow the current to be reversed only in the coil, while flowing in the same direction in the rest of the circuit.

iii. Theory

A current carrying wire generates a magnetic field. According to Biot-Savart's law, the magnetic field at a point due to an element of a conductor carrying current is,

1) Directly proportional to the strength of the current, 'I'
2) Directly proportional to the length of the element, 'dl'
3) Directly proportional to the Sine of the angle 'θ' between the element and the line joining the element to the point
4) Inversely proportional to the square of the distance 'r' between the element and the point.



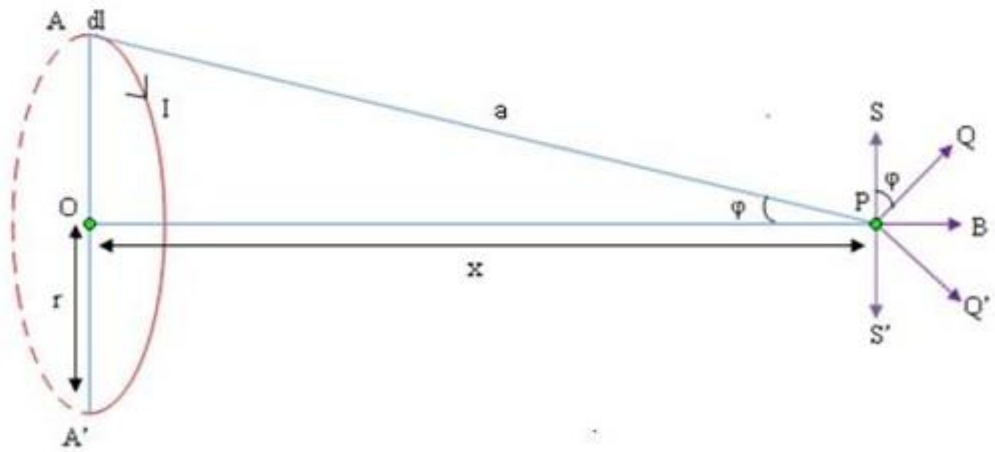
Thus, the magnetic field at O is dB, such that, $dB \propto \dfrac{I\ dl\ \sin\theta}{r^2}$

$$dB = \frac{\mu_0}{4\pi} \frac{I \; dl \; \sin\theta}{r^2}$$

(Where $\frac{\mu_0}{4\pi} = k$, is the proportionality constant. And $\mu_0 = 4\pi \times 10^{-7}$ NA^{-2}, is called the permeability of free space.)

In vector form, $dB = \frac{\mu_0}{4\pi} \frac{I \; dl \times \vec{r}}{r^3}$

Consider a circular coil of radius r, carrying a current I. Consider a point P, which is at a distance x from the centre of the coil. We can consider that the loop is made up of a large number of short elements, generating small magnetic fields. So the total field at P will be the sum of the contributions from all these elements. At the centre of the coil, the field will be uniform. As the location of the point increases from the centre of the coil, the field decreases.



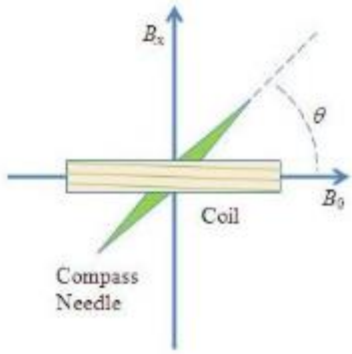
By Biot-Savart's law, the field dB due to a small element dl of the circle, centered at 'O' is given by,

$$dB = \frac{\mu_0 I}{4\pi} \frac{dl}{(x^2 + y^2)}$$

This can be resolved into two components, one along the axis 'OP', and other 'PS', which is perpendicular to 'OP'. 'PS' is exactly cancelled by the perpendicular component 'PS' of the field due to a current and centered at 'A'. So, the total magnetic field at a point which is at a distance 'x' away from the axis of a circular coil of radius 'r' is given by,

