Program Outcomes (POs)

Engineering Graduates will be able to:

- **PO1. Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- **PO2. Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- **PO3. Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- **PO4. Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
- **PO5. Modern tool usage:** Create, select, and apply appropriate techniques, resources,and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
- **PO6. The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequentresponsibilities relevant to the professional engineering practice.
- **PO7. Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
- **PO8. Ethics:** Apply ethical principles and commit to professional ethics, responsibilities, and norms of the engineering practice.
- **PO9. Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
- **PO10. Communication:** Communicate effectively on complex engineering activitieswith the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
- **PO11. Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
- **PO12. Life-long learning:** Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Lab Objectives

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1	To develop scientific understanding of the physics concepts.
2	To develop the ability to explain the processes and applications related to science subjects.
3	To apply skills and knowledge in real life situations.
4	To improve the knowledge about the theory concepts of Physics learned in the class.
5	To improve the knowledge about the theory concepts of Physics learned in the class.
6	To develop understanding about inferring and predicting.

Lab Outcomes

At the end of the laboratory course students will be able to:		Action verb	Bloom's Level
BSL101.1	Determine the wavelength of a laser source using a plane diffraction grating.	Determine	Applying Level 3
BSL101.2	Determine the numerical aperture of a given optical fiber.	Determine	Applying Level 3
BSL101.3	Perform experiments based on interference in thin film and determine radius of curvature of lens / diameter of wire / thickness of paper.	Perform	Applying Level 3
BSL101.4	Calculate the magnetic field of the coil by the variation with distance along the axis of a current carrying circular coil.	Calculate	Applying Level 3
BSL101.5	Calculate basic parameters / constants using semiconductor.	Determine	Applying Level 3
BSL101.6	Determine energy band gap / resistivity of a semiconductor.	Determine	Applying Level 3

Applied Physics Lab

List of experiments

Sr. No	List of Experiments	LO Mapping
01.	Determination of wavelength using Diffraction grating. (Laser source)	LO 1
02.	Study of divergence of laser beam	LO 1
03.	Determination of Numerical Aperture of an optical fibre	LO 2
04.	Measuring optical power attenuation in your plastic optical fiber	LO 2
05.	Determination of radius of curvature of a lens using Newton's ring	LO 3
06.	Determination of diameter of wire/hair or thickness of paper using Wedge shape film method	LO 3
07.	Determination of 'h' using photo cell	LO 4
08.	Determination of 'h' using LED	LO 4
09.	Determination of energy band gap of semiconductor	LO 5
10.	Determination of resistivity by four probe method	LO 5
11.	Virtual Lab/Simulation Based experiment	LO 6

Applied Physics Lab

Index

Sr. No.	Title of experiments	Page No.	Date of Performance	Date of Submission	Marks	Sign
1.	Determination of the wavelength of a Laser source using plane diffraction grating					
2.	Determination of the Numerical Aperture of an optical fibre					
3.	Determination of thickness of a paper using wedge shape film method					
4.	Study the variation of magnetic field with distance along the axis of a current carrying circular coil					
5.	Determination of Planck's constant (h) using LED					
6.	Determination of energy band gap of semiconductor					

INSTRUCTIONS FOR STUDENTS

- **General Information**

Some of the purpose of conducting experiments can be enumerated as below:

- To get familiarized with the basic components, measuring instruments, work bench, and basic machines.
- Observing basic phenomena and characteristics of machine.
- Reporting and analyzing the observations.
- Verify observations, basic rules and understanding physical concepts.
- Hands-on experience on machines.
- Observing safety and developing group-working culture.

To make lab-experiments safe and effective, each student must obey the following rules.

- **Dress:**

- **Boys**: Loose clothes not allowed. Shirt should be tucked-in properly, shoes with rubber sole, slippers are not allowed in the lab.
- **Girls**: Skirts with large flares not permitted, shoes with the rubber sole, slippers are not allowed in the lab.

- **Attendance:**

- All students are required to attend and contribute adequately while performing experiments in the group. Performance will be judged based on experiments conducted, quality & punctual submission of the lab report for each experiment.
- Faculty will take the attendance. Failure to be present for an experiment will result in losing entire marks for the corresponding experiment. However, genuine cases may be considered to repeat the experiment.
- Students must not attend a different lab group/section from the one assigned at the beginning of the class (unless otherwise approved by the instructor).
- If a student misses a lab session due to unavoidable circumstances, can provide a legitimate proof as soon as possible, he/she may then be allowed by the lab instructor, to make-it-up with a different section.

- **Preparation and Performance:**

- Before leaving the laboratory, each student must ask the lab instructor for the experiment number to be conducted on the next lab turn, so that the students come prepared after reading and reviewing the reallocated experiment.
- Faculty might check your preparedness and understanding of the experiment and failure to satisfactory reply may de-bar you from conducting the experiments.
- Record your observations in the Lab Manual's observation tables and do the calculations within the space provided. Do not hesitate to clear any of your doubts concerning the experiments.

- Leave the work place clean after you have finished with your experiments. Dismantle the circuit and put all the wires and equipment back at its original place.

➢ **General working discipline in the Lab:**

Students should strictly follow the instructions given below while working in the Lab:

1. Attendance in the laboratory is mandatory.
2. Students should wear an ID card issued by college around their neck when they are in lab.
3. Students will not be allowed after 5 minutes from the scheduled time.
4. No student will leave the Lab without permission.
5. Students should bring their Lab Manuals whenever they come in the lab.
6. Any confusion may be clarified from the faculty at the time of experimentation.
7. Students must maintain discipline and silence in the lab.
8. Students are to remain within their allotted experimental area.
9. Student should be attentive all the time.
10. Follow the instructions given by the faculty or course instructor.
11. Failure to obey safety rules may result in the disciplinary action.

➢ **Completion of Manual/journal**

- Manual/journal should be completed as per the guidelines and deadlines given by the subject teacher.
- Each student is required to complete the manual/journal well in time.
- Manual/journal should be neatly written and duly checked by the subject teacher.
- Questions given under the lab manual should be answered by students in the space provided in the lab manual.
- Individual comments/Notes must be written for the further improvement of the lab manual.

Name: -
Branch / Div: - Roll No: -
Experiment No: 01
TITLE: Diffraction using laser beam
Date of Performance:
Date of Completion:

Rubrics for Assessment of Experiment
Performance Indicators for assessing Lab Outcomes

Performance Indicator	Exceed Expectations (EE)	Meet Expectations (ME)	Below Expectations (BE)	Marks Obtained
Performance (03 marks)	*The entire experiment was performed within the assigned time with full attention. (03)*	*The entire experiment was executed on the deadline with less attention (02)*	*The entire experiment was performed beyond the assigned time. (01)*	
Readings, Calculations & Graphs (03 marks)	*All the readings taken are in the range. All figures & Graphs are correctly drawn & Calculations are done accurately (03)*	*All the readings taken are not in the range. All figures &, Graphs are correctly drawn but some important features are missing & Calculations are done incorrectly (02)*	*All the readings are beyond range. All figures & Graphs are poorly drawn & Calculations are done incorrectly (01)*	
Understanding (02 marks)	*Complete understanding of the aim of the experiment and the basic concepts (02)*	*Incomplete understanding of the aim of the experiment and the basic concepts (01)*	*Very less understanding of the aim of the experiment and the basic concepts (0.5)*	
Timely submission (02 marks)	*Very neat and complete write-ups submitted on the assigned day. (02)*	*Write-ups submitted late by 2-4 day (01)*	*Write-ups submitted late by 4-6 day (0.5)*	
Total Marks				

Experiment No. 1

DIFFRACTION USING LASER SOURCE

Aim:- To determine wavelength of a given laser source using plane diffraction grating.

Apparatus: - LASER source, optical grating, scale and screen.

Diagram: -

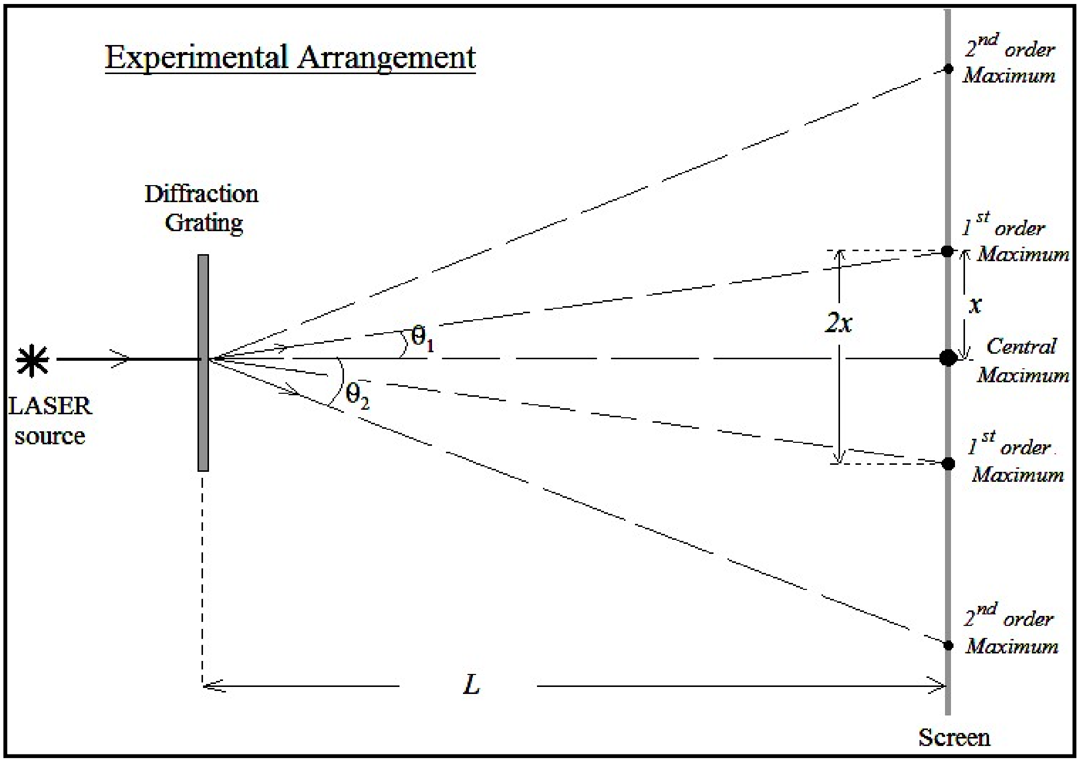

Figure 1: Schematic diagram of light diffraction using laser beam.

Formula:- $d \sin\theta = n\lambda$ OR $\sin\theta = nN\lambda$

Where d - Grating element =1/N

N -Number of lines per cm on grating

n -Order of maximum in diffraction pattern

θ -Angle of diffraction for n^{th} maximum

λ -Wavelength of LASER source

In experimental arrangement, to find angle of diffraction, we have from geometry of arrangement $\tan\theta = \frac{x}{L}$ i.e. $\theta = \tan^{-1}(x/L)$

Where, x -distance of n^{th} maximum from center of pattern on screen

L -distance of screen from grating

Precaution: - ***DO NOT DIRECTLY LOOK INTO THE LASER BEAM***.

Procedure: -

1. Allow the beam to fall on the grating and the diffraction pattern, in the form of series of dots is observed on the screen placed at a fixed distance 'L'. In the diffraction pattern, you will observe central or zeroth maximum as brightest spot & on its both sides other spots as 1st order, 2nd order maxima. You may notice the decrease in the irradiance as you move away from the zero order towards the higher order.
2. Measure the distance (L) between the screen and grating.
3. The distance between two first orders dots ($2x$) obtained on both sides of central spot is measured with the help of meter scale.
4. Similarly measure the distance between the two-second order dots obtained on both sides of central spot.
5. Repeat above steps for other grating having different grating element/number of lines.
6. Tabulate all the readings. Find the angle of diffraction in each case to find out wavelength of the laser source.

Observations: -

Distance of screen from grating, L = _________ cm

Grating	**Number of lines/cm (N)**	**Order of maximum 'n'**	**Distance 2x (cm)**	**x (cm)**	$\theta = \tan^{-1}(\frac{x}{L})$	$\sin\theta$	$\lambda = \frac{\sin\theta}{nN}$ ($\mathring{A}$)
I		1st					
		2nd					
II		1st					
		2nd					
III		1st					
		2nd					

Calculations: -

For gating-I, mean λ = __________ Å

For gating-II, mean λ = ___________ Å

For gating-III, mean λ = ___________ Å

Result: -

Grating	*Wavelength 'λ' (in Å)*
I	
II	
III	

Viva Questions:

1. What is LASER?
2. What is stimulated emission?
3. What is laser action?
4. Why does red color deviate the most in case of grating?
5. What gives a more intense spectrum, prism or grating?

Answers:

Name: -

Branch / Div: - Roll No: -

Experiment No: 02

TITLE: Numerical aperture of optical fibre

Date of Performance:

Date of Completion:

Rubrics for Assessment of Experiment
Performance Indicators for assessing Lab Outcomes

Performance Indicator	Exceed Expectations (EE)	Meet Expectations (ME)	Below Expectations (BE)	Marks Obtained
Performance (03 marks)	*The entire experiment was performed within the assigned time with full attention. (03)*	*The entire experiment was executed on the deadline with less attention (02)*	*The entire experiment was performed beyond the assigned time. (01)*	
Readings, Calculations & Graphs (03 marks)	*All the readings taken are in the range. All figures & Graphs are correctly drawn & Calculations are done accurately (03)*	*All the readings taken are not in the range. All figures &, Graphs are correctly drawn but some important features are missing & Calculations are done incorrectly (02)*	*All the readings are beyond range. All figures & Graphs are poorly drawn & Calculations are done incorrectly (01)*	
Understanding (02 marks)	*Complete understanding of the aim of the experiment and the basic concepts (02)*	*Incomplete understanding of the aim of the experiment and the basic concepts (01)*	*Very less understanding of the aim of the experiment and the basic concepts (0.5)*	
Timely submission (02 marks)	*Very neat and complete write-ups submitted on the assigned day. (02)*	*Write-ups submitted late by 2-4 day (01)*	*Write-ups submitted late by 4-6 day (0.5)*	
Total Marks				

Experiment No. 2

NUMERICAL APERTURE OF OPTICAL FIBER

Aim:- To measure the numerical aperture of the optical fiber provided with the kit using 660 nm wavelengths LED.

Apparatus:- Optical Fiber Experiment kit, holding fixture, ruler, graph-screen.

Theory:- Numerical aperture refers to the maximum angle at which the light is incident on the fiber end, suffers total internal reflection and is transmitted properly along the fiber. The cone formed by the rotation of this angel along the axis of fiber, is the cone of acceptance of the fiber. The light ray should strike the fiber end, within this cone of acceptance, else it is refracted out of the fiber & could not be transmitted through it.

Diagram:-

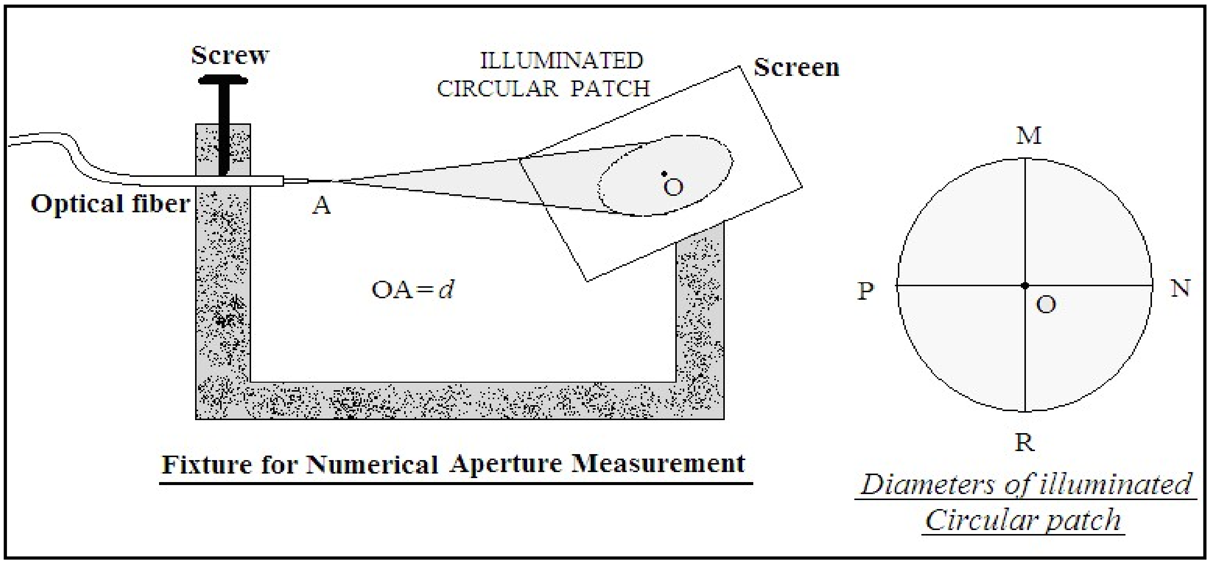

Figure 2: Schematic diagram for the measurement of N.A of an optical fiber.