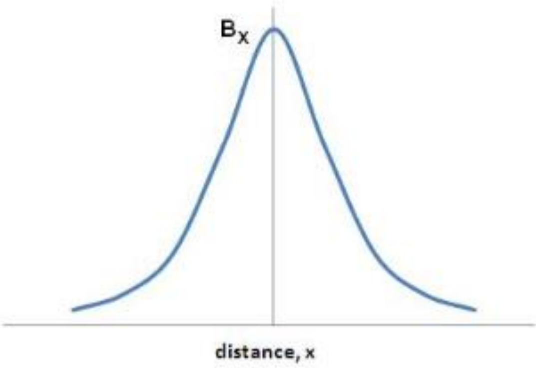
$$B_x = \frac{\mu_0 n I}{2} \frac{r^2}{\left(x^2 + r^2\right)^{3/2}}$$

Where 'n' is the number of turns of coil. Since this field B_x from the coil is acting perpendicular to the horizontal intensity of earth's magnetic field, B_0, and the compass needle align at an angle θ with the vector sum of these two fields, we have from the figure.



$$B_0 = \frac{B_x}{\tan\theta}$$

The variation of magnetic field along the axis of a circular coil is shown here.

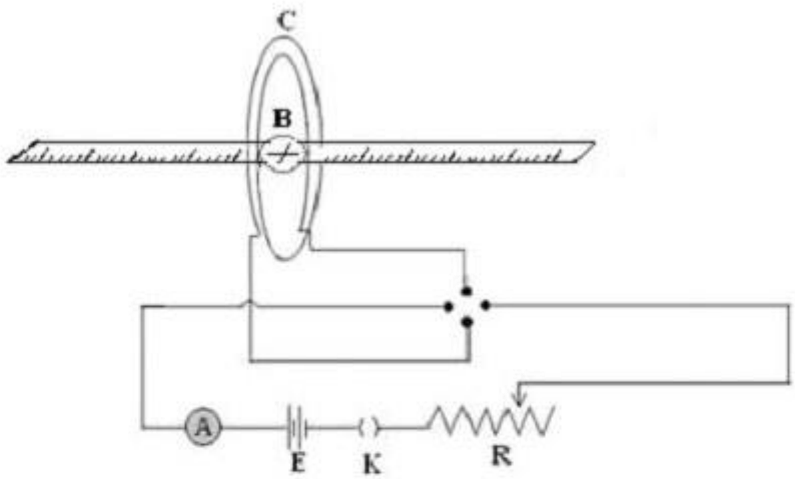


iv. Procedure

The connections are made as shown in the diagram and the initial adjustments of the apparatus are made as follows,

i. First, the coil is fixed at the middle of the platform and the compass box is placed at the centre of the coil.
ii. The compass box is rotated till the 90-90 line becomes parallel to the plane of the coil.
iii. Then the apparatus as a whole is rotated till the aluminium pointer reads 0-0.
iv. Close the circuit.
v. Adjust the rheostat until the deflection lies between 30 and 60 degrees. Note down the deflection of the compass needle and the current.
vi. Then current through the coil is reversed using the commutator and again the deflection and current are noted
vii. Average the magnitude of the two deflections and calculate the magnetic field at the centre of the coil from the equation
viii. Without changing the current or the number of turns, place the compass box at a particular distance from the centre of the coil. Note the deflection. Again reverse the current and average the magnitudes of the two deflections. Note the average, and the distance.
ix. The same procedure is repeated with the compass box at the same distance on the other side of the arm, keeping number of turns and current constant.

x. Take the average of the two values of measured on opposite sides of the coil.
xi. Then calculate the magnetic field B_x from the coil using equation (3).
xii. Repeat for various distances.
xiii. Draw graph of B_x on the vertical axis v/s. distance x on the horizontal axis.



C- Circular coil, A – Ammeter, B – Compass box, R – Rheostat, E -Cell

v. Observations

permeability of free space, μ_0 = ...NA^{-2}
Current, I = ...A
No: of turns of the coil, n = ...
Radius of the circular coil, r = ... cm

Distance from the axis, x (cm)	**Deflection with compass box on left side**				**Deflection with compass box on right side**				**Mean θ (Degrees)**	B_x **(T)**	$B_0 = \frac{B_x}{\tan\theta}$ **(T)**
	direct		**reversed**		**direct**		**reversed**				
	Θ_1	Θ_2	Θ_3	Θ_4	Θ_1	Θ_2	Θ_3	Θ_4			

vi. Results & Conclusions

i) Flux density due to earths horizontal field at the place=..........T
ii) Studied the variation of magnetic field with distance along the axis of a circular coil carrying current by plotting B_x - x graph.