Formula:- Find the numerical aperture of the fiber, using formula

$$NA = Sin\theta_{max} = \frac{r}{\sqrt{d^2 + r^2}}$$

Where, θ_{max} is the maximum angle at which if the light is incident, it is properly transmitted through the fiber.

Procedure: -

1. Insert the other end of the fiber into the numerical aperture measurement jig. Hold the white sheet / graph sheet, facing the fiber. Adjust the fiber such that its cut face is perpendicular to the axis of the fiber.
2. Keep the distance of about 50 mm between the fiber tip and the sheet screen.
3. Now observe the illuminated circular patch of the light on the screen.
4. Measure exactly, the distance'd' between fiber tip & the screen.
5. Outline the illuminated circular patch on the screen. Remove the screen & measure the vertical and horizontal diameters, MR and PN of the spot, as shown in the above figure.
6. Mean radius of patch can be calculated as, $r = \frac{MR + PN}{4}$

Observation Table:-

Obs No.	Distance of screen from fiber tip *'d'* cm	For the illuminated patch on screen			$NA = \frac{r}{\sqrt{d^2 + r^2}}$	Angle of cone of acceptance of fiber $\theta_{max} = \sin^{-1}(NA)$
		Horizontal diameter PN = D_1 cm	**Vertical diameter** MR = D_2 cm	**Radius** $r = \frac{D_1 + D_2}{4}$ cm		
1						
2						
3						
				Average		

Result: - For the given optical fiber,

- Numerical aperture = _______________
- Cone of acceptance (vertex angle) = _______________

Viva Questions:

1. What do you mean by fiber optics?
2. Define Critical angle, angle of acceptance and cone of acceptance.
3. Define Total Internal Reflection (TIR).
4. Give the significance of $n_2 > n_1$.

Answers:

Name: -

Branch / Div: - Roll No: -

Experiment No: 03

TITLE: Interference by wedge shaped film

Date of Performance:

Date of Completion:

Rubrics for Assessment of Experiment
Performance Indicators for assessing Lab Outcomes

Performance Indicator	Exceed Expectations (EE)	Meet Expectations (ME)	Below Expectations (BE)	Marks Obtained
Performance (03 marks)	*The entire experiment was performed within the assigned time with full attention. (03)*	*The entire experiment was executed on the deadline with less attention (02)*	*The entire experiment was performed beyond the assigned time. (01)*	
Readings, Calculations & Graphs (03 marks)	*All the readings taken are in the range. All figures & Graphs are correctly drawn & Calculations are done accurately (03)*	*All the readings taken are not in the range. All figures &, Graphs are correctly drawn but some important features are missing & Calculations are done incorrectly (02)*	*All the readings are beyond range. All figures & Graphs are poorly drawn & Calculations are done incorrectly (01)*	
Understanding (02 marks)	*Complete understanding of the aim of the experiment and the basic concepts (02)*	*Incomplete understanding of the aim of the experiment and the basic concepts (01)*	*Very less understanding of the aim of the experiment and the basic concepts (0.5)*	
Timely submission (02 marks)	*Very neat and complete write-ups submitted on the assigned day. (02)*	*Write-ups submitted late by 2-4 day (01)*	*Write-ups submitted late by 4-6 day (0.5)*	
Total Marks				

Experiment No: 03

WEDGE-SHAPED FILM

Aim:- To determine the thickness of a paper by using wedge shaped air film.

Apparatus:- Traveling microscope, thin paper / wire / thread, two plane glass plates (microscope slides), thin glass plat (to be used as reflector), condensing lens of small focal length, sodium source, magnifying lens etc.

Theory:- A thin film having zero thickness at one end and progressively increasing to a particular thickness at the other end is called a wedge. A thin wedge of air film can be formed by two glasses slides on each other at one edge and separated by a thin spacer at the opposite edge.

The arrangement for observing interference of light in a wedge-shaped film is shown in Figure 3. The wedge angle is usually very small and of the order of a degree. When a parallel beam of monochromatic light illuminates the wedge from above. The rays reflected from the two bounding surfaces of the film are not parallel they appear to diverge from a point near the film. These rays interfere constructively or destructively producing alternate bright and dark fringes (as shown in Figure-4)

When the light is incident on the wedge from above, it gets partly reflected from the glass-to-air boundary at the top of the air film. The other part of the light is transmitted through the air film and gets reflected at the air-to-glass boundary (as shown in Figure-3).

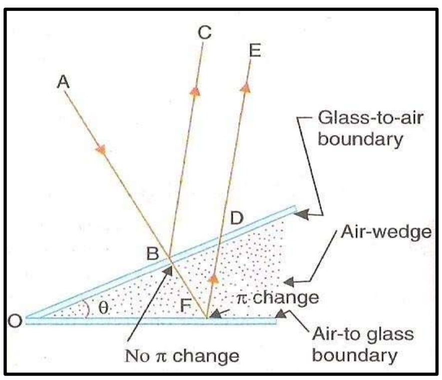

Figure: 3. Interference in wedge-shaped film

The two rays BC and DE reflected from the top and the bottom of the air film have a varying path difference along the length of the film due to variation of the film thickness. Because ray DE travels more distance than BC. Also, ray DE undergoes a phase change of half wave length (π change) occurs at the air to glass boundary due to reflection.

The optical phase difference between the two rays BC and DE is given by:

$$\Delta = 2\mu t + \lambda/2$$

Minima occurs when the phase difference is an *odd* multiple of $\lambda/2$, the two waves arriving are 180^o out of phase and give rise to destructive interference. Therefore, the condition for dark fringes or **destructive interference** is:

$$\Delta = (n + 1/2)\,\lambda \quad \text{where, n = order of the fringes}$$

$$2\mu t = n\lambda$$

$$\boxed{2t = n\lambda}$$

Because the film produced from air μ=1

The thickness of the spacer used to form the wedge-shaped air film between the glass slides can be determined using a travelling microscope.

$$t = \frac{\lambda L}{2\beta}$$

Where, (t) is thickness of the spacer.

(L) is the length of the glass plate.

(λ) is the wave length of the used monochromatic light (sodium) in vacuum.

(d) is the thickness of the fringe.

<u>Diagram</u>:-

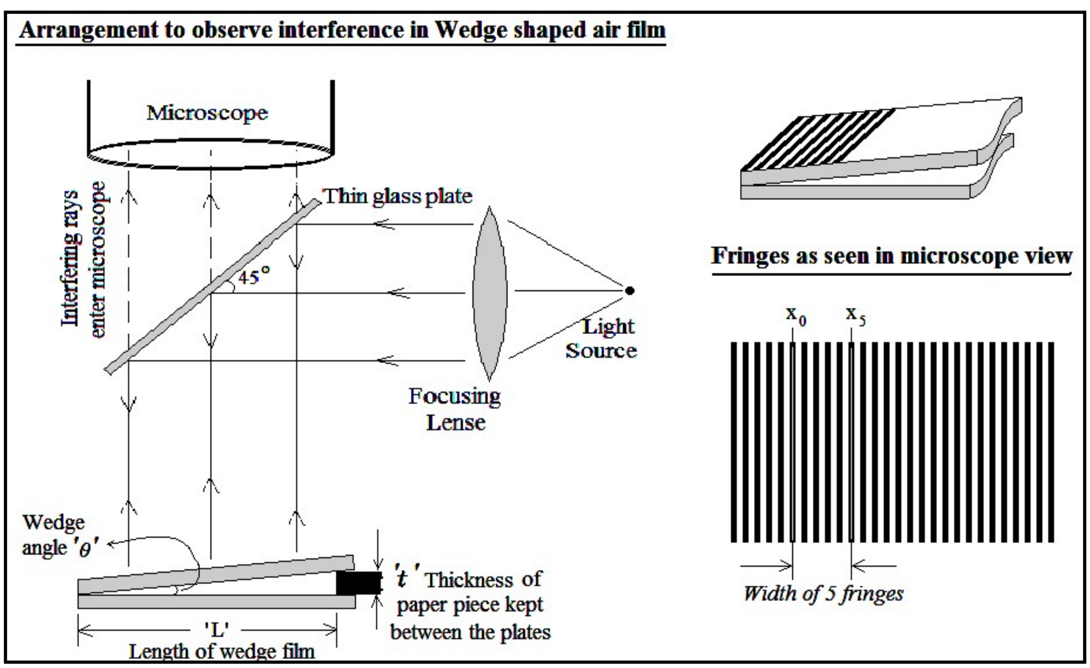

Figure: 4. Formation of Fringes in wedge-shaped films.