Experiment No.6. Deflection Magnetometer: Determination of magnetic dipole moment of a bar magnet

1. **Aim**
   To determine the magnetic dipole moment (m) of a bar magnet.

2. **Apparatus**
   Deflection magnetometer with a compass box, bar magnet.

3. **Theory**

The horizontal component of earth's magnetic field 'B_H' is the component of the magnetic field of the earth along a horizontal plane whose normal vector passes through the center of the earth. B_H is measured in Tesla, T.

The magnetic dipole moment m of a magnetic dipole is the property of the dipole which tends to align the dipole parallel to an external magnetic field. m is measured in Ampere-square meters (A m^2) or, equivalently, in Joules per Tesla (J/T).

Tangent Law

Consider a bar magnet with magnetic moment 'm', suspended horizontally in a region where there are two perpendicular horizontal magnetic fields, and external field B and the horizontal component of the earth's field B_H. If no external magnetic field B is present, the bar magnet will align with B_H. Due to the field B, the magnet experiences a torque 'τ_D', called the deflecting torque, which tends to deflect it from its original orientation parallel to B_H. If 'θ' is the angle between the bar magnet and B_H, the magnitude of the deflecting torque will be,

$$\tau_D = mB\cos\theta$$

The bar magnet experiences a torque 'τ_R' due to the field B_H which tends to restore it to its original orientation parallel to B_H. This torque is known as the restoring torque, and it has magnitude.

$$\tau_R = mB_H\sin\theta$$

The suspended magnet is in equilibrium when,

$$\tau_R = \tau_D$$

$$mB_H\sin\theta = mB\cos\theta$$

$$B = B_H\tan\theta$$

The above relation, called the tangent law, gives the equilibrium orientation of a magnet suspended in a region with two mutually perpendicular fields.

Tan-A position

In Tan A position (Fig. 1), prior to placement of the magnet, the compass box is rotated so that the (0-0) line is parallel to the arm of the magnetometer. Then the magnetometer as a whole is rotated till pointer reads (0-0). Finally, the bar magnet is placed horizontally, parallel to the arm of the deflection magnetometer, at a distance ‘d’ chosen so that the deflection of the aluminium pointer is between 30° and 60°.

The magnet is a dipole. Suppose that, analogous to an electric dipole, there are two magnetic poles P (though in reality no single magnetic pole can exist), one positive and one negative, separated by a distance $L = 2l$, with the positive pole labeled ‘N’ and the negative pole labeled ‘S’. By analogy with Coulomb’s law, for each pole we would have a field.

$$B = \frac{\mu_0}{4\pi}\frac{P}{r^2}$$

and a magnetic dipole moment, $m = \mathrm{PL} = 2\mathrm{P}\ell$

$$B = \frac{\mu_0 P}{4\pi}\left[\frac{1}{(d-\ell)^2} - \frac{1}{(d+\ell)^2}\right] = \frac{\mu_0}{4\pi}\frac{2md}{\left(d^2-\ell^2\right)^2}$$

Where, ℓ - $L/2$ is the half-length of the magnet

m - magnetic moment of the magnet

θ = deflection of aluminium pointer

Therefore, by the tangent law, at equilibrium,

$$B_H \tan\theta = \frac{\mu_0}{4\pi}\frac{2md}{\left(d^2-\ell^2\right)^2}$$

Solving for ‘m’, the magnetic moment of bar magnet. We get,

$$m = \frac{4\pi}{\mu_0}\frac{\left(d^2-\ell^2\right)^2}{2d}B_H \tan\theta$$

4. Procedure

i. The compass box alone is rotated so that the (0-0) line is parallel to the arm of the magnetometer. Then the apparatus as a whole is rotated till the aluminium pointer reads (0-0).

ii. The bar magnet is placed horizontally, parallel to the arm of the deflection magnetometer, at a distance ‘d’ from the center of the compass needle, chosen so that the deflection lies between 30° and 60°. The reading of the ends of the pointer are noted.