Formula: - From geometry of experimental situation, for wedge film formed we can write

$$\tan\theta = \frac{t}{L} \text{ with ‘}\theta\text{’ as wedge angle}$$

From theory of interference in reflected light from wedge shaped air film, we have fringe width ‘β’ given by

$$\beta = \frac{\lambda}{2\tan\theta} \qquad \text{i.e.} \qquad \tan\theta = \frac{\lambda}{2\beta}$$

Combining these two expressions, we get, Thickness of paper

$$t = \frac{\lambda L}{2\beta}$$

Where,

λ- Wavelength of monochromatic light incident on wedge (= 5893 A°)

β- Fringe width

L- Length of wedge film

Procedure: -

1. A very thin wedge of an air film is formed by placing two microscope slides in contact at one end and slightly separated at other end by placing a thin paper whose thickness is to be found out.
2. A monochromatic light from an extended source (sodium) illuminates the wedge. Straight, bright and dark fringes are observed, which are parallel to the edge of contact of the wedge.
3. Focus the microscope on the interference pattern till the parallel fringes of equal thickness are clearly seen.
4. Set the cross wire tangentially at the center of any fringe (brighter or dark) and take the microscope reading. Call this as say *zeroth* fringe.
5. Now gradually move the microscope to the right of the above fringe till the vertical cross wire crosses five fringes becomes tangential to the 5^{th} fringe. Take the microscope reading.
6. Now move the microscope again to the right by another five fringes (on 10^{th} fringe) and take the microscope reading.
7. Take such readings up to 25^{th} (or more if required) fringe with interval of five fringes.
8. Determine width of 5 fringes & hence the fringe width for pattern, from tabulated readings.

CAUTION: Within set of readings while moving the microscope, NEVER go back with SLOW MOTION SCREW OF MICROSCOPE.

Observations: -

L.C. of traveling microscope (HORIZONTAL SCALE) = ______ cm

Microscope reading= *M.S.R. + (C.D.* L.C.)*

Length of wedge-shaped air film = L =______ **cm**

(i.e. distance of paper piece edge from apex of wedge)

Observation Table:

Obs. No	**Assumed Fringe number 'k'**	**Microscope reading for position of k^{th} fringe 'x_k' cm**	**Width of five fringes X= $\lvert x_{k+5} - x_k \rvert$ cm**	**Fringe width β = X/5 cm**
1.	0	x_0 =		
2.	5	x_5 =		
3.	10	x_{10} =		
4.	15	x_{15} =		
5.	20	x_{20} =		
6.	25	x_{25} =		

Calculations:

Mean β = _______________ cm.

Substituting this in formula for thickness of paper

$$t = \frac{\lambda L}{2\beta} \quad = \quad \text{------------------------------}$$

$$t \quad = \quad \text{------------------------------}$$

OR

Wedge angle can be determined as

(in radian) $\tan\theta \approx \theta = \dfrac{\lambda}{2\beta}$ = ___________

(in degree) $\theta = \tan^{-1}\left(\frac{\lambda}{2\beta}\right) =$ ___________

Result:

1. The thickness of paper is ________
2. Wedge angle is ________

Viva Questions:

1. Why the glass plate used in the pathway of the light source should be inclined exactly at 45°?
2. Why do we get straight-line fringes in an air wedge?
3. When the length of the air-wedge is increased, what happens to the fringe width?

Answers:

Name: -

Branch / Div: -   Roll No: -

Experiment No: 04

TITLE: Determination of magnetic flux density

Date of Performance:

Date of Completion:

Rubrics for Assessment of Experiment
Performance Indicators for assessing Lab Outcomes

Performance Indicator	Exceed Expectations (EE)	Meet Expectations (ME)	Below Expectations (BE)	Marks Obtained
Performance (03 marks)	*The entire experiment was performed within the assigned time with full attention. (03)*	*The entire experiment was executed on the deadline with less attention (02)*	*The entire experiment was performed beyond the assigned time. (01)*	
Readings, Calculations & Graphs (03 marks)	*All the readings taken are in the range. All figures & Graphs are correctly drawn & Calculations are done accurately (03)*	*All the readings taken are not in the range. All figures &, Graphs are correctly drawn but some important features are missing & Calculations are done incorrectly (02)*	*All the readings are beyond range. All figures & Graphs are poorly drawn & Calculations are done incorrectly (01)*	
Understanding (02 marks)	*Complete understanding of the aim of the experiment and the basic concepts (02)*	*Incomplete understanding of the aim of the experiment and the basic concepts (01)*	*Very less understanding of the aim of the experiment and the basic concepts (0.5)*	
Timely submission (02 marks)	*Very neat and complete write-ups submitted on the assigned day. (02)*	*Write-ups submitted late by 2-4 day (01)*	*Write-ups submitted late by 4-6 day (0.5)*	
Total Marks				

Experiment No. 04

DETERMINATION OF MAGNETIC FLUX DENSITY

Aim:- To determine the magnetic flux density by the variation of magnetic field with distance along the axis of a current carrying circular coil.

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.

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 and
4. Inversely proportional to the square of the distance r between the element and the point.

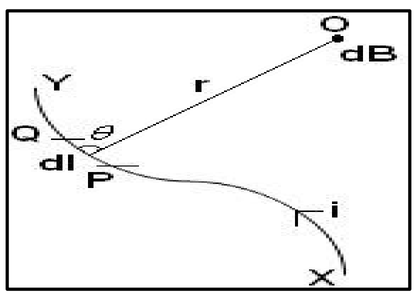

Figure: 5 Biot- Sawart's Law

Thus, the magnetic field at O is dB, such that,

$$dB \propto \frac{i\, dl\, Sin\,\theta}{r^2}$$

$$dB = k\frac{i\, dl\, Sin\,\theta}{r^2}$$

Where,
$$k = \frac{\mu_0}{4\pi}$$

$$\mu_0 = 4\pi \times 10^{-7}\ NA^{-2}$$

$$dB = \frac{\mu_0}{4\pi}\frac{i\, dl\, Sin\,\theta}{r^2}$$

In vector form,
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, as shown in the figure 7.

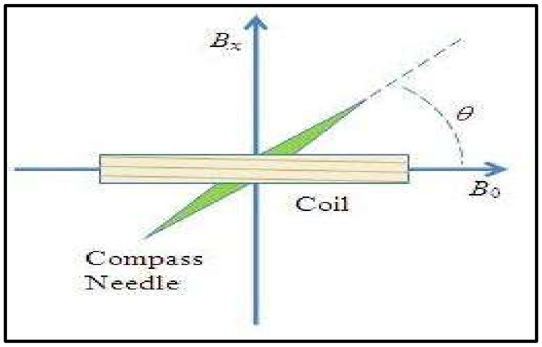

Figure:**6** Magnetic Compass

The apparatus consists of a circular coil C of 5 to 50 turns, having diameter about 10 centimeters. There is a brass frame in which the coil is wound. The frame is fitted to a stand, with its plane vertical. It can be moved along a rectangular wooden board. B is the deflection magnetometer. There is a scale fitted to the wooden board, from which the distance of the centre of the magnetic needle from the centre of the coil can be measured.

<u>Circuit Diagram</u>:

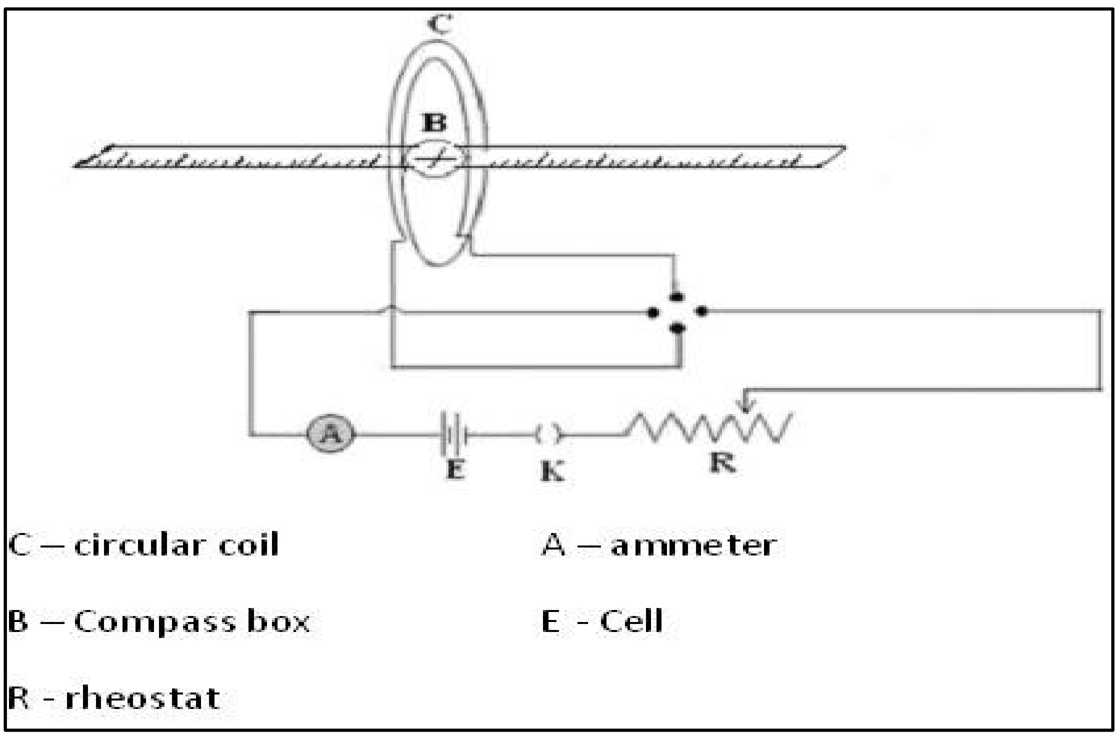

Figure: 7 Circuit diagram for determination of magnetic flux

Procedure:-

To find the magnetic field:

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

1. First, the coil is fixed at the middle of the platform and the compass box is placed at the centre of the coil.
2. The compass box is rotated till the 90-90 line becomes parallel to the plane of the coil.
3. Then the apparatus as a whole is rotated till the aluminium pointer reads 0-0.
4. Close the circuit.
5. Adjust the rheostat until the deflection lies between 30 and 60 degrees. Note down the deflection of the compass needle and the current.
6. Then current through the coil is reversed using the commutator and again the deflection and current are noted.
7. Average the magnitude of the two deflections and calculate the magnetic field at the centre of the coil from the equation.
8. 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.
9. 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.
10. Take the average of the two values of measured on opposite sides of the coil.
11. Then calculate the magnetic field B_x from the coil using equation (3).
12. Repeat for various distances.
13. Draw graph of B_x on the vertical axis *vs*. distance x on the horizontal axis.

Observations:

$B_0 = 3.5 \times 10^{-5}$ T

Current, I = ------

No: of turns of the coil, n = -----

Radius of the circular coil, r------ cm

Observation Table:

Distance from the centre, 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			

Calculation:

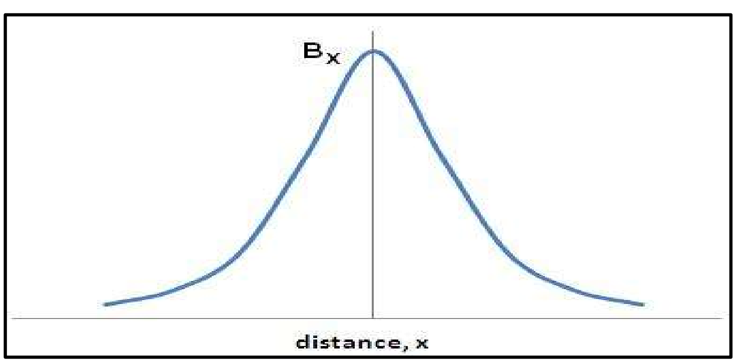

Figure: 8 Graphical Representation

Result:-

Flux density due to earths horizontal field at the place = ...T

Viva Questions:

1. Define Gradient, Divergence and Curl.
2. State Biot-Savart law?
3. What is the value of the divergence of the magnetic flux density?
4. What is the different classification of magnetic materials?

Answers:

Name:-

Branch / Div: - Roll No:-

Experiment No: 05

TITLE: Determination of 'h' by LED

Date of Performance:

Date of Completion:

Rubrics for Assessment of Experiment
Performance Indicators for assessing Lab Outcomes

Performance Indicator	Exceed Expectations (EE)	Meet Expectations (ME)	Below Expectations (BE)	Marks Obtained
Performance (03 marks)	*The entire experiment was performed within the assigned time with full attention. (03)*	*The entire experiment was executed on the deadline with less attention (02)*	*The entire experiment was performed beyond the assigned time. (01)*	
Readings, Calculations & Graphs (03 marks)	*All the readings taken are in the range. All figures & Graphs are correctly drawn & Calculations are done accurately (03)*	*All the readings taken are not in the range. All figures &, Graphs are correctly drawn but some important features are missing & Calculations are done incorrectly (02)*	*All the readings are beyond range. All figures & Graphs are poorly drawn & Calculations are done incorrectly (01)*	
Understanding (02 marks)	*Complete understanding of the aim of the experiment and the basic concepts (02)*	*Incomplete understanding of the aim of the experiment and the basic concepts (01)*	*Very less understanding of the aim of the experiment and the basic concepts (0.5)*	
Timely submission (02 marks)	*Very neat and complete write-ups submitted on the assigned day. (02)*	*Write-ups submitted late by 2-4 day (01)*	*Write-ups submitted late by 4-6 day (0.5)*	
Total Marks				

Experiment No. 05

DETERMINATION OF PLANCK'S CONSTANT 'h'

Aim: - To determine Planck's constant (h) using different light Emitting Diodes (LED)

Apparatus: 0-10 V power supply, milliammeter, DMM, a 1 K resistor and different known wavelength LED's (Light-Emitting Diodes).

Theory:

Planck's constant (h), a physical constant was introduced by German physicist named Max Planck in 1900. The significance of Planck's constant is that "quanta" (small packets of energy) can be determined by frequency of radiation and Planck's constant. It describes the behavior of particle and waves at atomic level as well as the particle nature of light.

An LED is a two terminal semiconductor light source. In the unbiased condition, a potential barrier is developed across the p-n junction of the LED.

When we connect the LED to an external voltage in the forward biased direction, the height of potential barrier across the p-n junction is reduced. At a particular voltage, the height of potential barrier becomes very low and the LED starts glowing, i.e., in the forward biased condition, electrons crossing the junction are excited, and when they return to their normal state, energy is emitted. This particular voltage is called the knee voltage or the threshold voltage. Once the knee voltage is reached, the current may increase but the voltage does not change.

The light energy emitted during forward biasing is given as,

$$E = \frac{hc}{\lambda} \qquad \text{---------------- (1)}$$

$$E = eV \qquad \text{---------------- (2)}$$

$$eV = \frac{hc}{\lambda}$$

$$h = \frac{eV\lambda}{c}$$

Where, h = Planck's constant

λ = wavelength of light emitted

e = electronic charge

c = speed of light

Circuit Diagram:

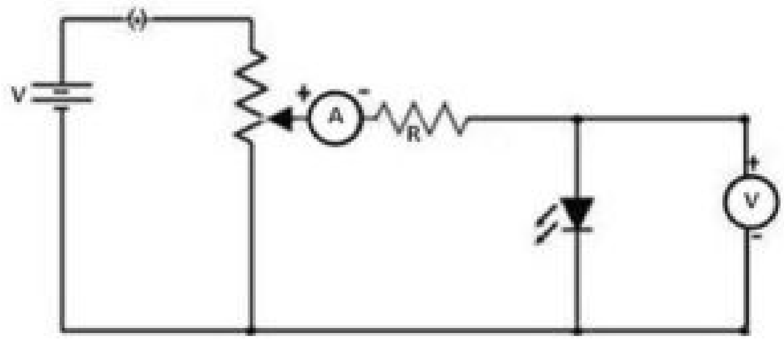

Figure: 9 Circuit diagram to determine Planck's constant.

Procedure:

1. Connect the circuit as shown in diagram.
2. By changing the input voltag, note down the voltage in voltmeter for red colour LED.
3. Repeat the same for other colour of LEDs.
4. Determine Planck's constant.