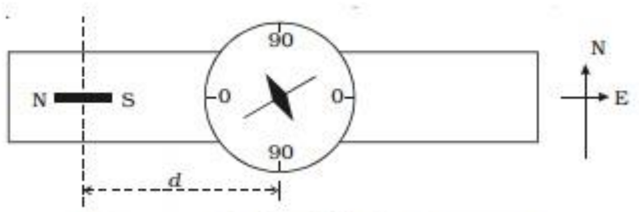


Fig. End-on (or) Tan A position

iii. The magnet is then reversed at the same position and the readings of the pointer are again noted.

iv. The magnet is then transferred to the other arm of the magnetometer, keeping it at the same distance '*d*', four more deflections are noted as before.

v. The experiment is repeated for different values of '*d*' and an average value for '*m*' is calculated.

5. Observation

Effective Length of bar magnet, 2ℓ = ... m
Half length, ℓ = ... m
Horizontal component of Earth's magnetic field, B_H= 0.38×10^{-4} T
Permeability of free space, μ_0= $4\pi\times10^{-7}$ H/m

Distance 'd' (cm)	Deflections 'θ'								Mean deflection 'θ'	Magnetic moment of the bar magnet 'm' (Am^2)
	East side				West side					
	Θ_1	Θ_2	Θ_3	Θ_4	Θ_5	Θ_6	Θ_7	Θ_8		

6. Calculations

Magnetic dipole moment of the bar magnet, $m = \frac{4\pi}{\mu_0}\frac{\left(d^2-\ell^2\right)^2}{2d} B_H \tan\theta$ =........ Am^2

Mean value of Magnetic dipole moment, m = ... Am^2

7. Results

Magnetic dipole moment of the given bar magnet, m = ……. Am^2

Experiment No.7. Newton's Rings: Determination of the wavelength of Sodium light

i. **Aim**

To determine the wavelength of Sodium light by Newton's Rings.

ii. **Apparatus**

A plane glass plate, a Plano convex lens of large radius of curvature, a flat glass sheet fixed at 45° to the vertical, sodium lamp and traveling microscope.

iii. **Theory**

It is based on Interference by division of amplitude in a wedge-shaped film of variable thickness. The film of air is enclosed between a plane glass plate and plano-convex lens.

The optical arrangement for Newton's rings is shown aside. The effective path difference between interfering rays in reflected light is given by,

$$\Delta = 2\mu t\ \cos(r+\theta) - \frac{\lambda}{2} \qquad \text{Eq. [1]}$$

Here, μ - Refractive index of the wedge-shaped film
T -Thickness of the film
r - Angle of refraction inside the film
θ - Angle of wedge
λ - Wavelength of the incident light

If the angle of the wedge 'θ' is very small, then for normal incidence (i.e., $r = 0$), $\cos(r + \theta) = \cos\theta \approx 1$, Hence the effective path difference is $\Delta=2\mu t - \lambda/2$. At the point of contact 'O' of the lens and the plate, $t = 0$; So, $\Delta = \lambda/2$. This is the condition of destructive interference. The central spot is, therefore, dark.

Condition for a dark fringe of nth order is, $2\mu t - \frac{\lambda}{2} = (2n-1)\frac{\lambda}{2}$; n=1,2,3,...

$$2\mu t = n\lambda \qquad \text{Eq. [2]}$$

Similarly, condition for a bright fringe of nth order is, $2\mu t = (2n+1)\frac{\lambda}{2}$; n=0,1,2,..

Thus, for a bright or dark fringe of any particular order, t should be constant. Here, the locus of points having same thickness of the film is a circle centered at the point of contact. Causing the formation of circular concentric rings(fringes) with the centre at the point of contact.

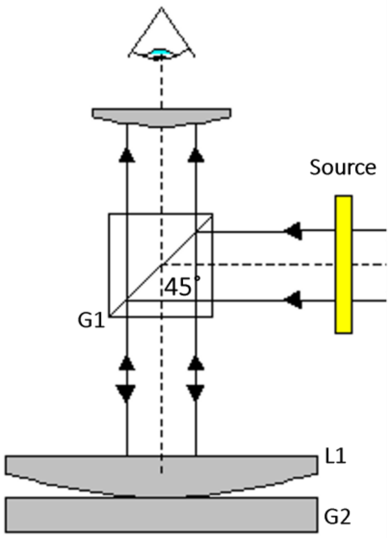
Diameter of dark rings and determination of λ:

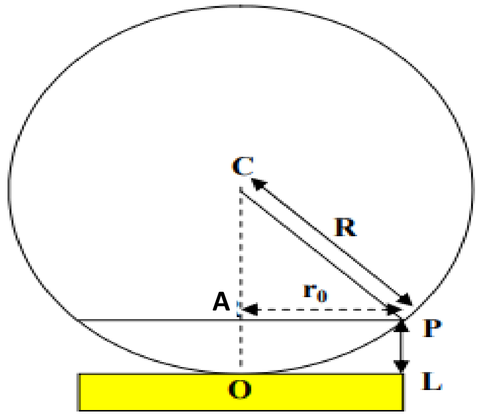
In Fig. 2, for the n^{th} dark ring, PL = AO = t. So, AC = R – t and AP = r_n. In ΔACP, $r_n^2 = R^2 - (R-t)^2 = 2Rt - t^2$ as $t << R$, t^2 can be neglected in comparison to 2Rt.

Hence, $r_n^2 = 2Rt$

Substituting the value of t from Eq. [5.2], we get, $r_n^2 = \frac{n\lambda R}{\mu}$

So, $D_n^2 = \frac{4n\lambda R}{\mu}$





For $(n+p)^{th}$ ring, $D_{n+p}^2 = \frac{4(n+p)\lambda R}{\mu}$

Hence, $D_{n+p}^2 - D_n^2 = \frac{4p\lambda R}{\mu}$ Eq. [5.3]

iv. Procedure

i. The glass plates G1, G2, and L1, is cleaned with a soft paper. Then L1 is placed over G2 as shown in Fig. [1]

ii. Light from an extended monochromatic source (sodium lamp) is allowed to fall on G1 inclined at an angle 45° to the vertical. Thus, a part of the incident light beam is reflected from the lower surface of G1, which in turn falls on L1.

iii. The position of G2 and L1 is so adjusted that its centre is well illuminated. Interference fringes (concentric circles) are formed due to the air formed between G2 and L1. These rings are observed directly through the traveling microscope.

iv. The centre of the fringe pattern should be dark. If it is white, then there should be a dust particle between G2 and L1.

v. Move the microscope in a horizontal direction to one side of the fringes. Fix up the crosswise tangential to the ring (say the 20^{th} ring). Now retrace the path and bring the crosswire to (say 18^{th} ring). Note this reading. Continue this procedure till you reach 2^{th} dark ring.

vi. Now repeat the same by taking readings for the dark rings on the other side from 2^{th}, 4^{th}, 6^{th}, all the way up-to 20^{th} dark ring.

v. Observations

Value of one Main Scale Division, x = …….cm
No. of divisions in vernier scale, n = …….
Least count, L.C = x/n = ………cm

Order of the Ring /n	Microscope readings for the rings						D_n = b – a /cm	D_n^2 /cm^2	$D_{n+p}^2 - D_n^2$ (for p=10) /cm^2
	Left end			Right end					
	M.S.R (cm)	V.S.R	Total Reading/ a (cm)	M.S.R (cm)	V.S.R	Total Reading/ b (cm)			
20									
18									
16									
14									
12									
10									
8									
6									
4									
2									

Mean value of $D_{n+p}^2 - D_n^2$ (for p=10) = …….cm^2

vi. Calculations

Focal length of the plano convex lens, f =……..cm
Radius of curvature of the given plano convex lens, R = f = ……cm
Wavelength of the sodium light, $\lambda = \frac{\mu}{4pR}\left(D_{n+p}^2 - D_n^2\right)$ = ……nm

vii. Results & Conclusions

Wavelength of the sodium light, λ = ……..nm

Experiment No.8. Diffraction grating: to determine the wavelength of laser

i. **Aim**

To determine the Wavelength (λ) of He-Ne laser light.

ii. **Apparatus**

He-Ne Laser apparatus, Grating, Scale.

iii. **Theory**

A diffraction grating consists of a large number of equally spaced, parallel slits or rulings. When light passes through a diffraction grating, it undergoes diffraction and produces a characteristic pattern of bright and dark fringes. The theory of diffraction grating is based on the principles of wave interference and diffraction.