Observation:

Colour of LED	Wavelength (λ) nm	Knee Voltage (V) Volt	λ x V	h=eVλ/c

Calculations:

Result:

Planck's constant (h) = ____________ J-sec

Viva Questions:

1. What are direct bandgap semiconductors?
2. What is the value of 'h'?
3. What are the units of Planck's constant?

Answers:

Name: -

Branch / Div: - Roll No: -

Experiment No: 06

TITLE: Energy Band gap of Semiconductor

Date of Performance:

Date of Completion:

Rubrics for Assessment of Experiment
Performance Indicators for assessing Lab Outcomes

Performance Indicator	Exceed Expectations (EE)	Meet Expectations (ME)	Below Expectations (BE)	Marks Obtained
Performance (03 marks)	*The entire experiment was performed within the assigned time with full attention. (03)*	*The entire experiment was executed on the deadline with less attention (02)*	*The entire experiment was performed beyond the assigned time. (01)*	
Readings, Calculations & Graphs (03 marks)	*All the readings taken are in the range. All figures & Graphs are correctly drawn & Calculations are done accurately (03)*	*All the readings taken are not in the range. All figures &, Graphs are correctly drawn but some important features are missing & Calculations are done incorrectly (02)*	*All the readings are beyond range. All figures & Graphs are poorly drawn & Calculations are done incorrectly (01)*	
Understanding (02 marks)	*Complete understanding of the aim of the experiment and the basic concepts (02)*	*Incomplete understanding of the aim of the experiment and the basic concepts (01)*	*Very less understanding of the aim of the experiment and the basic concepts (0.5)*	
Timely submission (02 marks)	*Very neat and complete write-ups submitted on the assigned day. (02)*	*Write-ups submitted late by 2-4 day (01)*	*Write-ups submitted late by 4-6 day (0.5)*	
Total Marks				

Experiment No: 06

ENERGY BAND GAP OF SEMICONDUCTOR

Aim: To determine the energy band gap (E_g) of the given semiconductor material.

Apparatus: Diode DR 25, water bath, dc power supply, micro ammeter, thermometer, connecting wires etc.

Theory: This energy band structure of a solid is formed due to the collection of electron energy levels from individual atoms while they combine to form molecules and molecules further combining to form a solid. The position of top most energy bands *viz conduction band & valence band,* decide the electrical & thermal properties of a solid. The valance band is formed by energies of all valance electrons in solid whereas energies of free electrons in solid form the conduction band. The band gap in a semiconductor solid (range of energy not allowed for any electron in solid) is the energy difference between the top of the valance band (E_v) and bottom of the conduction band (E_c). This is called the band gap energy ($E_g = E_c - E_v$). The energy band gap (E_g) of a semiconductor is found related to the reverse saturation current (I_s) of its p-n junction diode.

The relation is given by the Richardson equation: $I_s = AT^2\, e^{(-Eg/kT)}$

where, A = Richardson constant, T = temperature of diode in ºK and k = Boltzmann constant.

$$\therefore \quad \frac{I_s}{T^2} = A\,e^{(-Eg/kT)} \quad \Rightarrow \quad \boxed{\ell n\left(\frac{I_s}{T^2}\right) = \ell n\, A - \frac{E_g}{kT}}$$

Thus, a graph of $\ell n\left(\frac{I_s}{T^2}\right)$ Vs $\left(\frac{1}{T}\right)$ will be a straight line with slope $= -\frac{E_g}{k}$.

Diagram:

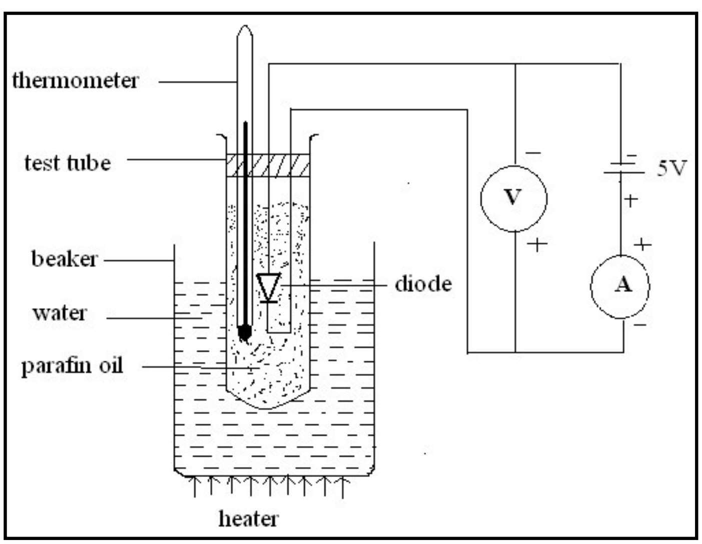

Figure: 10 Experimental setup to measure the energy band gap of a semiconductor.

Procedure:

1) Properly insert diode in the heating bath along with thermometer. Keep thermometer close to the diode.
2) Make connection as shown to reverse bias the diode. Keep dc voltage = 5 V.
3) A reverse saturation current flows from the diode. Note this current at room temperature.
4) Start heating the diode. Record the reverse saturation current for every 5 ºC rise in temperature. Stop heating when thermometer reaches 60 ºC.
5) Tabulate reading and plot the graph. Find the slope and perform necessary calculations for Eg.

Observations:

Applied reverse bias voltage to the diode = **5 V.**

Obs no.	Temperature t °C	Temperature T °K	$\frac{1}{T}$	I_s (μA)	$\ell n\left(\frac{I_s}{T^2}\right)$ *Here I_s is in Amp*
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

Graph: Plot $\ell n\left(\frac{I_s}{T^2}\right)$ on Y- axis against $\frac{1}{T}$ on X – axis.

(Take a suitable quadrant of graph)

Calculation: -

From graph, slope = ________

$$E_g = k \times |slope| = \_\_\_\_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_$$

Result:- Energy band gap of material of the diode (E_g) = _____________ eV

Conclusion: - Material of given diode is____________

Viva Questions:

1. What do you understand by band gap of a semi-conductor?
2. How charge carriers generation depends upon Temperature?
3. What is the energy band gap value in Si, Ge and GaAs?

Answers:

Name: -

Branch / Div: - Roll No: -

Experiment No: 07

TITLE: Divergence of laser beam

Date of Performance:

Date of Completion:

Rubrics for Assessment of Experiment
Performance Indicators for assessing Lab Outcomes

Performance Indicator	Exceed Expectations (EE)	Meet Expectations (ME)	Below Expectations (BE)	Marks Obtained
Performance (03 marks)	*Followed lab time table very well & focused attention on the experiment (03)*	*Did the lab but appeared less interested and. focus was lost on several occasions (02)*	*Participation was minimal (01)*	
Readings, Calculations & Graphs (03 marks)	*Readings are in range All figure & Graphs are correctly drawn & Calculations are done correctly(03)*	*Readings are not in the range, All figure &, Graphs are drawn but some important features missing & Calculations are done incorrectly(02)*	*Readings are beyond range. All figures & Graphs are poorly drawn & Calculations are done incorrectly (01)*	
Understanding (02 marks)	*Post lab questions with no errors Communicates effectively (02)*	*Post lab questions with few errors Communicates moderately (01)*	*Post lab questions with several errors Communicates poorly (0.5)*	
Timely submission (02 marks)	*Very neat and complete Write-ups submitted on assigned day. (02)*	*Write-ups submitted late by 2-4 day (01)*	*Write-ups submitted late by 4-6 day (0.5)*	
Total Marks				

Experiment No.: 7

STUDY OF DIVERGENCE OF LASER BEAM

Aim: -To determine divergence of laser beam.

Apparatus: - Laser source, screen, and scale.

Diagram:-

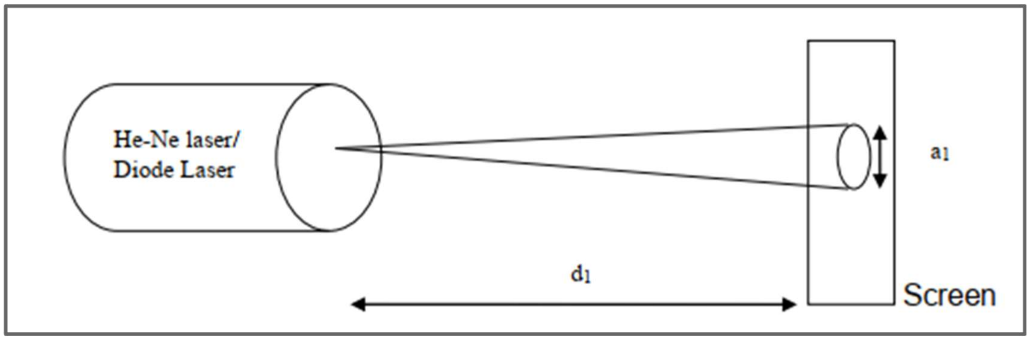

Figure 11: Light incident on the white screen from a He-Ne Laser source.

Procedure:-

1. The laser beam from He-Ne is made to fall on the screen, which is kept at a distance of d_1 from the source.
2. The spot size of the beam is noted and is taken as a_1.
3. Now the position of the screen is altered to a new position d_2 from the laser source and again the spot size of the beam is noted as a_2.
4. The same procedure is repeated by changing the position of the screen at equal intervals at least 5 times.
5. The readings corresponding to the position of the screen and spot size of the beam is tabulated.
6. From this, the angle of divergence of the laser beam is calculated using the formula $\theta = (a_2-a_1)/(d_2-d_1)$ radians.
7. The same can be repeated by using a semiconductor laser diode for the same distances as done with He-Ne laser.

Observation Table:

Sr. N.	Position of the screen	Diameter of spot (cm)	Angle of divergence θ (rad)	θ (degree)	θ (min)	Mean θ (rad)
1.						
2.						
3.						
4.						
5.						
6.						

Calculations:

Angle of divergence (θ) = $(a_2-a_1) / (d_2-d_1)$

Result:

Viva Questions:

1. What is the cause of divergence of a laser beam?
2. What is the unique property of laser?
3. What is beam profile?

Answers:

Name: -

Branch / Div: - Roll No: -

Experiment No: 08

TITLE: Measuring optical power attenuation in plastic optical fiber

Date of Performance:

Date of Completion:

Rubrics for Assessment of Experiment
Performance Indicators for assessing Lab Outcomes

Performance Indicator	Exceed Expectations (EE)	Meet Expectations (ME)	Below Expectations (BE)	Marks Obtained
Performance (03 marks)	*The entire experiment was performed within the assigned time with full attention. (03)*	*The entire experiment was executed on the deadline with less attention (02)*	*The entire experiment was performed beyond the assigned time. (01)*	
Readings, Calculations & Graphs (03 marks)	*All the readings taken are in the range. All figures & Graphs are correctly drawn & Calculations are done accurately (03)*	*All the readings taken are not in the range. All figures &, Graphs are correctly drawn but some important features are missing & Calculations are done incorrectly (02)*	*All the readings are beyond range. All figures & Graphs are poorly drawn & Calculations are done incorrectly (01)*	
Understanding (02 marks)	*Complete understanding of the aim of the experiment and the basic concepts (02)*	*Incomplete understanding of the aim of the experiment and the basic concepts (01)*	*Very less understanding of the aim of the experiment and the basic concepts (0.5)*	
Timely submission (02 marks)	*Very neat and complete write-ups submitted on the assigned day. (02)*	*Write-ups submitted late by 2-4 day (01)*	*Write-ups submitted late by 4-6 day (0.5)*	
Total Marks				

Experiment No.: 08

MEASURING OPTICAL POWER ATTENUATION IN PLASTIC OPTICAL FIBER

Aim: - To measure the optical power attenuation in a plastic optical fibre using an optical source and a power meter.

Apparatus: Plastic optical fiber, Optical power source (LED or laser diode), Optical power meter, Optical connectors and couplers, Ruler or measuring tap, Cutting tools (for fiber length adjustment).

Theory: Plastic fiber works in the same manner as glass optical fiber but uses plastic instead of glass and usually has a much larger core area. The large core area and easy-to-cut and terminate properties of plastic optical fiber have long held the promise of a low cost, easy to install communications medium that offers all the benefits of optical fiber with the ease of termination of copper. By contrast, glass fiber requires highly trained technicians and expensive equipment; this is a major difference, and one of the reasons for interest in plastic fiber for the do-it-yourself installations of homes and small offices. A significant inhibitor to wider use of optical links in this environment is the high cost of installation compared with the more reasonable cost of hardware and raw materials. Both step index and graded index plastic fiber are available, although only step index is considered a commercial product at this time. While there are many potential plastics that could be considered, the most commonly used is Poly (Methy1 MethylAcrylate) or PMMA. Attenuation is very high compared with glass fiber at all wavelengths. PMMA has attenuation minima occurring at 570 nm (yellow) , 520 nm (green), and 650 nm (red) as shown in Figure below. Both 650 nm (red) and 520 nm (green) devices have long been available and they found in the laboratory.

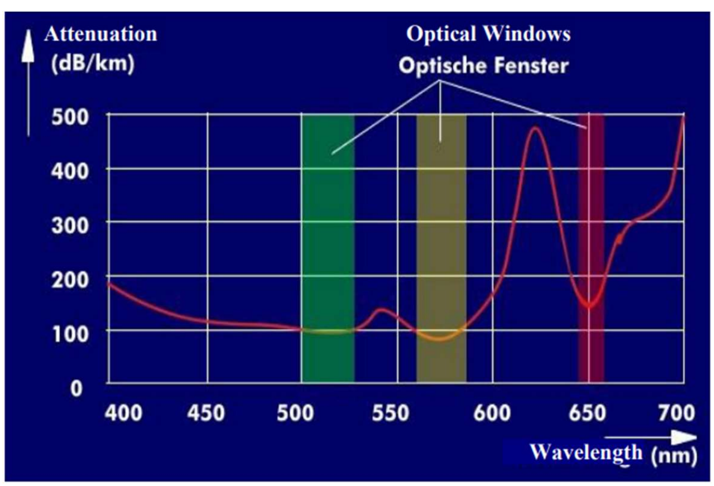

Figure 12: Plastic fiber links are also used with visible light sources around 570 nm to 650 nm wavelength; this makes alignment of the fibers easier to perform, and high-power visible sources are readily available at low cost. Table 1 shows typical specifications of POF used for communication applications.

Formula:

In general, the output power from a fiber cable at a given length is defined by the equation:

$$\alpha = \frac{10}{L} \log_{10}\left(\frac{P_{in}}{P_{out}}\right)$$

Where:

- α = Attenuation (dB/m)
- P_{in} = Input optical power (mW)
- P_{out} = Output optical power (mW)
- L = Length of the optical fibre (m)

Procedure:

1. Cut the plastic optical fibre to a suitable known length (e.g., 1 meter).
2. Connect one end of the fibre to the optical source.
3. Connect the other end to the optical power meter.
4. Turn on the optical source and measure the input power (P_{in}).
5. Measure the output power (P_{out}) at the end of the fibre.
6. Repeat the experiment with different lengths of fibre.
7. Use the attenuation formula to calculate power loss per unit length.

Observation Table:

Sr. No.	Fibre Length (m)	Input Power (P_{out}) (mW)	Output Power (P_{in}) (mW)	Attenuation (dB/m)

Graph:

Plot Attenuation (Y-axis) vs Fibre Length (X-axis)

Calculations:

Results:

The average attenuation of the plastic optical fibre was found to be __________ dB/m

Viva Questions:

1. What is optical attenuation?
2. Why is plastic optical fibre used over glass in some applications?
3. What factors affect attenuation in optical fibres?
4. How is optical power measured in this experiment?
5. How can you minimize losses in an optical fibre system?

Answers:

Name: -

Branch / Div: - Roll No: -

Experiment No: 09

TITLE: Measuring optical power attenuation in plastic optical fiber

Date of Performance:

Date of Completion:

Rubrics for Assessment of Experiment
Performance Indicators for assessing Lab Outcomes

Performance Indicator	Exceed Expectations (EE)	Meet Expectations (ME)	Below Expectations (BE)	Marks Obtained
Performance (03 marks)	*The entire experiment was performed within the assigned time with full attention. (03)*	*The entire experiment was executed on the deadline with less attention (02)*	*The entire experiment was performed beyond the assigned time. (01)*	
Readings, Calculations & Graphs (03 marks)	*All the readings taken are in the range. All figures & Graphs are correctly drawn & Calculations are done accurately (03)*	*All the readings taken are not in the range. All figures &, Graphs are correctly drawn but some important features are missing & Calculations are done incorrectly (02)*	*All the readings are beyond range. All figures & Graphs are poorly drawn & Calculations are done incorrectly (01)*	
Understanding (02 marks)	*Complete understanding of the aim of the experiment and the basic concepts (02)*	*Incomplete understanding of the aim of the experiment and the basic concepts (01)*	*Very less understanding of the aim of the experiment and the basic concepts (0.5)*	
Timely submission (02 marks)	*Very neat and complete write-ups submitted on the assigned day. (02)*	*Write-ups submitted late by 2-4 day (01)*	*Write-ups submitted late by 4-6 day (0.5)*	
Total Marks				

Experiment No: 09

DETERMINATION OF 'h' USINGH PHOTOCELL

Aim: Determination of Planck's constant using a photoelectric cell.

Apparatus: Planck's constant setup having a photoelectric cell, a tungsten light source, an adjustable dc power supply (0 to 10 V dc, with polarity reversal switch), digital voltmeter (0 to 10 V) and a multirange ammeter (0 to 100 µA), Color filter set.