When light, which is an electromagnetic wave, encounters a diffraction grating, it interacts with the individual slits or rulings in the grating. This interaction results in the phenomenon of wave interference. Interference occurs when waves from different slits overlap and combine. Diffraction is the bending of light waves as they encounter an obstacle or aperture. In the case of a diffraction grating, the slits or rulings act as multiple apertures through which light waves pass. As the waves pass through these apertures, they diffract and spread out.

The grating equation relates the angle of diffraction, the grating spacing, the wavelength of light, and the order of diffraction. This fundamental equation describes the behavior of a diffraction grating is known as the grating equation:

$$d\sin\theta = n\lambda \qquad \text{Eq. [9.1]}$$

Here, d – Grating element,
Θ – Diffraction angle
n – Order of diffraction
λ – wavelength of spectral line

The grating element, $d = \frac{1}{N}$

Where 'N' is the number of lines per specified unit length of the grating.
Eq. [2.1] can be rearranged to determine the wavelength of light source used,

Wavelength of the light source, $\lambda = \frac{\sin\theta}{nN}$

Diffraction gratings causes the spectral dispersion dispersing light into its constituent colors or wavelengths. This dispersion occurs because different wavelengths of light are diffracted at different angles according to the grating equation. This property is used in spectroscopy to analyze the spectral composition of light. Diffraction gratings are widely used in spectrometers and monochromators because they can provide high spectral resolution. Resolution is the ability to distinguish closely spaced wavelengths. It depends on factors such as the number of rulings in the grating and the order of diffraction.

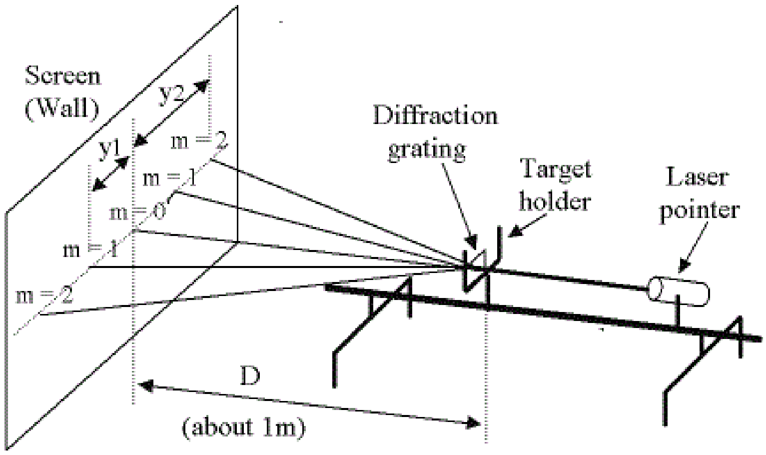


Figure.9.1. Visual representation of diffraction pattern produced

iv. Procedure

i. Switch on the electric power supply which is given to He-Ne Laser Apparatus.
ii. Observe the diffraction pattern on the Screen.
iii. Measure the distance between grating & the Screen (D).
iv. For the 1st order spectrum, measure the distance y1 & y2.
v. Similarly, for 2nd order spectrum also measure y1 & y2.
vi. From the available data, compute wavelength (λ) for the given He-Ne Laser light.

v. Observations

Order of the diffraction	Dist. between Grating & screen (D) / (cm)	Left (y1/ (cm)	Right (y2) / (cm)	Mean Y = (y1+y2)/2 (cm)	θ = $\tan^{-1}$ (Y/D)	sin θ	$\lambda = \frac{\sin\theta}{nN}$ (nm)

Wavelength of He- Ne Laser Source, $\lambda = \frac{\sin\theta}{nN}$ =…….nm

vi. Result

Wavelength of He- Ne Laser Source, $\lambda = \cdots nm$