Theory: This experiment demonstrates wave-particle duality, where the particle-like behavior of light is clearly observed. When a light beam with a frequency higher than a certain threshold strikes the surface of a metal, the electrons in the metal absorb sufficient energy to become free and are ejected from the metal without any time lag. The minimum frequency required for this effect to occur is known as the threshold frequency, which is characteristic of the metal and is related to its work function. This phenomenon is particularly observable when the metal is in a vacuum or under very low pressure Photocurrent is produced only when the light of frequency $\nu > \nu_0$ (threshold frequency) is incident on the metal surface.

According to Einstein's photoelectric equation: $eV = h\nu - \phi$

Where:

- h = Planck's constant
- ν = Frequency of incident light
- φ = Work function of the metal
- e = Charge of the electron
- V_s = Stopping potential

By plotting stopping potential against frequency ν, we can calculate from the slope of the line.

Formula:

Einstein's photoelectric equation: $eV_s = h\nu - \phi$

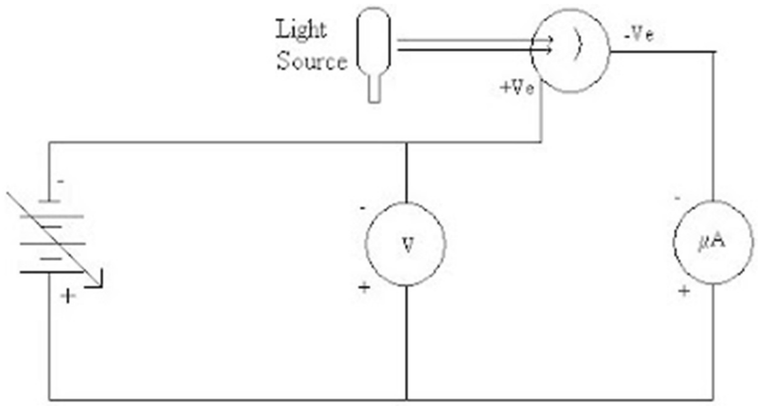

Figure 13: Circuit diagram

Procedure:

1. Arrange the experimental setup with the photocell, light source, voltmeter, and variable power supply.

2. Illuminate the photocell with a monochromatic light source (LED or filtered light).

3. Adjust the power supply to find the stopping potential—voltage at which photocurrent just becomes zero.

4. Record the frequency of the light used.

5. Repeat the procedure with other light sources of different frequencies.

6. Plot a graph of stopping potential against frequency.

7. Calculate Planck's constant from the slope of the graph.

Observations:

Sr. No.	Colour/LED Used	Wavelength (nm)	Frequency (Hz)	Stopping Potential (V)

Graph:

Plot Stopping Potential (Y-axis) vs Frequency (X-axis)

Calculations:

Example:

- Calculate the slope of the V vs ν graph.
- Use h = Slope × e

Results:

The value of Planck's constant as determined from the experiment is __________ Js.

Viva Questions:

1. What is the photoelectric effect?
2. Why is stopping potential used in this experiment?
3. How is Planck's constant related to the photoelectric effect?
4. What factors influence the emission of photoelectrons?
5. Why is monochromatic light preferred for this experiment?

Answers:

Name: -

Branch / Div: - Roll No: -

Experiment No: 10

TITLE: Measuring optical power attenuation in plastic optical fiber

Date of Performance:

Date of Completion:

Rubrics for Assessment of Experiment
Performance Indicators for assessing Lab Outcomes

Performance Indicator	Exceed Expectations (EE)	Meet Expectations (ME)	Below Expectations (BE)	Marks Obtained
Performance (03 marks)	*The entire experiment was performed within the assigned time with full attention. (03)*	*The entire experiment was executed on the deadline with less attention (02)*	*The entire experiment was performed beyond the assigned time. (01)*	
Readings, Calculations & Graphs (03 marks)	*All the readings taken are in the range. All figures & Graphs are correctly drawn & Calculations are done accurately (03)*	*All the readings taken are not in the range. All figures &, Graphs are correctly drawn but some important features are missing & Calculations are done incorrectly (02)*	*All the readings are beyond range. All figures & Graphs are poorly drawn & Calculations are done incorrectly (01)*	
Understanding (02 marks)	*Complete understanding of the aim of the experiment and the basic concepts (02)*	*Incomplete understanding of the aim of the experiment and the basic concepts (01)*	*Very less understanding of the aim of the experiment and the basic concepts (0.5)*	
Timely submission (02 marks)	*Very neat and complete write-ups submitted on the assigned day. (02)*	*Write-ups submitted late by 2-4 day (01)*	*Write-ups submitted late by 4-6 day (0.5)*	
Total Marks				

Experiment No: 10

DETERMINATION OF RESISTIVITY BY FOUR PROBE METHOD

Aim: To determine the resistivity of a semiconductor sample using the four-probe method.

Apparatus: Four-probe apparatus, Semiconductor sample (e.g., Germanium wafer), Constant current source, Digital voltmeter, Thermometer Connecting wires.

Theory: The four-probe method is used to measure the resistivity of materials, especially semiconductors. It eliminates the error caused by contact resistance which is significant in low-resistance materials. In this method, current is passed through the outer two probes, and voltage is measured across the inner two probes.

The resistivity ρ is calculated using the measured voltage V and current I with a geometric correction factor based on the sample dimensions.

Formula: For a thin sample (thickness t << spacing s):

$$\rho = I2\pi sV \times f(st)$$

Where:

- ρ: Resistivity (Ω·cm)
- V: Voltage between inner probes
- I: Current through outer probes
- s: Probe spacing
- $f(t/s)$: Correction factor depending on the ratio t/s

For simplicity (if t is negligible), $\rho = 2\pi sV / I$

Experimental Arrangement:

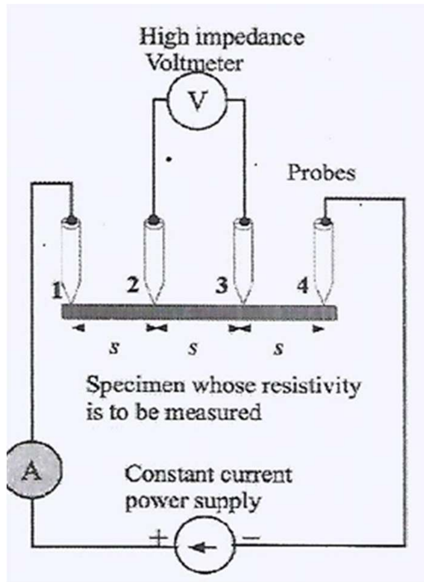

Figure 14: Schematic showing the arrangement of four probes placed linearly on a semiconductor wafer with connections to the current source and voltmeter.

Four Probe Method:

The 4-point probe set up (Fig.2) consists of four equally spaced tungsten metal tips with finite radius. Each tip is supported by springs on the end to minimize sample damage during probing. The four metal tips are part of an auto-mechanical stage which travels up and down during measurements. A high impedance current source is used to supply current through the outer two probes, a voltmeter measures the voltage across the inner two probes to determine sample resistivity. Typical probe spacings ~ 1 mm.

These inner probes draw no current because of the high input impedance voltmeter in the circuit. Thus, unwanted voltage drops (IR drop) at point B and point C caused by contact resistance between probes and the sample is eliminated from the potential measurements. Since these (such as oxidation of either surface), error with the conventional two-electrode technique (in which potential-measuring contact passes a current) can be quite large.

Procedure:

1. Connect the semiconductor sample to the four-probe setup.

2. Ensure equal spacing between the four probes.

3. Connect the outer probes to a constant current source.

4. Connect the inner probes to a voltmeter.

5. Switch on the current and note the current reading from the ammeter.

6. Record the voltage between the inner probes.
7. Repeat the readings for different current values if needed.
8. If temperature dependence is to be studied, heat the sample gradually and repeat measurements at various temperatures.

Observations:

1. Semiconductor chip material = __________________

2. Spacing (distance) between the probes, s = __________________

3. Thickness of the sample, t = __________________

4. Constant current passed through the sample = __________________

Sr No..	Current (I) (mA)	Voltage (V) (mV)	Spacing (s) (cm)	Resistivity (ρ) (Ω·cm)

Graph:

Plot Resistivity ρ (Y-axis) vs Temperature (X-axis) if temperature variation is studied.

Calculations:

Results:

The resistivity of the given semiconductor sample is __________ Ω·cm.

11. Viva Questions:

1. What is the purpose of using four probes instead of two?
2. Why is contact resistance negligible in this method?
3. What is the correction factor in the four-probe method?
4. How does temperature affect the resistivity of semiconductors?
5. What are the advantages of the four-probe method?

Answers: