

ENGINEERING PHYSICS LAB MANUAL CUM OBSERVATION

(Common to All Branches)



Sir C.V. RAMAN LABORATORY FOR EXPERIMENTAL PHYSICS

DEPARTMENT OF PHYSICS

LENDI INSTITUTE OF ENGINEERING AND TECHNOLOGY

An Autonomous Institution

Approved by AICTE & Permanently Affiliated to JNTUGV, Vizianagaram

Accredited by NAAC with "A" Grade and NBA (ECE, CSE, EEE & ME)

Jonnada (Village), Denkada-(Mandal), Vizianagaram Dist - 535 005

Engineering Physics Lab @ Lendi

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VISION & MISSION OF THE INSTITUTE

VISION

Producing globally competent and quality technocrats with human values for the holistic needs of industry and society

MISSION

- Creating an outstanding infrastructure and platform for enhancement of skills, knowledge and behaviour of students towards employment and higher studies.
- Providing a healthy environment for research, development and entrepreneurship, to meet the expectations of industry and society.
- Transforming the graduates to contribute to the socio-economic development and welfare of the society through value based education.

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

VISION

To be a frontier in computing technologies to produce globally competent computer science engineering graduates with moral values to build a vibrant society and nation.

MISSION

- Providing a strong theoretical and practical background in computer science engineering with an emphasis on software development.
- Inculcating professional behavior, strong ethical values, innovative research capabilities, and leadership abilities.
- Imparting the technical skills necessary for continued learning towards their professional growth and contribution to society and rural communities.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1: Graduates will have strong knowledge and skills to comprehend latest tools and techniques of Computer Engineering so that they can analyze, design and create computing products and solutions for real life problems.

PEO2: Graduates shall have multidisciplinary approach, professional attitude and ethics, communication and teamwork skills, and an ability to relate and solve social issues through computer engineering.

PEO3: Graduates will engage in life-long learning and professional development to adapt to rapidly changing technology.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1: Ability to grasp advanced programming techniques to solve contemporary issues.

PSO2: Have knowledge and expertise to analyze data and networks using latest tools and technologies.

PSO3: Qualify in national and international competitive examinations for successful higher studies and employment.

DEPARTMENT OF COMPUTER SCIENCE & SYSTEM ENGINEERING

VISION

To be a Centre of Excellence to impart the High Quality Education with productive Research and Consultancy in the field of Computer Science and Systems Engineering to globally competent ,highly competitive Professional with Ethical and Human values to serve the society

MISSION

- To impart high quality education with strong foundation of Computer Science and Systems Engineering principles that enables them to meet the challenges in profession/ career.
- To nurture research activities to get patents amongst faculty and students by providing necessary facilities and environment.
- To train the students into effective intrapersonal and communication skills and to develop team spirit, leadership capabilities, integrity and social responsibility with professional ethics and human values.
- To promote internships to students and consultancy works among faculty by enhancing Industry-Institute Interaction.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1: Graduates of Computer Science and Systems Engineering will acquire the knowledge to analyze, design and developing the new software and hardware products and acquire the skills to grasp the latest tools and techniques.

PEO2: Graduates of Computer Science and Systems Engineering will penetrate to interdisciplinary activities, with professional attitude and ethics, communication, to work under team and to ability to solve social issues through their Employment, Higher Studies and Research..

PEO3: Graduates of Computer Science and Systems Engineering will expose to learn life skills and Intrapersonal development activities to face the dynamically changing technology.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1: Ability to grasp the knowledge and expertise to solve all the contemporary issues.

PSO2: To acquire the knowledge on modern tools to solve hardware and software solutions.

PSO3: Qualify in national and international competitive examinations for successful higher studies and employment.

DEPARTMENT OF COMPUTER SCIENCE & INFORMATION TECHN.

VISION

To excel in computing arena and to produce globally competent computer science and Information Technology graduates with Ethical and Human values to serve the society.

MISSION

- To impart strong theoretical and practical background in computer science and information technology discipline with an emphasis on software development.
- To provide an open environment to the students and faculty that promotes professional growth
- To inculcate the skills necessary to continue their education and research for contribution to society.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1: Graduates of Computer Science and Information Technology will acquire strong knowledge to analyze, design and develop computing products and solutions for real life problems utilizing latest tools, techniques and technologies

PEO2: Graduates of Computer Science and Information Technology shall have interdisciplinary approach, professional attitude and ethics, communication, teamwork skills and leadership capabilities to solve social issues through their Employment, Higher Studies and Research.

PEO3: Graduates will engage in life-long learning and professional development to adapt to dynamically computing environment.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1: Ability to solve contemporary issues utilizing expertise.

PSO2: To acquire the knowledge on latest tools and technologies to provide technical solutions.

PSO3: To qualify in national and international competitive examinations for successful higher studies and employment.

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VISION

Emerge as a Center of Eminence in Electronics and Communication Engineering to impart quality education towards competent and skilled engineers.

MISSION

- Offering an inspiring and conducive learning environment to prepare skilled and competent engineers by having good infrastructure, laboratory facilities and effective teaching-learning process.
- Fostering culture to face complex technological challenges through Internships, projects and Industry-Institute Interactions in order to enhance employability skills.
- Creating an environment for higher studies and entrepreneurship by way of imparting quality education and promoting research activities.
- Imparting professional behavior and strong ethical values towards societal issues by encouraging socially relevant activities.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1: Graduates will have strong knowledge, skills and attitudes towards employment, higher studies and research.

PEO2: Graduates shall comprehend latest tools and techniques to analyze, design and develop novel systems and products to solve real life problems.

PEO3: Graduates shall have multidisciplinary approach, professional attitude, ethical values, good communication, team work and engage in life-long learning to adapt the rapidly changing technologies.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1: Capable of design, develop, test, verify and implement analog and digital electronics and communication engineering systems and products.

PSO2: Qualify in national and international competitive examinations for successful higher studies and employment.

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

VISION

To be a hub for imparting knowledge, skills, and behavior for exemplary contributions in the field of Electrical and Electronics Engineering.

MISSION

- To impart Technical Education through the state-of-the-art infrastructure facilities, laboratories and instruction.
- To inculcate industry oriented learning through industrial visits, internships, projects at Industries, MOUs, to make students' technically skills oriented.
- Creating conducive environment for higher education, employment and entrepreneurship through quality education, professional skills and research.
- To promote societal commitment among students by inculcating moral and ethical values.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1: Graduates shall have strong foundation in core and allied Electrical and Electronics Engineering, in sciences and mathematics, to become globally competent in designing, modeling & critical problem solving.

PEO2: Graduates shall involve in research activities in the field of electrical and electronics engineering through lifelong learning and provide solutions to engineering problems for sustainable development of society.

PEO3: Graduates shall have good communication skills and socio-ethical values for getting employment or higher studies by excelling in competitive examinations and be able to work in supportive and leadership roles.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1: Capable of design, develop, test, verify and implement electrical and electronics engineering systems and products.

PSO2: Succeed in national and international competitive examinations for successful higher studies and employment.

DEPARTMENT OF MECHANICAL ENGINEERING

VISION

Envisions mechanical engineers of highly competent and skilled professionals to meet the needs of the modern society.

MISSION

- Providing a conducive and inspiring learning environment to become competent engineers.
- Providing additional skills and training to meet the current and future needs of the Industry.
- Providing a unique environment towards entrepreneurship by fostering innovation, creativity, freedom and empowerment.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1: Graduates will have strong knowledge, skills and attitudes towards employment, higher studies and research.

PEO2: Graduates shall comprehend latest tools and techniques to analyze, design and develop novel systems and products for real life problems.

PEO3: Graduates shall have multidisciplinary approach, professional attitude, ethics, good communication, teamwork and engage in life-long learning to adapt the rapidly changing technologies.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1: Capable of design, develop and implement sustainable mechanical and environmental systems.

PSO2: Qualify in national and international competitive examinations for successful higher studies and employment.

PROGRAM OUTCOMES (POs)

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 consequent responsibilities 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 and 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 activities with 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.

COURSE OBJECTIVES

1. To impart the practical knowledge in basic concepts of Wave optics, Lasers and Fiber optics, Mechanics and Semiconductor physics
2. To familiarize the handling of basic physical apparatus like Vernier calipers, screw gauge, spectrometers, travelling microscope, laser device, optical fibers, etc.
3. To familiarize the students with the basic concepts of Physics
4. To expose the students in practical aspects of the theoretical concepts.

COURSE OUTCOMES

1. Apply the working principles of laboratory experiments in optics, mechanics, electrical and electronics
2. Compute the required parameter by suitable formula using experimental values (observed values) in optics, mechanics, electrical and electronics experiments.
3. Analyze the experimental results through graphical interpretation.
4. Recognize the required precautions to carry out the experiment and handling the apparatus in the laboratory.
5. Demonstrate the working principles, procedures and applications.

COs – POs & PSOs MAPPING (CSE & CSSE)

| SNO | DESCRIPTION | PO(1..12) MAPPING | PSO(1..3) MAPPING |
|-----|---|-------------------------------|----------------------|
| CO1 | Apply the working principles of laboratory experiments in optics, mechanics, electrical and electronics. | PO1, PO2, PO5, PO6, PO9, PO12 | |
| CO2 | Compute the required parameter by suitable formula using experimental values (observed values) in optics, mechanics, electrical and electronic experiments. | PO1, PO2, PO9, PO12 | |
| CO3 | Analyze the experimental results through graphical Interpretation. | PO1, PO2, PO9, PO12 | |
| CO4 | Recognize the required precautions to carry out the experiment and handling the apparatus in the laboratory. | PO1, PO2, PO5, PO6, PO9, PO12 | |
| CO5 | Demonstrate the working principles, procedures and applications. | PO1, PO2, PO5, PO6, PO9, PO12 | |

COURSE OVERALL PO/PSO MAPPING: PO1, PO2, PO5, PO6, PO9 & PO12

| SNO | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 | PO 11 | PO 12 | PSO 1 | PSO 2 | PSO 3 |
|---------------|------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|
| CO1 | 3 | 1 | | | 1 | 1 | | | 2 | | | 1 | | | |
| CO2 | 3 | 1 | | | | | | | 2 | | | 1 | | | |
| CO3 | 3 | 1 | | | | | | | 2 | | | 1 | | | |
| CO4 | 3 | 1 | | | 1 | 1 | | | 2 | | | 1 | | | |
| CO5 | 3 | 1 | | | 1 | 1 | | | 2 | | | 1 | | | |
| R23BSH-PH1202 | 3 | 1 | | | 1 | 1 | | | 2 | | | 1 | | | |

COURSE OUTCOMES VS POs MAPPING (DETAILED; HIGH: 3; MEDIUM: 2; LOW: 1):

COs VS POs MAPPING JUSTIFICATION:

| S.NO | PO/PSO MAPPED | LEVEL OF MAPPING | JUSTIFICATION |
|------|---------------|------------------|--|
| CO1 | PO1 | 3 | The student can able to apply the working principles of laboratory experiments of optics, mechanics, electrical & electronics. |
| | PO2 | 1 | The student can able to identify suitable formula of laboratory experiments for computing the required parameter. |
| | PO5 | 1 | The student can able to apply the basic knowledge of Lasers & optical fibers as modern engineering tools in the career. |
| | PO6 | 1 | The student can able to use the basic knowledge of Lasers & optical fibers in the health & Society relevant applications. |
| | PO9 | 2 | The student can able to understand how to work in a team as a member by sharing his ideas; thoughts & knowledge to identify the procedure of laboratory experiments. |
| | PO12 | 1 | The student can able to utilize this basic experimental knowledge for further development in the career. |
| CO2 | PO1 | 3 | The student can able to apply the working principles of laboratory experiments of optics, electrical and electronics. |
| | PO2 | 1 | The student can able to compute the required parameter by suitable formula of laboratory experiments. |
| | PO9 | 2 | The student can able to understand how to work in a team as a member by sharing his ideas; thoughts & knowledge to compute the required parameter of laboratory experiments. |
| | PO12 | 1 | The student can able to utilize this basic experimental knowledge for further designing & development in the career. |

| | | | |
|-----|------|---|---|
| CO3 | PO1 | 3 | The student can able to apply the knowledge of optics, electrical and electronics to analyze the experimental results through graphical interpretation. |
| | PO2 | 1 | The student can able to analyze the experimental results through graphical interpretation. |
| | PO9 | 2 | The student can able to understand how to work in a team as a member by sharing his ideas; thoughts & knowledge to analyze the experimental results through graphical interpretation. |
| | PO12 | 1 | The student can able to utilize these fundamental principles, procedures and applications life long for the improvement. |
| CO4 | PO1 | 3 | The student can able to apply the knowledge of optics, electrical and electronics to recognize the required precautions to carry out the experiment and handling the apparatus in the laboratory. |
| | PO2 | 1 | The student can able to identify the required precautions to carry out the experiment and handling the apparatus in the laboratory. |
| | PO5 | 1 | The student can able to apply the basic knowledge of Lasers & optical fibers as modern engineering tools in the career. |
| | PO6 | 1 | The student can able to use the basic knowledge of Lasers & optical fibers in the health& Society relevant applications. |
| | PO9 | 2 | The student can able to understand how to work in a team as a member by sharing his ideas; thoughts & knowledge to recognize the required precautions to carry out the experiment and handling the apparatus in the laboratory. |
| | PO12 | 1 | The student can able to utilize this basic experimental knowledge for further designing & development in the career. |
| CO5 | PO1 | 3 | The student can able to apply the knowledge of optics, electricals and electronics to demonstrate the working principles, procedures and applications of experiments through viva-voce. |
| | PO2 | 1 | The student can able to demonstrate the working principles, procedures and applications of experiments through viva-voce. |
| | PO5 | 1 | The student can able to apply the basic knowledge of Lasers & optical fibers as modern engineering tools in the career. |
| | PO6 | 1 | The student can able to use the basic knowledge of Lasers & optical fibers in the health& Society relevant applications. |

| | | | |
|---------------|--------------------------------|-------------|--|
| | PO9 | 2 | The student can able to understand how to work in a team as a member by sharing his ideas; thoughts & knowledge to demonstrate the working principles, procedures and applications of experiments through viva-voce. |
| | PO12 | 1 | The student can able to utilize these fundamental principles, procedures and applications lifelong for the improvement. |
| R23BSH-PH1202 | PO1,PO2 PO5,PO6 PO9,PO12 | 3,1,1,1,2,1 | The student can able to acquire knowledge of basic experiments of Applied Physics and apply these principles & knowledge in his/her engineering course. |

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List of Experiments

(As Per autonomous syllabus of Lendi Institute of Engg & Technology)

1. Determination of the temperature co-efficient of resistance of a given Thermistor
2. Determination of the radius of curvature of the lens by Newton's rings method
3. Verification of laws of vibrating string by sonometer.
4. Determination of wavelength of mercury light by plane diffraction grating.
5. Determination of the energy band gap of a given semi-conductor.
6. Determination of acceleration due to gravity by Compound Pendulum.
7. Determination of wavelength of laser light by normal incidence method.
8. Determination of rigidity modulus of a given wire by Torsional Pendulum.
9. Determination of the Numerical Aperture of a given Optical Fiber & find its acceptance angle.
10. Determination of the resolving power of grating.

Virtual Physics Lab Experiments

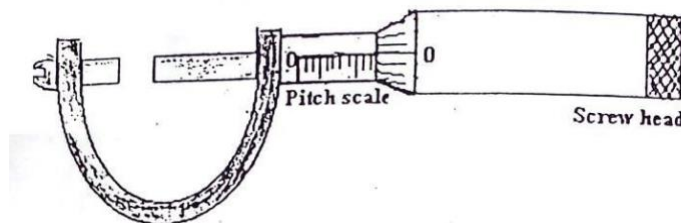
11. Determination of the Brewster's angle.
12. Determination of the Hall coefficient & the carrier concentration of charge carriers in the given sample material by Hall Effect.

Instructions for Students @ Applied Physics Laboratory

- The objective of the laboratory is learning (application point of view). The experiments are designed to illustrate phenomena in different areas of Physics and to expose you to measuring instruments. Conduct the experiments with interest and an attitude of learning.
- You need to come well prepared for the experiment.
- Work quietly and carefully (the whole purpose of experimentation is to make reliable measurements & to experience the application based analytical thinking) and equally share the work with your partners.
- Be honest in recording and representing your data. Never make up readings or manipulate them to get a better fit for a graph. If a particular reading appears wrong repeat the measurement carefully. In any event all the data recorded in the tables have to be faithfully displayed on the graph.
- Bring observation book cum manual and necessary graph papers for each of experiment. Learn to optimize on usage of graph papers.
- Graphs should be neatly drawn with pencil. Always label the graphs, the axes and display units. Please write the scale at the top-right most corner of the graph paper.
- If you finish early, spend the remaining time to complete the calculations and drawing graphs.
- Come equipped with calculator, pen, scale, pencil, eraser, sharpener, etc.
- Get the signature from your Lab Faculty before leaving the lab on your observation book. And also submit your pending calculations & graph works within two days after completion of your lab.
- Do not fiddle idly with apparatus. Handle instruments with care. Report any breakage to the Lab-Technician/ Faculty.
- Return all the equipment at the end of your experiment.
- Bring your records at each lab session & submit it for the correction of previously completed experiments.

SCREW GAUGE

It is an instrument used for the measurement of very small lengths (such as the diameter of a wire and thickness of a disc) with greater accuracy than is possible with Vernier calipers. The screw gauge consists of U-shaped metal frame which is attached to a hollow cylinder with a screw head. The screw head has a cap which is marked with 100 equal divisions. This is called Head scale. The hollow cylinder is marked in millimeters called Pitch scale. The distance advanced on the pitch scale when the screw head is turned through one complete revolution is called the pitch of the screw. Least count of the screw gauge is the distance advanced by the screw when the screw is turned through one division on the head scale.



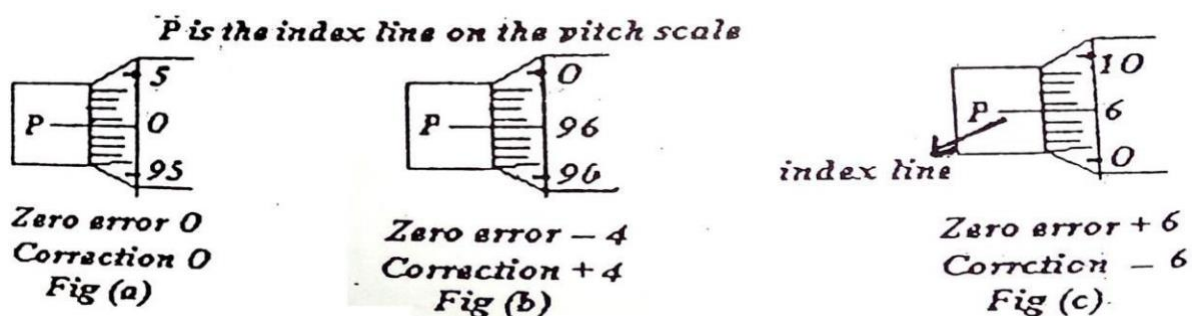
L.C of the screw gauge = pitch of the screw/No of Head scale divisions.

Pitch of the screw = Distance moved on the pitch scale for one rotation of the head.

The distance is divided by 5 gives the value of the pitch of the screw. Again the pitch of the screw is divided by the number of head scale divisions and the resulting value is the least count of the screw gauge.

The screw head is turned until the two jaws touch each other. If the zero of the head scale exactly coincides with the zero of the pitch scale line (called index line) then there is no zero error and no correction is to be made to the head scale reading. If they do not coincide then the instrument is said to have zero error and a correction is to be applied. In fig (a) the zero of the head scale coincides with the pitch scale line and hence correction is zero. If the zero division of the head scale is above the pitch scale line then the error is negative and the correction is positive. In fig (b) the zero of the head scale is 4 divisions above the index line, hence the error is -4 and the correction is +4. Therefore 4 must be added to the head scale reading.

In fig(c) zero of the head scale is below index line the error is +6 and correction is -6 which means that 6 must subtracted from the head scale reading.



Place the given object between the two jaws of the screw gauge and the screw head is turned gently until the two jaws touch the object. Note down the pitch scale reading (PSR) and head scale division opposite to the pitch scale index line called head scale reading (HSR). Correct the head scale reading (CHSR) in case the correction is not zero. Then

Total reading = PSR + (CHSR x Least count)

VERNIER CALIPERS

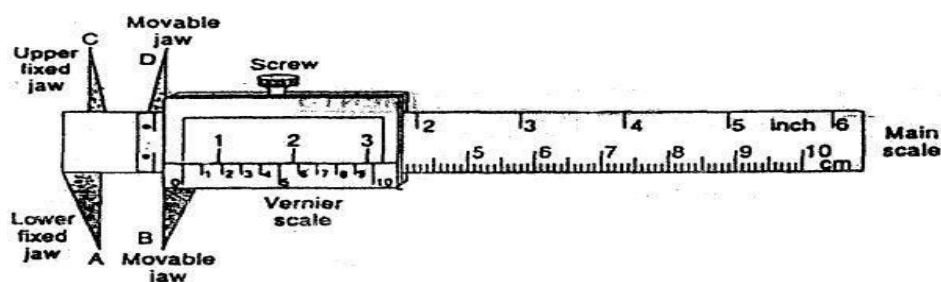
A scale is used to measure the length of an object. One end of the object is made to coincide with the zero of the scale, the other end of the object falls between the fifth and sixth divisions. This means that the length of the object is greater than 5 divisions and less than 6 divisions. So the length of the object is 5 divisions plus some fraction of a scale division. An accurate measurement of this fractional length can be made by means of Vernier calipers and screw gauge.

A Vernier caliper is an instrument used for the measurement of small lengths such as diameter of a disc and diameter of a bob. The vernier calipers consist of a rectangular metal strip, graduated in centimeters, with a fixed jaw at one end. This is called main scale. A movable jaw with Vernier attached to it slides along the main scale and can be fixed at any position with a screw. This is called Vernier scale. The Vernier scale is graduated in such a way that the length of 10 divisions on the Vernier scale (VSD) is equal to length of 9 main scale divisions (MSD). Thus the length of 1 VSD = $\frac{9}{10}$ of the MSD. Then the difference between one MSD and one VSD is $1 - \frac{9}{10}$ MSD = $\frac{1}{10}$ MSD, which is called the Least count of the Vernier calipers. The least count of Vernier calipers of an instrument is the smallest value that can be measured with that instrument.

$$1 \text{ MSD} = \frac{1}{10} \text{ cm}; 10 \text{ VSD} = 9 \text{ MSD or } 1 \text{ VSD} = \frac{9}{10} \text{ MSD}$$

$$\text{Least count of Vernier calipers} = 1 \text{ MSD} - 1 \text{ VSD} = (1 - \frac{9}{10}) \text{ MSD} = \frac{1}{10} \text{ MSD}$$

$$= (\frac{1}{10}) \times \frac{1}{10} \text{ cm} = \frac{1}{100} \text{ cm} = 0.01 \text{ cm}$$

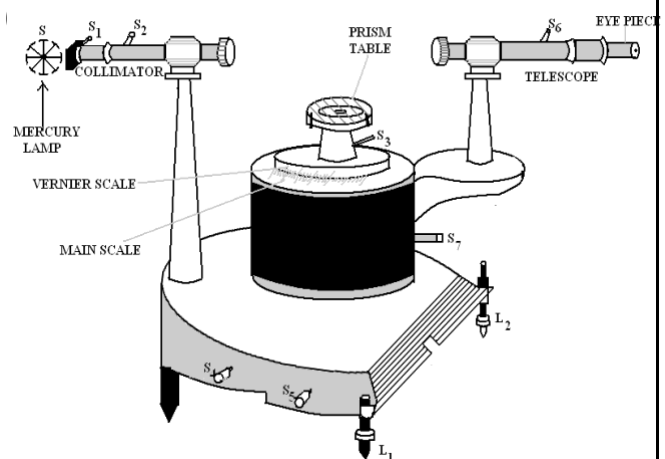


Least count can also be expressed as $1 \text{ MSD} / \text{No. of Vernier scale divisions}$.

Suppose the length of the object is to be measured using Vernier calipers. The object is placed between the fixed jaw and movable jaw. Suppose the zero of the Vernier lies between 1.7 cm and

cm. This means the length of the object is greater than 1.7 cm and less than 1.8 cm. The fractional part exceeding 1.7 cm (called main scale reading MSR) can be determined from the Vernier coincidence. Suppose the 4 division on the Vernier exactly coincides with one of the main scale divisions. This Vernier division which coincides with the main scale division is called Vernier coincidence. So the fraction exceeding the 1.7 cm is $(4 \text{ MSD} - 4 \text{ VSD})$. This fraction is equal to $4 (1 \text{ MSD} - 1 \text{ VSD}) = 4 \times \text{Least count}$. Therefore the length of the object = MSR + (Vernier coincidence \times L.count) = $1.7 \text{ cm} + 4 \times$

SPECTRO METER



Align the spectrometer in order to correctly measure angles with the spectrometer, we must first align it. To do so, use the following steps:

a) **Telescope focus:** Do not put the prism onto the silver table yet. That will come later. Notice that there are two knobs associated with the telescope. They are located directly under the telescope barrel. One points along the barrel and one is perpendicular to it. The knob that is along the barrel will lock the telescope's position and will prevent it from rotating. When it is locked down in this way, you can use the other knob for a fine adjustment, to rotate it by very small amounts. If the telescope is not unlocked, turn the knob that is parallel to the barrel counterclockwise until you can freely rotate the telescope. Turn the telescope so that it is not pointing at the collimator but is instead aimed at something as far away from you in the room as possible. Now rotate the focus adjustment (**see diagram on page 12**) until you can see through the telescope clearly. You may notice that the image is upside down. This is normal. Just ensure that it is as clear and in focus as you can. ***After this adjustment, you should not adjust the focus of the telescope again.***

b) **Telescope alignment:** Now place a white light (desk lamp) in front of the slit on the end of the collimator (**in the diagram on page 12**), the desk lamp goes where the "HG lamp" is pictured). Now rotate the telescope until it is pointed at the collimator. You should imagine a straight line going from the lamp through the collimator, and through the telescope. By looking through the telescope, you should be able to line up the crosshair with the slit in the far end of the collimator. By locking down the telescope and using the fine adjustment (the knob perpendicular to the one that you used to lock down the telescope) you should be able to do this very accurately.

If you are unable to see the slit, it may be closed too tightly. You can widen and narrow the slit by rotating the adjuster on the collimator (it is located on the far end of the collimator, much like the focus for the telescope). This will adjust the slit width, but will not focus the slit. If the slit does not have very crisp edges when you look through the telescope, move the end of the collimator near the lamp in and out to focus it. If your slit is not vertical in the telescope, you can also rotate it so that it is. Once you have a nice thin, well-focused slit, with your crosshairs centered on it **and your telescope locked down**, you are now ready to align the scales to read the angle.

c) **Angle adjustment:** If you look below the set of knobs that control the telescope, you will see another pair of knobs that look identical to the ones for the telescope. These knobs perform the same functions (locking down and fine adjustment) for the black table itself. If you unlock the black table, you can rotate it. Notice that there are two windows in which you can read an angle. We want to rotate the table until one of the windows has 0 (zero) lined up with 0 (zero) or 360 (since a circle is 360 degrees, 360 is the same as 180. If at all possible, we should try to use set it so that this window is to the left of the telescope (as we are looking over the barrel toward the lamp) because this will make reading our angle easiest. (Please have a look at the diagram on page 5) On some scopes there is a small magnifier attached to the black table over one window, and this would also be advantageous to use. Once you have aligned them, you will ***lock down the black table and will not rotate it again.*** From now on, we will ***only rotate the telescope.***

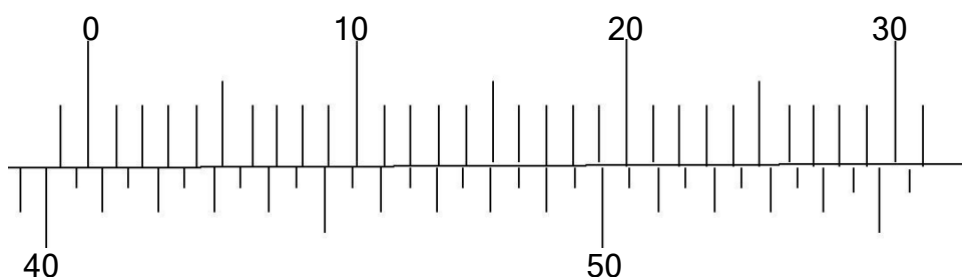
d) **Prism placement:** Now you should place the prism in the center of the silver table. Recall that light is bent toward the base of the prism, so it should be placed on the silver table so that the gray plastic part makes a "C" shape if

you were to look at it from the telescope side of the apparatus. Now, without moving the telescope, move your head to the left (about to where the telescope is rotated to in the diagram on page 5) and look into the prism. You will have to put your head down at the height of the telescope/collimator. Now rotate the silver table clockwise until you can see a nice rainbow like spectrum "inside" the prism. (You should notice that the rainbow is inside of a black circle. You are seeing the light coming out of the collimator and bent through the prism.) If it does not look like a very nice, bright, well formed rainbow, you probably do not have your head in the right place; move further left and try to rotate the silver table back and forth. Once you have found it, unlock the telescope (**not the black table**) and rotate it **to the left** where you were looking. Now look through the telescope, and you should be able to find the rainbow. We are now in about the right place to find our spectrum with the mercury vapor lamp and to adjust for the minimum angle of deviation.

e) **Minimum angle of deviation:** Now, remove the white light and replace it with the mercury vapor lamp. You will want to move the lamp until it is aligned with the slit. To do this, look through the telescope and move the lamp back and forth until it is nice and bright in the telescope. **Instead of a complete rainbow, you should now see only certain bands of colors.** If your bands do not look nice and sharp, you may have to adjust your slit focus or width. Some lines are better seen if you tighten the slit. (The lamp should be very close to the slit.) Move the telescope back and forth until you get the cross hair lined up on the **green band**. Now look back to the diagram on page 12. We want to make the angle as small as possible. To do this, rotate the silver table back and forth just a little bit. You should be able to get the green line to move **to the right**. Now realign the crosshair on the green line and rotate the silver table a little bit again. Then realign the crosshair on the green line. You should repeat this process until no matter which way you rotate the silver table, the green line goes to the left, not the right. When this occurs, and the green line is as far as you can get it to go to the right, you are at the minimum angle of deviation. This angle should be around 51 or 52 degrees for the green line. If it is not, you may not have aligned the scales correctly, please repeat steps c, d, and e from above. (Record it below). Every time that you do a different color, you will have to repeat this process.

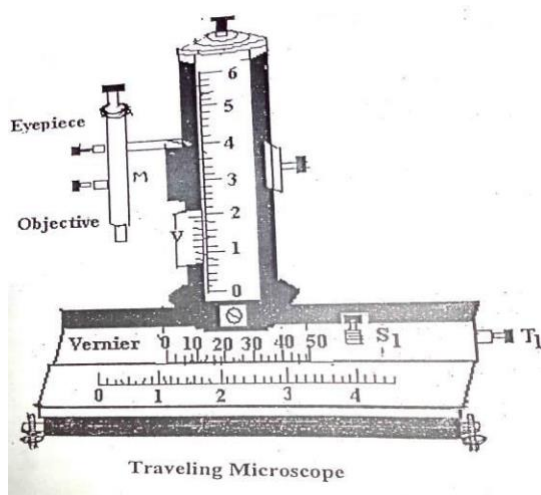
PROCEDURE: Become familiar with the spectrometer identify each component: the black table, the prism table, the collimator, and the telescope (see figure above). Note the clamping screws and the fine adjustment screws for the telescope and the black table. Note the clamping screw for the prism table. Note how to adjust the slit focusing in the collimator tube. Note how the slit width can be adjusted and how the slit orientation can be rotated

Practice reading the angle from a precise protractor scale on the rim of the black table. Use the Vernier scale with the little magnifying glass to read the angle to the nearest arc minute. (1 arc min = 1' = 1/60 degree.) **The following is an example:**



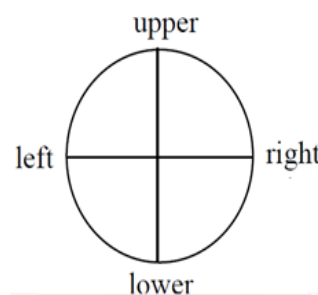
In this example, the zero line of the Vernier scale (the upper scale) is between 40° 30' and 41°, so the angle is somewhere between 40° 30' and 41°. The Vernier scale tells exactly where in between. Look along the Vernier for the line that exactly lines up with the line below it. In this case, it's the 17' line. So the angle is 40° 47', which we get by adding 17' to 40° 30'. Before using this angle in equation (2), we must convert it to decimal degrees: $40 + (47/60)$ degrees = 40.78°.

A Travelling Microscope



A travelling microscope is used to determine small distance to an accuracy of **0.001 cm**. The measurement principle is based on the principle of Vernier. In a typical travelling microscope, the main scale divisions are of magnitude **1/20 cm = 0.05 cm (0.5 mm)** each and the Vernier scale contains 50 divisions. This makes the Least Count to be **0.05/50 = 0.001 cm**.

Determination of diameter: For determination of diameter of the capillary along the horizontal direction. Mount the capillary tube in horizontal direction in a stand with the help of a rubber cork to place and hold the capillary tube. Rotate the microscope so that it is horizontal and in line with the tip of the capillary tube. Now looking through the microscope, turn the focusing screw to get a clear image of the capillary tube. Now adjust the microscope in such a way that the vertical crosswire coincides with the left end of the capillary tube. Take the reading in the horizontal scale, look the zero of the Vernier, and find out the division on the main scale just before the zero mark. Note it as the MSR. Now look carefully at the Vernier. Any one of the fifty lines will come exactly in line with one of the lines of the main scale. That division on the **Vernier** is the Vernier scale reading. Note it down in the observation table. Now move the telescope horizontally to focus on the right end of the capillary tube. Again take the reading as before. Repeat the experiment by moving the telescope vertically coinciding the horizontal crosswire with top and bottom and now the readings are taken on the vertical scale. From the observations you will get two values of diameter, one for vertical and one for the horizontal.



Total reading = Main scale reading + Vernier coincidence x Least count

OBSERVATIONS: Least count of the traveling microscope = 0.001 cm

BACK – LASH ERROR:

This error occurs when instruments like screw gauge, speedometer and travelling microscope are used, which work on screw-nut principle. Due to wear and tear of the screw or imperfect fitting, some space will be left between the screw and nut for its operation. If the screw is rotated for a certain angle of rotation in the forward direction and afterwards in the backward direction, then the screw will not move for a little motion of the head of the screw (or the misfits in the nut through which it moves). This error is called back-lash error. In order to avoid this error, the screw must always be moved in the same direction. This is to be remembered whenever we use any instrument using / involving screw motion.

EXPERIMENT NO – 1 THERMISTOR

Experiment No:
Date:

AIM: To determine the temperature coefficient of resistance of a given Thermistor

APPARATUS

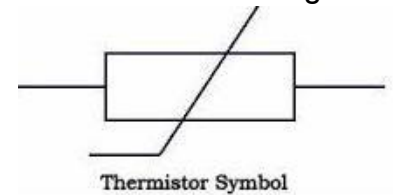
A Thermistor, thermometer, a heating arrangement to heat the Thermistor, constant current power supply, galvanometer, millimeter and volt meter

WORKING PRINCIPLE: *Thermally Varying Resistance:* The basic the electrical resistance of the device changes drastically when the temperature is varied. These devices are called thermistor because of their thermally sensitive property of resistance. These materials have a negative temperature coefficient of resistance.

Formula:

The temperature coefficient of resistance of Thermistor is

$$\alpha = \frac{R_2 - R_1}{R_1 T_2 - R_2 T_1} \text{ } ^\circ\text{C}$$

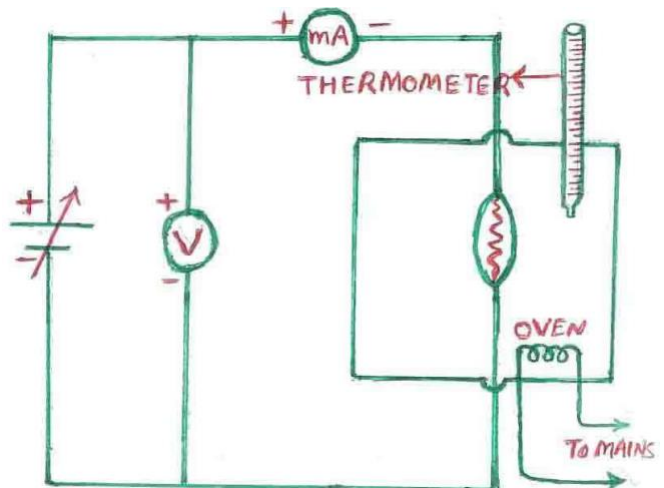


Where R_1 and R_2 are the resistances of thermistor and T_1 and T_2 are temperatures

THEORY:

Thermistors are semiconductor devices. The basic property is the electrical resistance of the device changes drastically when the temperature is varied. These devices are called thermistor because of their thermally sensitive property of resistance. Thermistor materials are mainly ceramic compounds having semiconductor properties. They are made up of oxides of Mn, Ni, Fe and Co and blended in suitable proportion and compressed in to desired shapes from powders and heat treated to re crystallize them, Suitable combination of these oxide materials are used to obtain the necessary range of resistance. Conduction is controlled by the concentration of the oxygen in the semiconductors. N-type oxide semiconductors are produced when the metal oxides are compounded with deficiency of oxygen.

Circuit diagram:



Because of this process there will be excess ionized metal atoms in the lattice. P-type semiconductors are produced when there is excess of oxygen, which results in deficiency of ionized metal atoms in the lattice. ' α ' is called the temperature coefficient of resistance for a given material.

It is positive for metallic elements as their resistance increases with temperature. Hence the materials have a positive temperature coefficient of materials. On the other hand α is negative for carbon and semiconductors because their resistance which decreases with increasing temperature. These materials have a negative temperature coefficient of resistance.

The variation of resistance (R) of a thermistor with temperature (T) is given by,

$$R = A e^{\frac{B}{T}} \quad (1)$$

where 'A' and 'B' are constants, which are to be experimentally determined, 'R' is the resistance of the thermistor and 'T' is the temperature.

Taking logarithm on both sides, we get

$$\log_{10} R = \log_{10} A + \left(\frac{B}{2.303} \right) \frac{1}{T} \quad (2)$$

Now the temperature coefficient of resistance ' α ' of the thermistor is given by,

$$\alpha = \frac{1}{R} \frac{dR}{dT} = - \frac{B}{T^2} \quad (3)$$

Evidently, α is negative (as expected) and is also temperature dependent.

The temperature coefficient of thermistor materials is many orders of magnitude greater than that of metals. From (2),

$$\log_{10} R = \log_{10} A + \left(\frac{B}{2.303 \times 10^3} \right) \frac{10^3}{T} \quad (4)$$

This is in the form $y = mx + c$ where the slope $m = \frac{B}{2.303 \times 10^3}$ (5)

Taking the value of B from the above equation (5), the activation energy can be determined as follows

$$E_g/2k = B \quad \text{or} \quad E_g = 2KB \quad (6)$$

The temperature resistance characteristics of the thermistor exhibits an exponential type of behavior and it is given by the relation

$$R = R_0 \exp \left[B \left(\frac{1}{T} - \frac{1}{T_0} \right) \right]$$

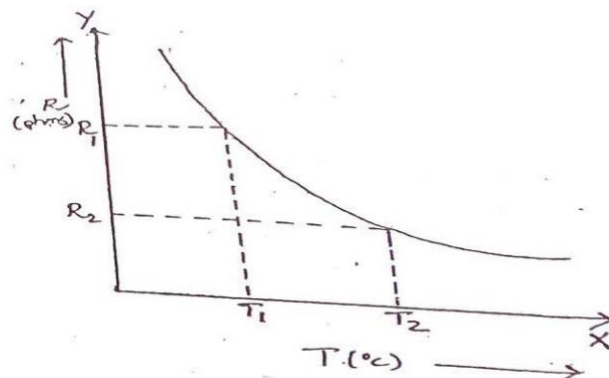
If we differentiate this equation we get,

$$\frac{\Delta R}{\Delta T} = R_0 \exp \left[B \left(\frac{1}{T} - \frac{1}{T_0} \right) \right] \frac{-B}{T^2}$$

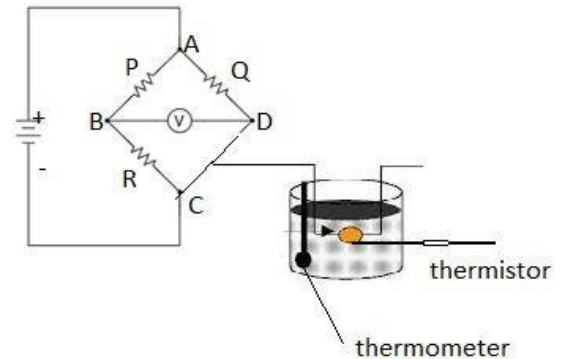
$$\text{But } \frac{1}{R} \frac{\Delta R}{\Delta T} = \alpha, \text{ where } \alpha = \frac{-B}{T^2}$$

GRAPH:

A plot drawn between $\log R$ on y-axis and $10^3/T$ on x-axis gives a straight line and slope of this line is equal to $B/2.303 \times 10^3$. By measuring the slope of the graph we can determine the value of B



Experimental diagram



The intercept (OP) along the y-axis as shown in the model graph gives the value of log A from which the value of 'A' is calculated.

From the graph temperature coefficient of resistance 'α' can be calculated using the formula

$$\alpha = \frac{R_2 - R_1}{R_1 T_2 - R_2 T_1} \text{ } ^\circ\text{C}$$

Where R_1 and R_2 are the resistances of the thermistor at the temperatures T_1 and T_2 respectively.

PROCEDURE:

1. Connect the +5V power supply to power supply socket and galvanometer or Voltmeter socket
2. Also connect the variable resistance (0 to 1000 Ω) to variable resistance socket and thermistor terminal to thermistor socket which are given on heater.
3. Put up the thermistor to heater where the thermistor keeps up option
4. Switch on the kit and set the galvanometer to zero by variable resistance. Switch on the heater
5. As soon as the temperature increases i.e. 30°C, 35°C, 40°C, 45°C, 50°C, 55°C, 60°C, 65°C, 70°C and 75°C the value of resistance is found by multimeter. (Suppose the temperature is 40°C, now the galvanometer shows some deflection now decrease it to zero by variable resistance and take reading of resistance by multimeter. This is the reading of R at 40°C. Similar take readings for different temperatures).
6. Note down the readings & Plot the graph between R Vs T(K).

OBSERVATIONS: Input Voltage $V_i =$

| SNo | Temperature t ($^\circ\text{C}$) | Current (I) mA | Temperature $T = t + 273$ (K) | $\frac{1000}{T}$ (K^{-1}) | Resistance R K Ω | Log R |
|-----|---|-------------------|-------------------------------------|--------------------------------------|-------------------------------|-------|
| 1 | 30 $^\circ$ | | | | | |
| 2 | 35 $^\circ$ | | | | | |
| 3 | 40 $^\circ$ | | | | | |
| 4 | 45 $^\circ$ | | | | | |
| 5 | 50 $^\circ$ | | | | | |
| 6 | 55 $^\circ$ | | | | | |
| 7 | 60 $^\circ$ | | | | | |
| 8 | 65 $^\circ$ | | | | | |
| 9 | 70 $^\circ$ | | | | | |
| 10 | 75 $^\circ$ | | | | | |

APPLICATIONS:

1. Thermistor can be used as current-limiting devices for circuit protection, as replacements for fuses. Current through the device causes a small amount of resistive heating. If the current is large enough to generate more heat than the device can lose to its surroundings, the device heats up, causing its resistance to increase, and therefore causing even more heating. This creates a self-reinforcing effect that drives the resistance upwards, reducing the current and voltage available to the device.
2. Thermistors are used for Self regulating heaters, Liquid level sensing, Motor starting.
3. Thermistors are used as resistance thermometers in low-temperature measurements of the order of 10 K.
4. Thermistors are regularly used in automotive applications. For example, they monitor things like coolant temperature and/or oil temperature inside the engine and provide data to the ECU (Engine Control Unit).
5. Thermistors are also commonly used in modern digital thermostats and to monitor the temperature of battery packs while charging.

PRECAUTIONS:

1. The thermistor and thermometer are kept at the same level in the oil bath.
2. The temperature of the thermistor should not be allowed to go beyond 80° C.

CALCULATIONS:

RESULT: The temperature coefficient of resistance of the given Thermistor is =

Conclusion: Course outcomes **CO1 to CO5**, Program outcomes **PO1, PO2, PO9 & PO12** are attained.

Signature of Faculty
with date & Remark

VIVA QUESTIONS

1. What is a thermistor?

Thermistor is a semiconductor material usually prepared from metal oxides whose electric resistance changes drastically for even minute changes in temperature.

2. What is positive temperature coefficient of resistance?

A positive temperature coefficient (PTC) refers to materials that experience an increase in electrical resistance when their temperature is raised. e.g. all conductors

3. What is negative temperature coefficient of resistance?

A negative temperature coefficient (NTC) refers to materials that experience a decrease in electrical resistance when their temperature is raised. e.g. semiconductors

4 What is the difference of semiconductor diode and thermistor?

In a semiconductor the carrier concentration depends on temperature but the carrier concentration is temperature independent in case of thermistor. The variation of electrical resistance in thermistor with temperature is due to only the thermal activation of charge carriers with increase of temperature.

5 What is activation energy?

The quantity of energy required for the electric conduction to take place in a thermistor is called as the activation energy.

Experiment No:
Date:

EXPERIMENT NO - 2

NEWTON'S RINGS

AIM: To determine the radius of curvature of given Plano-convex lens by Newton's rings method

APPARATUS: A Plano-convex lens, piece of thick glass plate, thin glass plate, sodium vapour lamp, traveling micro scope and black sheet.

WORKING PRINCIPLE: *Interference of Light*: The light reflected from the upper and lower surfaces of thin air film formed in between the lower surface of convex lens and upper surface of glass plate.

FORMULA: The Newton's rings experiment is an example of interference of light by division of amplitude in reflected light according to the theory of Newton's rings, the diameter of the m^{th} dark ring is given by $D_m = 2\sqrt{m\lambda R}$ where $m=1,2..$ etc and diameter of the n^{th} dark ring is $D_n = 2\sqrt{n\lambda R}$ where $n=0,1,2..$ etc

Therefore, $D_m^2 - D_n^2 = 4m\lambda R - 4n\lambda R$ or

$$R = \frac{D_m^2 - D_n^2}{4\lambda(m-n)} \text{ cm}$$

Where,

R is the radius of curvature of the lens in constant with the glass plate (cm)

D_m and D_n are the diameters of the m^{th} and n^{th} dark rings respectively (cm)

m, n are the number of chosen rings

λ is the wavelength of the monochromatic source of light(sodium light)

($\lambda = 5893 \text{ \AA} = 5893 \times 10^{-8} \text{ cm}$)

Concentric ring system is formed because the path difference between the two interfering light rays is constant radially or the locus of all points having the same air gap is a circle.

The values of D_m and D_n are small and are measured accurately with the traveling microscope. It can be seen from the formula that the diameter of the ring increases with the radius of curvature R . Therefore it is desirable to select a suitable convex lens of long focal length for forming rings. The diameter of the bright fringes is proportional to the square root of the natural numbers.

$$D_n (\text{bright}) = \sqrt{(2n-1)\lambda R}$$

$$D_n (\text{dark}) = 2\sqrt{n\lambda R}$$

ARRANGEMENT OF APPARATUS:

Clean the surface of the convex lens and thick glass plate P_1 . With lens paper. Keep the glass plate on a black paper laid on the platform of the traveling microscope. Place the convex lens of large radius of curvature on the glass plate with its spherical surface in contact with the glass plate. Direct a parallel beam of light from a sodium lamp on to a thin glass plate P_2 kept inclined at 45° to the horizontal as shown in fig. The beam of light is reflected on to the lens by the glass plate P_2 . As a result of interference between the light rays reflected from the lower surface of the convex lens and the top surface of the thick glass plate P_1 , a concentric ring system (Newton's rings) with alternate dark and bright rings having a black spot at the center, will be seen through the microscope. In other words the light reflected from the top and bottom surfaces of the air film superimpose giving rise to interference fringes in the form of alternate bright and dark concentric rings,

called Newton's rings.

Ray Diagram

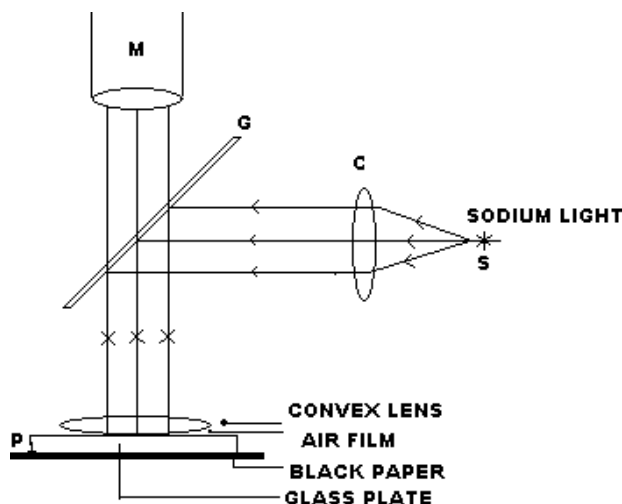


Fig: Experimental arrangement to observe Newton's Rings

Adjust the microscope until the rings are in sharp focus. Improve the definition of the rings by slightly adjusting the reflecting glass plate P_2 with respect to the sodium light. Sometimes due to the presence of the dust particles between the lens and the thick glass plate the central spot may be bright. In such a case clean the surface of the lens and glass plate to get a dark spot at the center.

PROCEDURE:

Determine the least count of the traveling microscope and record it in your observation book. Scribble with pen on a piece of white paper and place it on the glass plate and focus the microscope such that the writing on the white paper is clearly visible. Bring the point of intersection of the cross-wire to the center of the ring system and if necessary turn the cross-wires such that one of them is perpendicular to the line of travel of the microscope. This wire can be set tangential to any ring while making measurement. Starting from the center of the ring system move the microscope, say to the left across the field of view counting the numbers of the rings.

After passing beyond the 14th dark ring tangential to it, note the main scale reading and vernier coincidence on the horizontal scale using a reading lens. Similarly note the readings with the cross wire set successively on the 14th, 12th, 10th, 8th... up to 14th dark ring on the right side. Readings should be taken with the microscope moving in the same direction to avoid errors due to back-slash. Record the observations in the table given below. Note that as the microscope is moved from 14th dark ring on the left to the 14th dark ring on the right the microscope decreases continuously.

OBSERVATIONS: Least count of the microscope = $\frac{\text{Value of one M.S.D}}{\text{Total Number of vernier scale divisions}}$

TABLE:

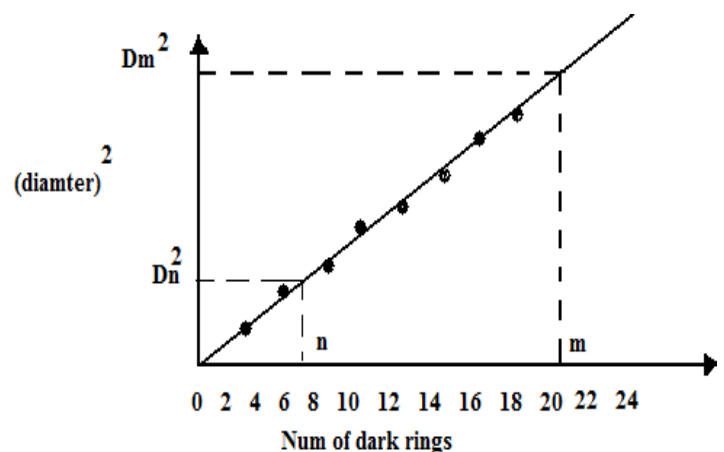
| No. Of Rings | Microscope Readings | | | | | | Diameter D= (a ~ b) Cm | (Diameter) ² D ² cm ² |
|--------------|---------------------|----|--|-----------|----|--|------------------------------|---|
| | Left | | | Right | | | | |
| | MSR Cm | VC | Total M.S.R+ (V.C X L.C) (a) cm | MSR Cm | VC | Total M.S.R+ (V.C X L.C) (b) cm | | |
| 14 | | | | | | | | |
| 12 | | | | | | | | |
| 10 | | | | | | | | |
| 8 | | | | | | | | |
| 6 | | | | | | | | |
| 4 | | | | | | | | |
| 2 | | | | | | | | |

Graph:

Draw a graph with number of dark rings on the X-axis and the square of the diameter of the rings on Y-axis. A straight line passing through the origin will be obtained. From the graph, note down the values of D_m^2 and D_n^2 corresponding to m^{th} (say 5 or 7) by substituting these values in above equation the radius of curvature of the given lens can be found.

Applications:

1. Interference is used in interference Auto Compensators in measurement engineering.



2. Interference is used in CWDM (Coarse Wavelength Division Multiplexing) system, which can have many diverse applications than the existing passive fiber optics.
3. Interference in thin films concept is used in non-reflecting coatings in engineering applications.
4. Laser light optical interference is used in MFM (Magnetic Force Microscopy).

CALCULATIONS: From Graph:

$$1) \quad m = 13, n = 3;$$

$$D_m^2 = \quad D_n^2 =$$

$$2) \quad m = 12, n = 2;$$

$$D_m^2 = \quad D_n^2 =$$

$$3) \quad m = 11, n = 1;$$

$$D_m^2 = \quad D_n^2 =$$

$$R1 = \frac{D_m^2 - D_n^2}{4\lambda(m-n)} \text{ cm}$$

$$R2 = \frac{D_m^2 - D_n^2}{4\lambda(m-n)} \text{ cm}$$

$$R3 = \frac{D_m^2 - D_n^2}{4\lambda(m-n)} \text{ cm}$$

RESULT: Radius of curvature of the given convex lens is R=

Signature of Faculty
with date & Remark

Conclusion: Course outcomes **CO1 to CO5**, Program outcomes **PO1, PO2, PO9 & PO12** are attained.

Viva Questions

1. What do you mean by interference of light?

The modification in the distribution of light energy due to the superposition of two or more waves of light is called interference of light.

2. What are the conditions for sustained interference?

- (a) The light waves superposing at a point must have the same wavelength or same frequency.
- (b) The amplitude of superposing light waves should be equal or almost equal.
- (c) The waves superposing should either have the same phase or constant phase difference.
- (d) Light sources must be very narrow and very close to each other.

3. Explain the term coherent sources?

Any two sources of light continuously emitting light waves have zero or constant phase difference are called coherent sources.

4. How Newton's rings are formed?

When a monochromatic light falls normally on a plano-convex lens and glass plate set, the light reflected by the lower surface of the lens and the upper surface of the glass plate superpose to produce an interference pattern. This circular interference pattern is called Newton's rings.

5. Why the central ring is dark?

The path difference is introduced b/w the two rays as a result of the phase change of $\lambda/2$ for a ray reflecting from the glass plate and no phase change for the ray reflecting from the plano-convex lens. The central ring is dark because the two interfering rays have a path difference ($\lambda/2$) in spite of the fact that the thickness is zero.

6. How to obtain central bright spot in Newton's rings?

By interposing a film of refractive index less than that of the material of the plate. Then the path difference b/w the two rays becomes central bright spot.

7. On what factors does the diameter of the ring depend?

It depends on the wavelength of the light and the radius of the curvature of the plano-convex lens.

8. What are the applications of Newton's rings?

It is used to:

- (i) Determine wavelength of unknown light source.
- (ii) To determine radius of curvature of given lens.
- (iii) Refractive index of the given liquid.

9. Why the center of the rings is dark?

Because the plano-convex lens and the plane glass plate both are in contact and at that particular place the center ring will appear dark.

10. Why the Newton's rings are circular?

The thin air film formed in between the glass plate and the convex lens is having zero thickness at the point of contact of lens and glass plate. Its thickness is symmetrically increasing on both sides of the point of contact. Hence the obtained fringes having dark spot at the center followed by alternate bright and dark circular fringes. These are called Newton's rings. The path difference along the circle is constant that's why the rings are circular in this experiment.

11. What is meant by radius of curvature?

If we extend the curved path of the convex lens to make a sphere, then the radius of such an extended sphere is called Radius of curvature.

Experiment No:
Date:

SONOMETER

Aim: To verify the laws of transverse vibrations of a stretched string using Sonometer.

Apparatus: Sonometer, tuning forks of known frequency, rubber block, slotted weights, paper riders (small V shaped paper bits).

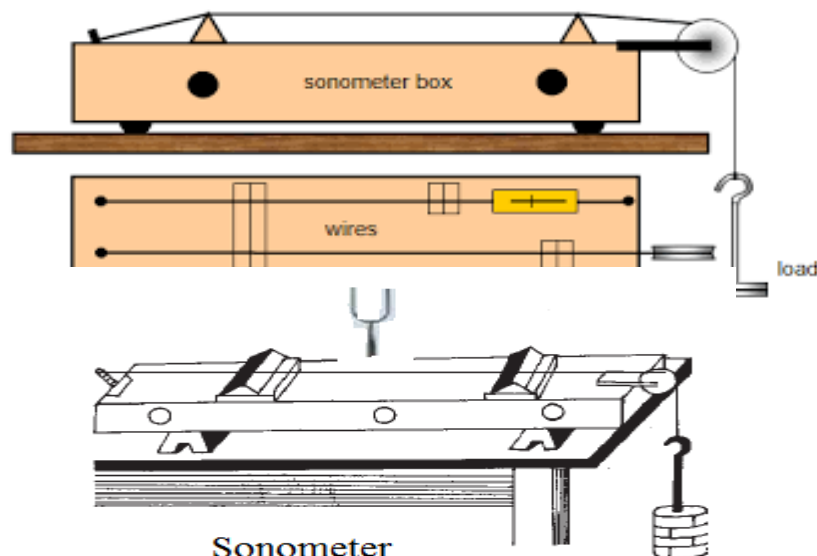
Working Principle: *Resonance*: Resonance takes place when the frequency of the external body/tuning fork is equal to the natural frequency of the segment of the wire (vibrating air column in between the bridges inside the Sonometer).

Formula: The frequency of transverse wave is

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

Where T is tension,
l is the length of the vibrating loop and
m is the mass per unit length of the wire i.e., linear density.

Experimental Diagram:



PROCEDURE:

A wave that travels from a point into an infinite medium and never returns to the origin is called a progressive wave. If the particles of the medium vibrate parallel to the direction of propagation of the wave then the wave is called longitudinal wave. If the particles of the medium vibrate perpendicular to the direction of propagation of the wave then the wave is called transverse wave.

If the applied frequency is equal to the natural frequency of the body, then the body vibrates with maximum amplitude and the phenomenon is called resonance. When two simple harmonic waves of the same amplitude and frequency travelling in opposite directions in a straight line superimpose then the resultant wave obtained is called as stationary wave.

A stretched string vibrating in a single loop when plucked at the middle due to formation of stationary waves

with nodes at the end and antinodes at the middle
fundamental frequency.

The fundamental frequency is given by

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

is said to be vibrating with the

From the above relation, the laws of transverse vibration of stretched strings may be stated as:

1. The frequency (n) of the stretched string is inversely proportional to its length, where tension T and linear density m are kept constant.

$$n l = \text{constant, where } T \text{ and } m \text{ are constants}$$

2. The frequency of the stretched string is proportional to the square root of the tension T , linear density m and length l are kept constant

$$\sqrt{T/l} = \text{constant, where } n \text{ and } m \text{ are constants.}$$

3. With the constant frequency(n) of the stretched string, the length l is inversely proportional to the square root of the linear density m , where tension T and length n are kept constant

$$l/m = \text{constant, where } T \text{ and } n \text{ are constants}$$

Verification of I Law:

The sonometer wire is kept under tension by a suitable load, say 2 kg. A small paper rider is placed on the wire between the movable bridges. The stem of an excited tuning fork of known frequency (n) is placed on the sonometer box. By adjusting the positions of the bridge gently, the length of the vibrating segment is changed till the paper rider flutters violently and is thrown off. The length of string between the movable bridges, ' l ' gives the resonating length.

Keeping the tension constant the experiment is repeated with the tuning forks of different frequencies and corresponding vibrating lengths of the wire are found out as before. The values are tabulated and the product ' $n l$ ' is found to be a constant verifying the first law.

$T =$ dyne/ cm^2 .

String =

| S.No. | Frequency (n) Hz | Length of the vibrating segment | | Mean length $l = (l_1 + l_2)/2$ | $n \times l = \text{constant}$ |
|-------|-------------------------|---------------------------------|---------------------|---------------------------------|--------------------------------|
| | | Trail 1 l_1 cm | Trail 2 l_2 cm | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Verification of II Law:

| S.No | Tension $T = mg$ | Length of the vibrating segment | | Mean length $l = (l_1 + l_2)/2$ | \sqrt{T} | $\sqrt{T/l} = \text{constant}$ |
|------|---------------------|---------------------------------|---------------------|------------------------------------|------------|--------------------------------|
| | | Trail 1 l_1 cm | Trail 2 l_2 cm | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

The Sonometer wire is kept under tension by a load of 1 kg . Using a tuning fork of known frequency, the resonating length (l) is found out as explained earlier. By increasing the load in steps of 0.5 kg , the corresponding resonating lengths are found out for the same fork. The tension of the wire T is calculated in each case using the relation $T = mg$ where g is the acceleration due to gravity.

$n =$ Hz.

String =

Verification of III law:

To verify the 3rd law, resonating lengths are determined for two different wires of material brass and steel, using the same tuning fork and same load applied to the wire. Using the value of density ρ of the material of the wire, according to the relation $m = \rho \pi d^4/4$.

$n =$ Hz.

$T =$

dyne/ cm^2 .

| S. No | Material of the wire | Length of the vibrating segment | | Mean length $l = (l_1 + l_2)/2$ | $l/m = \text{constant}$ |
|-------|----------------------|---------------------------------|----------------------------|------------------------------------|-------------------------|
| | | Trail 1 $l_1\text{ cm}$ | Trail 2 $l_2\text{ cm}$ | | |
| | Iron | | | | |
| | Copper | | | | |
| | Brass | | | | |

Density of Iron is 7.86 gm/cc

Density of Copper is 8.9 gm/cc

Density of Brass is 8.5 gm/cc

To determine the radius of the Iron wire:

Correction =

Least Count = pitch of the screw/ $N =$

| S.No | P.S.R. $a\text{ (cm)}$ | Head scale Reading | | Diameter of the wire $d = a + (nxL.C)$ |
|------|---------------------------|--------------------|---------------|---|
| | | Observed | Corrected (n) | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |

To determine the radius of the Copper wire:

Correction =

Least count = pitch of the screw/ $N =$

| S.No | P.S.R. $a\text{ (cm)}$ | Head scale Reading | | Diameter of the wire $d = a + (nxL.C)$ |
|------|---------------------------|--------------------|---------------|---|
| | | Observed | Corrected (n) | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |

To determine the radius of the Brass wire:

Correction =

Least count = pitch of the screw/ N =

| S.No | P.S.R. a (cm) | Head scale Reading | | Diameter of the wire $d = a + (n \times L.C)$ |
|------|------------------|--------------------|---------------|--|
| | | Observed | Corrected (n) | |
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |

Calculations:

Applications:

1. Sonometer is used in Acoustics of buildings.
2. Sonometer is used to know the natural frequency of a vibrating wire.
3. Sonometer is used to find the frequency of unknown tuning fork.
4. It is commonly used in Melde's experiment.
5. Sonometer is a very ancient device used to study the factors influencing the frequency of oscillation of a vibrating string or wire.

Precautions:

1. The wire should be uniform throughout. It should be straight and free from kinks.
2. The pulley should be free from friction.
3. The mass applied on string should be freely suspended, otherwise tension will be varied.
4. The excited tuning fork should be placed vertically with its shank pressed on the sonometer box.

Result: The three laws of transverse vibrations of stretched strings are verified.

Conclusion: Course outcomes CO1 to CO5 and Program outcomes PO1, PO2, PO9 & PO12 are attained.

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Viva Questions

1. What is the principle involved in the Sonometer experiment?

A Sonometer is a device; it works based on the principle of Resonance

2. Which type of waves is produced in Sonometer experiment?

Stationary transverse waves.

3. What are the transverse waves?

A transverse wave is a moving wave that consists of oscillations occurring perpendicular (or right angled) to the direction of energy transfer or wave propagation.

4. How the resonance takes place in this experiment?

When the frequency of the vibrating tuning fork is equal to the natural frequency of the vibrating air column in between the bridges of the stretched string then the resonance takes place.

5. What is resonance?

In physics, resonance is the tendency of a system to oscillate with greater amplitude at some frequencies than at others. Frequencies at which the response amplitude is a relative maximum are known as the systems resonant frequencies, or resonance frequencies.

Experiment No:
Date:

EXPERIMENT NO – 4 DIFFRACTION GRATING

AIM: To determine the wavelength of prominent lines of mercury spectrum by plane diffraction grating in normal incidence position.

APPARATUS: Spectrometer, Mercury lamp, Spirit level, diffraction grating and reading lens.

WORKING PRINCIPLE: *Diffraction of Light:* Bending of the light rays at the transparent spaces between the equidistant parallel lines on the grating plate is the responsible for diffraction pattern and the grating spectrum.

FORMULA: If N is the number of lines per cm of the grating, then the width of the slit $d = 1/N$. When light is incident normally on plane grating and if θ is the angle that the diffracted ray makes with the normal then the path difference between two rays passing through successive slits is ' $d \sin \theta$ ' for maximum of the diffracted beam $d \sin \theta = n\lambda$. Therefore the wavelength λ of light incident normally on the grating is

$$\lambda = \frac{\sin \theta}{n N} A^0$$

Where,

θ is the angle of diffraction,

N is the number of lines per cm on the grating (**15000 LPI = 5905.511 lines/cm**)

n is the order of the spectrum

PROCEDURE:

i. Find the least count of the spectrometer:

Least count = Value of one M.S.D / No of Vernier scale divisions.

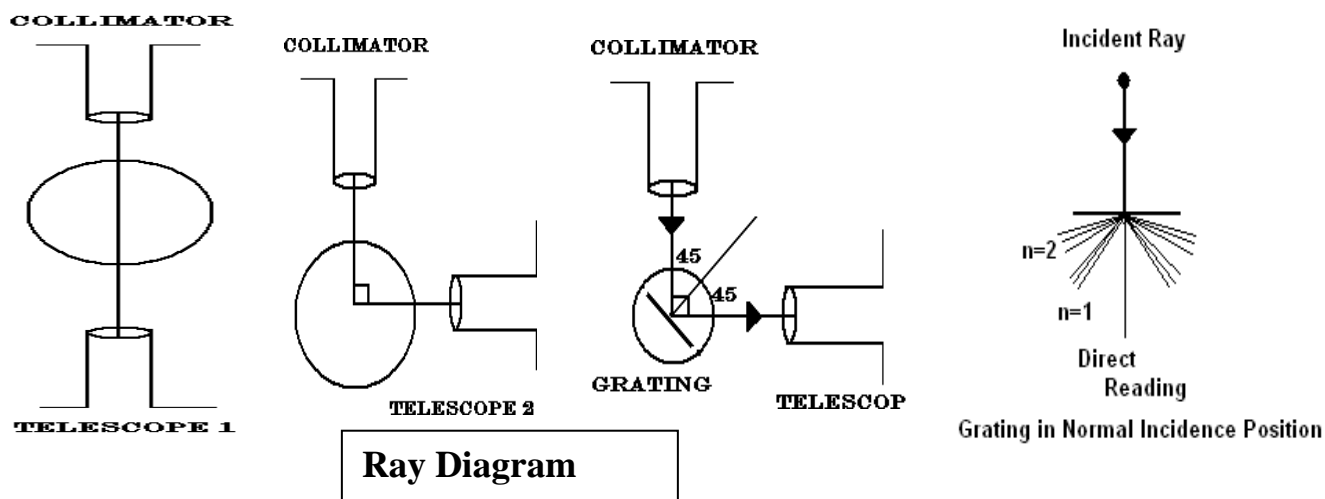
ii. Preliminary adjustments of the spectrometer:

Turn the telescope towards a white surface. Move the eye-piece in or out until the cross wires are seen distinctly. Now focus the telescope to a distant object and by the turning the pinion screw adjusts the distance of the eye-piece from the object until the distant object is clearly seen in the plane of the cross-wires. Now the telescope is adjusted to receive the parallel rays.

The slit of the collimator is illuminated with mercury light and the telescope is brought in line with the collimator. Set the slit of the collimator vertical. Observing through the telescope, the width of the slit and the distance of the slit from the collimator lens are adjusted until a clear image of the slit with well-defined edges is formed in the plane of the cross-wires.

iii. To set the grating in normal incidence position:

Turn the telescope exactly in line with the collimator and observe the image of the slit. Clamp the Vernier table to the prism table. Adjust the position of the telescope so that the vertical cross-wire exactly coincides with the image of the slit and note down the direct reading on both the vernier (Fig 1). Release the telescope and rotate it exactly through 90° from the direct reading position and fix it. At this position the axis of the collimator and telescope are perpendicular to each other (Fig 2).

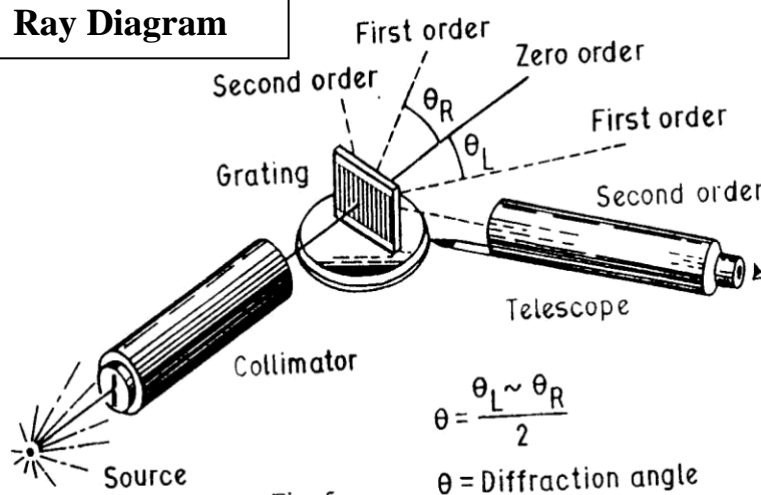


Mount the grating on the prism table such that the ruled surfaces the collimator. Then release the prism table and looking through the telescope. Rotate the prism table slowly until the reflected image of the slit from the grating exactly coincides with the vertical cross-wire. Keeping the prism table and telescope fixed, release the Vernier table and rotate it exactly though 45° towards the collimator such that the ruled surface of the grating is towards the collimator. Release the telescope and bring it in line with the collimator. Now the grating is said to be in normal incidence position and the light rays from the collimator will be incident on the grating surface perpendicularly. (Fig 3)

iv. Diffracted lines of mercury spectrum:

Now turn the telescope to each the diffracted spectral lines of the mercury spectrum on one side, say to the left. Starting from the extreme left coincide the vertical cross-wire with yellow-2 and note the reading. Similarly note the readings for all lines on the right side of the direct position (Fig 3). The difference between the readings corresponding to any line on left side (L) and right side (R) gives twice the angle of diffraction (2θ) for that line. Half the difference in the readings corresponding to any line gives the angle of diffraction (θ) for that line in the first order spectrum. Tabulate your results as shown in table.

Ray Diagram



OBSERVATIONS:

Note down the number of lines per inch marked on the grating and calculate the number of lines N per cm by using the formula

$$\text{No. of lines per inch} / 2.54 \quad (N) = \quad 15000 / 2.54 = \quad \text{lines/cm}$$

$$\text{Order of the spectrum} \quad (n) =$$

$$\text{L.C of the spectrometer} = \text{Value of one M.S.D /total No of Vernier scale divisions}$$

$$=$$

| Order of the spectrum (n) | Colour of the line | Telescope Reading | | | | | | Angle of Diffraction θ = (L ~ R)/ 2 | $\lambda = \frac{\text{Sin } \theta}{n \text{ N}} A^0$ |
|---------------------------|--------------------|-------------------|----|----------------------------------|-----------|----|----------------------------------|--|--|
| | | Left (L) | | | Right (R) | | | | |
| | | MSR | VC | Total Reading= MSR+(VC X LC) (L) | MSR | VC | Total Reading= MSR+(VC X LC) (R) | | |
| 1 | Violet | | | | | | | | |
| 1 | Blue | | | | | | | | |
| 1 | Bluish Green | | | | | | | | |
| 1 | Green | | | | | | | | |
| 1 | Yellow | | | | | | | | |
| 1 | Red | | | | | | | | |

CALCULATIONS:

$$\lambda_v = \frac{\sin \theta_v}{n N} A^0 =$$

$$\lambda_b = \frac{\sin \theta_b}{n N} A^0 =$$

$$\lambda_{bg} = \frac{\sin \theta_{bg}}{n N} A^0 =$$

$$\lambda_g = \frac{\sin \theta_g}{n N} A^0 =$$

$$\lambda_y = \frac{\sin \theta_y}{n N} A^0 =$$

$$\lambda_r = \frac{\sin \theta_r}{n N} A^0 =$$

Applications:

1. Diffraction of light plays a dominant role in limiting the resolving power of cameras, binoculars, telescopes, microscopes and the eyes.

2. Diffraction gratings are used in the laser shows which are popularly used in opening and closing ceremonies of film fare awards, IPL and Olympic games, etc.
3. Spectra produced by diffraction gratings are extremely useful in applications from studying the structure of atoms and molecules to investigating the composition of stars.
4. Diffraction grating is an immensely useful tool for the separation of the spectral lines associated with atomic transitions
5. Diffraction grating leads to application for measuring atomic spectra in both laboratory instruments and telescopes.
6. The hologram on a credit card and the closely spaced tracks of a CD or DVD act as a diffraction grating for producing a separation of the colors of white light.
7. Diffraction grating is used in ICPAES (Inductively Coupled Plasma Auger Electron Spectroscopy).

RESULT: The wavelengths of prominent lines in the mercury spectrum are determined by using diffraction grating in normal incidence position.

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Conclusion: Course outcomes **CO1 to CO5**, Program outcomes **PO1, PO2, PO9 & PO12** are attained

Viva Questions

1. What is diffraction grating?

A plate of glass or metal ruled with very close parallel lines, producing a spectrum by diffraction grating and interference of light.

2. What are the essential parts of the spectrometer?

The essential parts of the spectrometer are Eye-piece, telescope, objective lens, prism table, collimator, slit.

3. How many types of spectra are available?

The familiar spectrum colors are easy to remember with the mnemonic "VIBGYOR" for Red, Orange, Yellow, Green, Blue, Indigo, and Violet. Different light sources have different amounts of these colors.

4. What is dispersive power of grating?

Dispersive power is defined as the rate of change of angle of diffraction with the change of wavelength in a particular order of spectrum.

5. Define grating element?

The distance b/w two adjacent slits is known as grating element/its value is obtained by dividing the length of grating by total number of lines ruled on the grating.

$$d = L/N; \quad L = \text{length of the grating}; \quad N = \text{number of lines ruled on the grating}$$

6. What is plane transmission diffraction grating?

A plane transmission diffraction grating is an optically plane parallel glass plate on which equidistant, extremely close grooves are made by ruling with a diamond point.

7. In our experiment, what class of diffraction occur and how?

Fraunhofer class of diffraction occurs. Since the spectrometer is focused for parallel rays, the source and the image are effectively at infinite distances from the grating.

8. What type of diffraction occurs in this experiment?

Fraunhofer diffraction

9. What are maximum numbers of possible orders with the given grating?

Three ($n=3$).

10. Among the three possible orders which order you are observing?

First order ($n=1$)

EXPERIMENT NO – 5 ENERGY GAP OF THE SEMICONDUCTOR

Aim

To determine the energy band gap of the given semiconductor using p-n junction diode.

Apparatus

Semiconductor diode, dc power supply, Thermometer, Oven, Ammeter and Voltmeter.

Introduction

A semiconducting material is comprised of valence band and conduction band separated by a narrow energy difference of nearly 1eV. The conduction band is almost empty while the valence band is nearly full. This narrow energy gap is called as the forbidden energy gap or the energy band gap. There are two types of semiconductors. They are intrinsic (or) pure semiconductors and extrinsic (or) impure semiconductors. The electrical conductivity of a pure semiconductor can be drastically varied by addition of minute impurities. Extrinsic semiconductors are formed by adding impurity (doping) to pure semiconductors. The n-type semiconductor is formed by doping trivalent impurity (e.g. Ga^{3+}) to pure semiconductor while the p-type semiconductor is formed by doping a pentavalent impurity (As^{5+}). The p-type semiconductors are electron deficient while the n-type are excess in electrons.

WORKING PRINCIPLE:

The electrical conductivity of a germanium or silicon test piece is measured as a function of temperature. The energy gap is determined from the measured values.

FORMULAE:

The temperature dependence of reverse saturation current I_s in p-n junction diode is given by,

$$I_s = A e^{\frac{-E_g}{\eta KT}} \quad (1)$$

where, A is the constant, E_g is the band energy gap of the semiconductor in eV, K in Boltzmann constant in 8.625×10^{-5} eV/K, T is the absolute temperature and $\eta = 1$ for Ge and $\eta = 2$ for Si. for instance in case of Ge,

$$I_s = A e^{\frac{-E_g}{KT}} \quad (2)$$

On taking logarithm to base 10 on both sides, we get,

$$\begin{aligned} \log I_s &= \log A - 0.4303 \left(\frac{E_g}{KT} \right) \\ \log I_s &= \log_{10} A - 5036 \left(\frac{E_g}{T} \right) \end{aligned} \quad (3)$$

In the operating range of diodes, the temperature dependence of I_s is mainly determined by the second term of Eq. (3) even though A is temperature dependent.

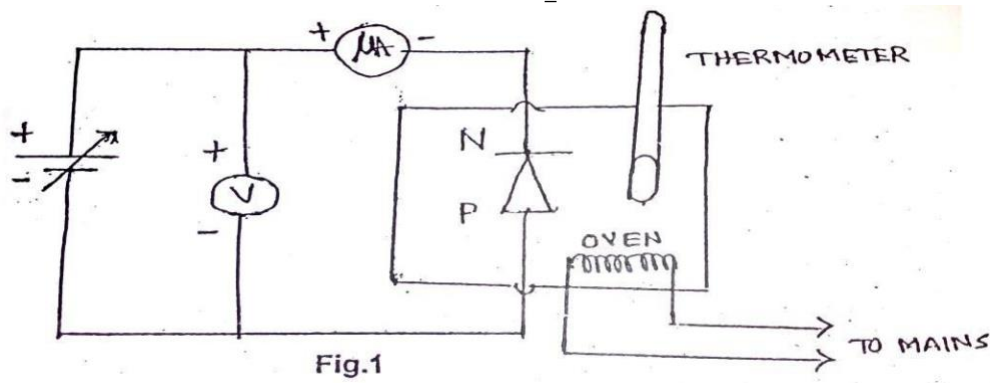
Hence, a graph with $\frac{1}{T}$ on x-axis T in K and $\log_{10} I_s$ on Y-axis will be a straight line having a slope of magnitude $m = 5.036 \times E_g$. From this the energy band gap of the p-n junction diode is calculated to be

$$E_g = |m|/5.036 \quad \text{eV} \quad (4)$$

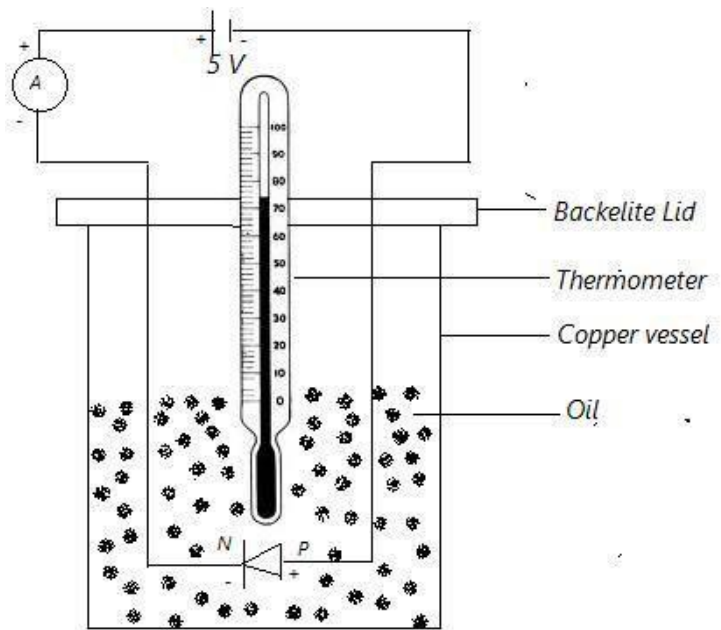
Where m-slope of the straight line from graph

Description: The arrow head of p-n junction diode 'D' represents the anode (of p region) and the vertical line represents the cathode (n region). As shown in figure (1). When diode is reverse biased i.e. p-region is connected to negative terminal of the battery and n-region is connected via the ammeter to the positive terminal of battery, the current flowing through the diode is negligibly small in range of μA and is called as reverse saturation current.

Circuit Diagram:



Experimental Diagram:



In our experiment we study the effect of temperature on the reverse saturation current in the diode and there from estimate the energy band gap of the semiconductor material.

Procedure

The connections are made as shown in the figure (1). A small reverse bias voltage is applied across the diode by adjusting the potentiometer 'P'. The applied voltage is recorded using a voltmeter and the corresponding reverse saturation current (I_S) is noted using a micro-ammeter.

The reverse bias voltage is maintained constant throughout the experiment. During heating cycle, the oven is switched on and the temperature of the diode increases slowly. Now, the reverse saturation current values ($(I_S)_{increase}$) are noted together with the corresponding temperatures in

Conversely in the cooling cycle, the oven is switched off and system is cooled. Now, the reverse saturation current values ($(I_S)_{decrease}$) corresponding to the temperature range of 70°C to 30°C are tabulated in steps of 5°C respectively.

At any temperature, the average value of reverse saturation current will be considered.

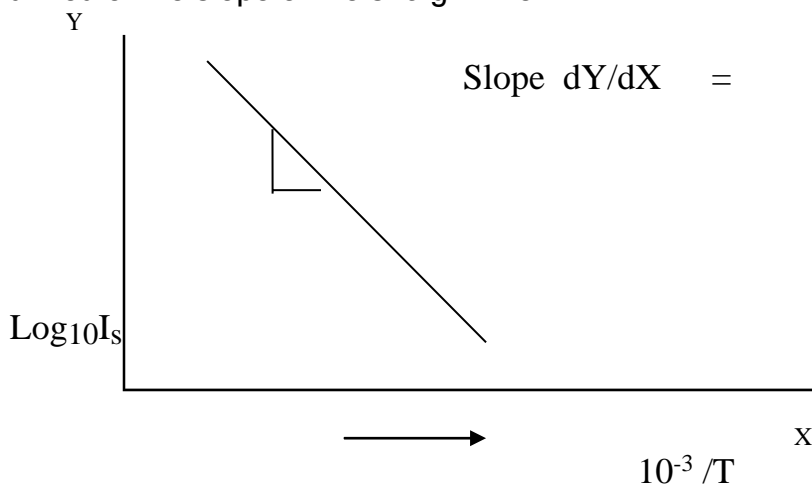
$$I_S = ((I_S)_{increase} + (I_S)_{decrease}) / 2.$$

Readings are tabulated in the table and graph is between $\frac{1}{T} \times 10^3$ on x- axis T in K and $\log_{10} I_S$ on Y- axis is drawn and slope is found and E_g is calculated.

Observations:

| S.No | Temperature | | Reverse Saturation Current (I) in μA | | | $\text{Log}_{10} (I_s)$ | $1/T \times 10^{-3} \text{ K}^{-1}$ |
|------|----------------------------|------------|---|---------------------------|-------------------------|-------------------------|-------------------------------------|
| | Temp in $^{\circ}\text{C}$ | Temp T (K) | Current (I_H) Heating | Current (I_C) Cooling | $I_S = (I_H + I_C) / 2$ | | |
| 1 | 30 ⁰ | | | | | | |
| 2 | 35 ⁰ | | | | | | |
| 3 | 40 ⁰ | | | | | | |
| 4 | 45 ⁰ | | | | | | |
| 5 | 50 ⁰ | | | | | | |
| 6 | 55 ⁰ | | | | | | |
| 7 | 60 ⁰ | | | | | | |
| 8 | 65 ⁰ | | | | | | |
| 9 | 70 ⁰ | | | | | | |
| 10 | 75 ⁰ | | | | | | |

Graph: Draw the graph between $1/T$ versus $\log (I_s)$, straight line passing through positive 'X' axis. Find mod of the slope of the straight line



CALCULATIONS:

From graph slope of the line $dy/dx =$

$$E_g = \text{slope} / 5.04 = \underline{\hspace{2cm}} \text{ eV}$$

Standard value for Ge = 0.72 eV; Standard value for Si = 1.1 eV

Precautions:

1. Do not operate above 90°C.
2. Temperatures are to be determined accurately.
3. Observations should be taken not only as the temperature rise but also when it cools.
4. The current flow should not be too high, if the current is high then the internal heating of the device will occur. This will cause actual temperature of the junction to be higher than the measured value. This will produce non-linearity in the curve.

Result: The Energy band gap of semiconductor is $E_g = \text{----- eV}$.

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Conclusion: Course outcomes **CO1 to CO5**, Program outcomes **PO1, PO2, PO9 & PO12** and Program specific outcome **PSO3** are attained.

VIVA QUESTIONS

1. **What is a p-type semiconductor?**
Semiconductor formed by adding trivalent impurities in which the majority carriers are holes is called as a p-type semiconductor
2. **What is an n-type semiconductor?**
Semiconductor formed by adding pentavalent impurities in which the majority carriers are electrons are called as a n-type semiconductor.
3. **What is doping?**
The process of changing the performance of a semiconductor by introducing a small number of suitable replacement atoms as impurities into the semiconductor lattice is called as doping.
4. **Due to what phenomenon does the reverse saturation current arise?**
The reverse saturation current arise in a junction diode due to the diffusion of minority charge carriers. (Electrons in p-region & holes in n-region are respective minority charge carriers.)
5. **Why does the reverse saturation current depend on temperature?**
This is because the reverse saturation current is due to diffusion of minority charge carriers which are thermally generated. The diffusion is also temperature dependent. Hence the reverse saturation current is highly sensitive to temperature.
7. **What is diffusion?**
The motion of charge carriers takes place when there is a non uniform distribution of charged particles. This process is called as diffusion.
8. **Why reverse bias current is called as reverse saturation current?**
Because the reverse current becomes saturated quickly with the increase in the reverse bias.
9. **What are the values of band gap for metals, semiconductors and insulators?**
For metals = 0 eV, Semiconductors = 0.5 - 3 eV and for insulators greater than 3 eV.
10. **Which type of semiconductor is used in the given apparatus?**
Germanium (Ge)
11. **Which type of transformer is used in this experiment and what is it?**
Step down transformer. It is a device, which converts high voltage currents to low voltage currents.

EXPERIMENT NO - 6 COMPOUND PENDULUM

Experiment No:
Date:

AIM: To determine the acceleration due to gravity 'g' and radius of gyration using a compound pendulum.

APPARATUS: Compound pendulum with suitable support for its suspension, stop-clock and a scale.

WORKING PRINCIPLE: *Modified Simple Harmonic Motion:* Any rigid body mounted upon a horizontal axis so as to vibrate under the force of gravity is a compound pendulum. The motion of such a body is an angular vibration about the axis of suspension is called Angular SHM or M SHM.

FORMULA: Acceleration due to gravity at a given place is.

$$g = 4\pi^2 \left(\frac{l}{T^2} \right) \text{cm/s}^2$$

Where,

g = Acceleration due to gravity at a place in cm/s^2

l = Distance between the point of suspension and point of oscillation in cm

T = Time period of oscillation in seconds

THEORY: The point at which the steel bar is suspended is called the centre of suspension, (Points) while the other extreme point (Point O) is called the centre of oscillation. These two points are interchangeable. The distance between the point of suspension and the point of oscillation gives the length of equivalent pendulum with the same time period. There will be many such pair of points i.e., the point of suspension and the point of oscillation, and 'T' is the corresponding time period, then we have

$$g = 4\pi^2 \left(\frac{l}{T^2} \right) \text{cm/s}^2$$

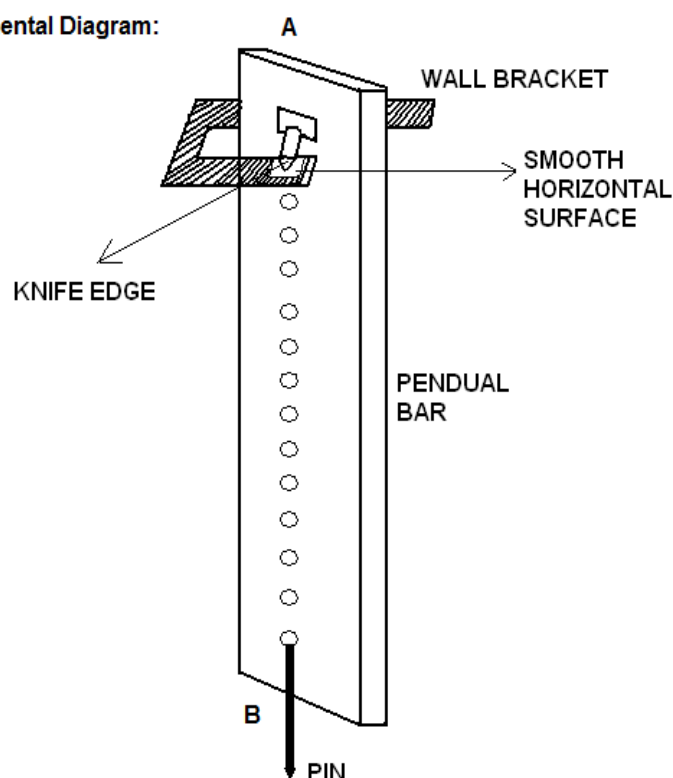
PROCEDURE:

One end(A end) of the steel bar is suspended through the hole(S) as shown and allowed to oscillate(30 oscillations) and the time taken for 30 oscillations is noted (trail 1).The oscillations set up should be confined to vertical plane only. The experiment is repeated for the same point of suspensions and again the time taken for 30 oscillations is noted(Trail 2).The average time of these two trials is noted and then the time period T(i.e. time taken for one oscillation) is noted.

The bar is now suspended through the next hole and the experiment is repeated each time noting the time taken for 30 oscillations and the time period. The experiment is continued by suspending the bar through the successive holes and the time period is recorded. As we approach the centre of the bar, i.e., centre of gravity of the bar, the time period would increase considerably.

Now the pendulum is reversed i.e., B end is made to suspend through the hole and is allowed to oscillate as before (30 oscillations) and the time period is noted. It is to be noted that even after reversal, the distance of point of suspension is to be measured from the same end i.e., from same end A. The observations are recorded in the tabular form as shown.

Experimental Diagram:



A graph is drawn with the distance of the point of oscillation from one end (A end) on the X-axis and the period of oscillation on the Y-axis. The graph consists of two symmetrical curves corresponding to the two halves of the bar. The bar is taken out and is balanced on a knife edge (the centre point) and the centre of gravity (G) of the bar is determined. The distance is from the A end of the bar to the centre of gravity is noted (50 cm) and is marked on the graph paper as G. It is to be noted that the ordinate through G is the line about which the two curves are symmetrical.

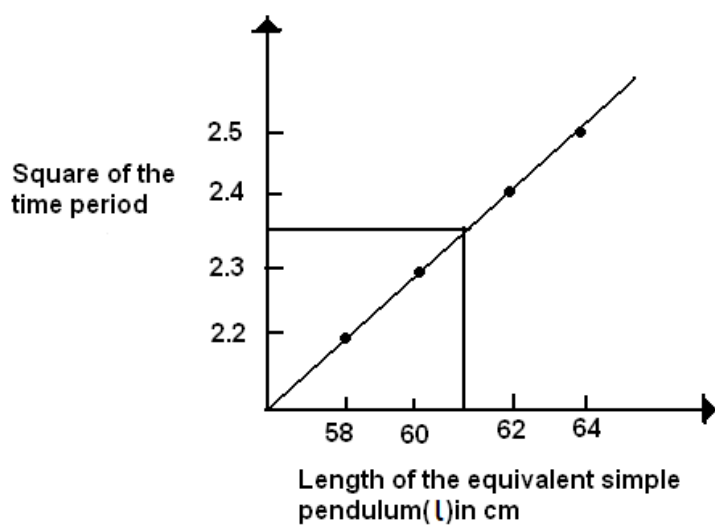
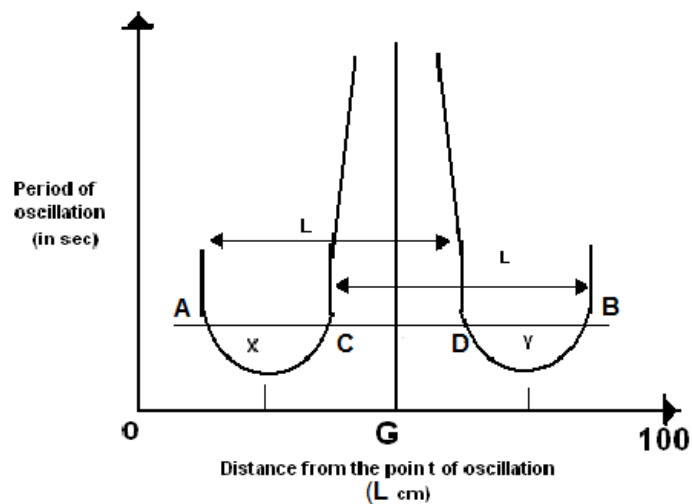
On the graph paper, a line ABCD is drawn parallel to x-axis intersecting the two curves at four points A, B, C, and D. It is to be noted that AC will be equal to BD. Each being equal to the length of the equivalent pendulum (l), corresponding to the time period (T). This value of l and t are substituted in the equation

$$g = 4\pi^2 \left(\frac{l}{T^2} \right) \text{ cm/s}^2 \text{ and the 'g' value at that place is obtained.}$$

Table to determine the period of oscillation T of the compound pendulum

| S.No | Distance of the point of suspension measured from one end of the bar(A-end only) (L in cm) | Time taken for 10 (or 5) oscillations (Sec) | | | Period of oscillation T (Sec) |
|------|--|---|---------|------|-------------------------------|
| | | Trail 1 | Trail 2 | Mean | |
| 1 | 5 | | | | |
| 2 | 10 | | | | |
| 3 | 15 | | | | |
| 4 | 20 | | | | |
| 5 | 25 | | | | |
| 6 | 30 | | | | |
| 7 | 35 | | | | |
| 8 | 40 | | | | |
| 9 | 45 | | | | |
| 10 | 95 | | | | |
| 11 | 90 | | | | |
| 12 | 85 | | | | |
| 13 | 80 | | | | |
| 14 | 75 | | | | |
| 15 | 70 | | | | |
| 16 | 65 | | | | |
| 17 | 60 | | | | |
| 18 | 55 | | | | |

Graph:



The radius of gyration k of the pendulum about an axis through its centre of gravity perpendicular to the broad face of the bar is obtained from the graph as:

$$K = \frac{XY}{2}$$

The moment of inertia (I_g) of the bar about an axis through its centre of gravity and perpendicular to the broad face is given by:

$$I_g = MK^2$$

Where, M is the mass of the bar.

The moment of inertia (I_g) of the bar about any other parallel axis at a distance ' d ' from the center of gravity is given by:

$$I = I_g + Md^2$$

$$= M(k^2 + d^2)$$

Table for to find the values of l , T^2 from the graph and to determine 'g'

| S.No | Time Period | T^2 | Length of the equivalent simple pendulum | | | l/T^2 Cm/sec ² |
|------|-------------|-------|--|----|------------------------------------|--------------------------------|
| | | | AD | BC | $l = \frac{AD+BC}{2} \text{ cm}^2$ | |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |

Applications:

1. It is used in developing the experiments to measure the moments of inertia of hockey sticks, golf clubs, Frisbees, etc.
2. It is used in the analysis of compound pendulum rocket suspension modeling.
3. Examples of the application of compound pendulum theory to the practical measurements of the moments of inertia of human beings, farm tractors and sailing boats.
4. It is also used in CPJC (Compound Pendulum Jaw Crusher). CPJC is a kind of commonly crusher and is used in broken missions of the metallurgy, mining, chemicals, building materials, industries, as well as highway and railway construction.

CALCULATIONS:

PRECAUTIONS:

1. The knife edge should perfectly rest on the smooth horizontal surface.
2. The knife-edge should be horizontal and the pendulum should oscillate in a vertical plane.
3. Amplitude of oscillations must be small.
4. The time should be noted when the oscillations are regular.
5. The graph drawn should be a free-hand curve.

Result: Acceleration due to gravity g at a given place =

Radius of gyration

$K =$

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Conclusion: Course outcomes CO1 to CO5 and Program outcomes PO1, PO2 & PO9 and PO12 are attained.

Viva Questions

1. What is acceleration due to gravity?

The acceleration due to gravity is the acceleration of a body due to the influence of the pull of gravity alone, usually denoted by 'g'.

2. What is simple harmonic motion?

Simple harmonic motion is a type of periodic motion where the restoring force is directly proportional to the displacement.

3. What is compound pendulum?

Pendulum consists of an actual object allowed rotating freely around a horizontal axis.

4. What is the 'g' value at the pole and at the equator?

At the equator and at the sea level its value of g is about 9.78m/s^2 and at the poles it is 9.83m/s^2 .

5. What is the equivalent length of a simple Pendulum?

For these pendulums the appropriate equivalent length is the distance from the pivot point to a point in the pendulum called the center of Oscillation.

6. What is meant by center of gravity?

It's the geometric center of the sphere, for other shapes or for objects where the density is not the same throughout, it's more complicated.

7. What are units and dimensions of g?

The units of g are m/s^2 and the dimensions is Length/time²

8. What is radius of gyration?

Radius of gyration or gyrations refers to the distribution of the components of an object around an axis. In terms of moment of inertia, it is the perpendicular distance from the axis of rotation to a point mass (of mass, m) that gives an equivalent inertia to the original object(s) of mass, (m).

EXPERIMENT No-7 LASER BEAM DIFFRACTION

Experiment No:
Date:

AIM: To determine the wavelength of laser beam using n-parallel slits i.e., diffraction grating.

APPARATUS: Laser light source, N-parallel slits (Diffraction grating), Screen and a Meter scale.

FORMULA: The wavelength λ of laser light is given by

$$\lambda = \frac{\sin \theta}{n N} A^0$$

Where, θ is the angle of diffraction, **N** is the number of lines per cm on the grating,
n is the order of the spectrum

$$\theta = \tan^{-1} (d/D)$$

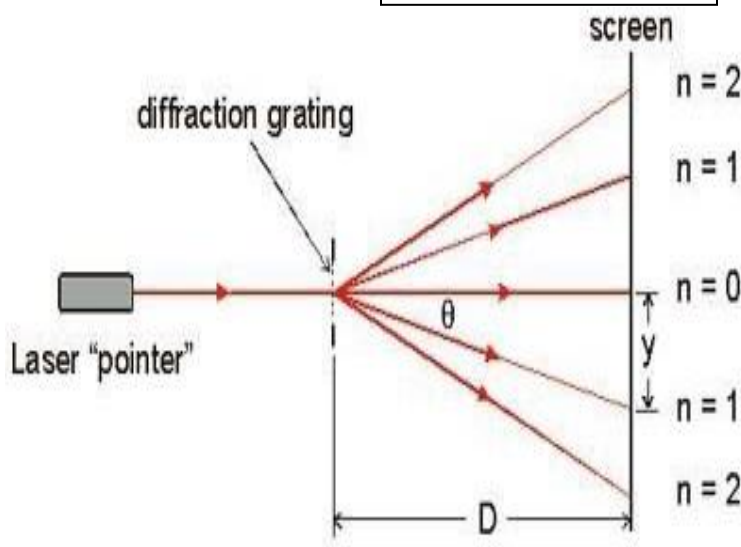
Where, λ is the wavelength of laser light, **D** is the distance between the grating (slits) and the screen, **d** is the distance on the screen from the central maximum to the n^{th} maximum.

WORKING PRINCIPLE: Diffraction of Light: Bending of the light rays at the transparent spaces between the equidistant parallel lines on the grating plate is the responsible for diffraction pattern and the grating spectrum.

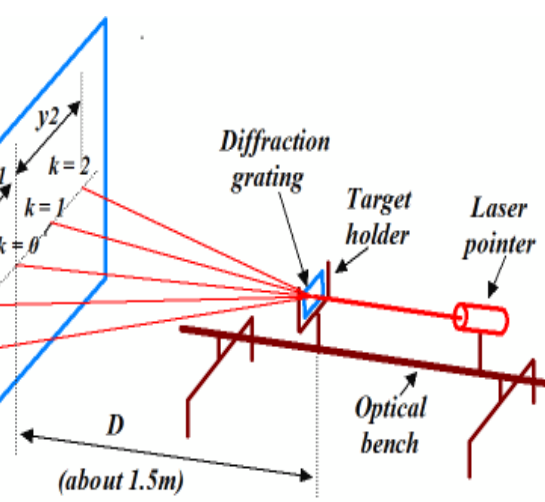
THEORY:

He-Ne Laser, Ga-As or Semiconductor Laser is generally used as laser source in this experiment. When a laser beam of wavelength λ is allowed to fall on the single slit or diffraction grating placed at a distance D from the screen, the incident laser beam bends at the corners of the slit and produces diffraction pattern on the screen. The diffraction pattern consists of a broad central maximum with narrow secondary maxima and minima on either side of the central maximum as shown in the ray diagram.

Ray Diagram



Experimental Diagram:



PROCEDURE:

Laser source is mounted on a stand. Slit or Diffraction grating is kept at a convenient distance with the lines being vertical at the same height as the source. A screen is placed in front of the slit or grating and the images are formed on the white wall. The distance of the first order image from the direct image is measured on left side as well as right side. The mean of the distance (d) is found. The distance (D) from the grating to the screen is measured (d/D) gives Tan θ . The wavelength of

the light is given by $\lambda = \frac{\sin(\theta)}{Nn}$ Where N=number of lines per unit length on the grating. n=order of the spectrum. The experiment is repeated for first and second order spectrums. The readings are tabulated as follows.

Table to determine the wavelength λ of laser light

| S.No | Order of the spectrum (n) | Distance of screen from the grating D (in cm) | Distance of the slit image from direct slit (central maximum) d (in cm) | | | $\theta = \tan^{-1}(d/D)$ | Sin θ | $\lambda = \frac{\sin \theta}{n N}$ | A ⁰ |
|------|---------------------------|---|--|----------|--------------------|---------------------------|--------------|-------------------------------------|----------------|
| | | | Left d1 | Right d2 | Mean d = (d1+d2)/2 | | | | |
| 1 | 1 | 15 | | | | | | | |
| 2 | 1 | 20 | | | | | | | |
| 3 | 1 | 25 | | | | | | | |
| 4 | 1 | 30 | | | | | | | |
| 5 | 1 | 35 | | | | | | | |
| 6 | 1 | 40 | | | | | | | |
| 7 | 1 | 45 | | | | | | | |
| 8 | 1 | 50 | | | | | | | |
| 9 | 2 | 15 | | | | | | | |
| 10 | 2 | 20 | | | | | | | |
| 11 | 2 | 25 | | | | | | | |
| 12 | 2 | 30 | | | | | | | |
| 13 | 2 | 35 | | | | | | | |
| 14 | 2 | 40 | | | | | | | |
| 15 | 2 | 45 | | | | | | | |
| 16 | 2 | 50 | | | | | | | |

Applications:

1. Diffraction gratings are used in the production of holograms.
2. Diffraction gratings are used in the laser shows which are popularly used in opening and closing ceremonies of film fare awards, IPL and Olympic games, etc.
3. Spectra produced by diffraction gratings are extremely useful in applications from studying the structure of atoms and molecules to investigating the composition of stars.

PRECAUTIONS:

2. Do not look directly into the laser beam under any circumstance.
3. The source, screen and slit or grating should be at the same height.
4. Readings should be taken without parallax error.
5. Diffraction pattern (minima) should be marked with fine pencil carefully.

RESULT:

The wavelength of the given laser source $\lambda =$

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Conclusion: Course outcomes **CO1 to CO5**, Program outcomes **PO1, PO2, PO5, PO6, PO9 & PO12** are attained

EXPERIMENT NO-8 TORSIONAL PENDULUM

Aim: To determine the rigidity Modulus of the given wire by dynamical method.

Apparatus: Torsional pendulum, stop watch, screw gauge, Vernier calipers, scale.

Working Principle: Torsional pendulum is an *angular form the linear simple harmonic oscillator* in which the elasticity is associated with twisting a suspension wire. In Torsional pendulum the mass rotates around its center point and twists the suspending wire. This is called Torsional pendulum with torsion referring to the twisting motion.

Formula: The Rigidity modulus of the given wire is

Where, η is the rigidity modulus,

a is the radius of the given wire,

I is the moment of inertia

l is the length of the pendulum from the fixed point

T is time period.

$$\eta = \frac{8\pi I}{a^4} \times \frac{l}{T^2}$$

Theory: A heavy cylindrical disc suspended from one end of a fine wire whose upper end is fixed constitutes a Torsional pendulum. The disc is turned in its old plane to twist the wire, so that on being released, it executes Torsional vibrations about the wire as axis.

Let θ be the angle through which the wire is twisted.

Then the restoring couple set up in it is equal to

$$\frac{(\pi n a^4 \theta)}{2l} = c\theta \text{ Where } \frac{(\pi a^4 n)}{2l} = c \text{ ----- (1)}$$

is the twisting couple per unit (radian) twist of the wire.

This produces an angular acceleration ($d^2\theta/dt^2$) in the disc

Therefore if " I " is the moment of inertia of the disc about the

wire we have $I \cdot \frac{d^2\theta}{dt^2} = -c\theta \Rightarrow \frac{d^2\theta}{dt^2} = -\left(\frac{c}{I}\right)\theta$

i.e the angular acceleration ($\frac{d^2\theta}{dt^2}$) of the angular displacement(θ).

Therefore its motion is simple harmonic hence time period is given

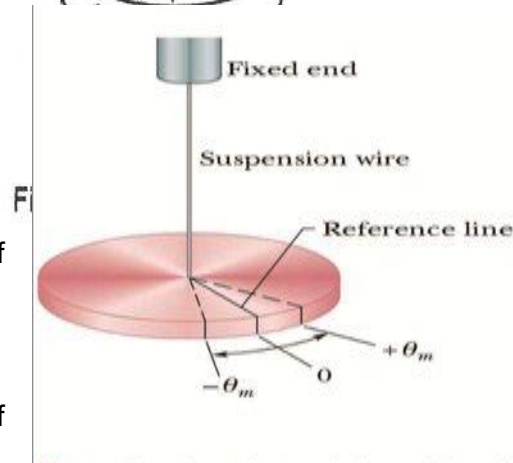
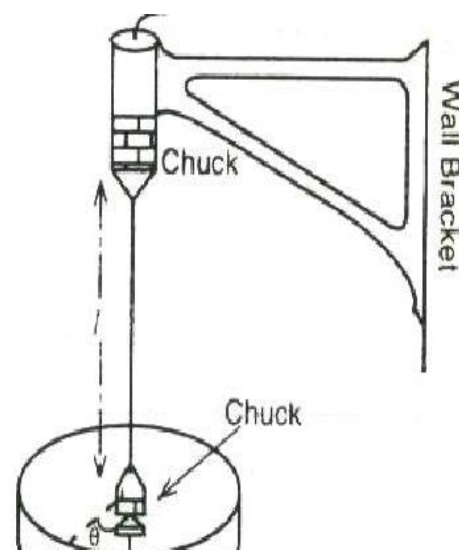
$$T = 2\pi \sqrt{\frac{I}{c}} \text{ ---- (2)}$$

From (1) & (2) $\eta = \frac{8\pi I}{a^4} \times \frac{l}{T^2}$

In case of a circular disc whose geometric axes coincide with the axis of rotation. The moment of inertia " I " is given by $I = \frac{MR^2}{2}$

Where $\eta = \frac{8\pi}{a^4} \times$ M is the mass of disc and " R " is the radius of

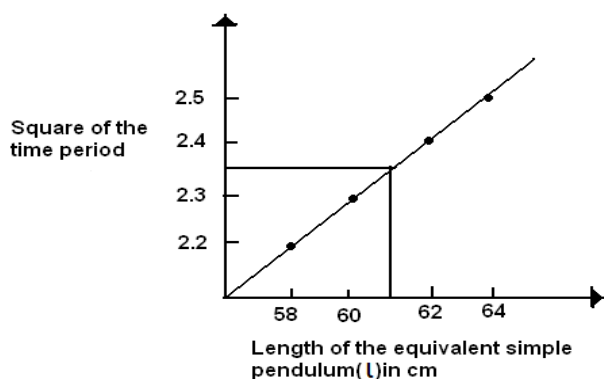
Experimental Diagram:



the disc.

$$\frac{(MR^2)}{2} \times \text{Slope} \quad \text{dynes/cm}^2$$

Graph: Plot a curve for l Vs T^2 and calculate the slope.



Determination of the Period of Oscillation 'T':

| S.No | Length of the Wire l (cm) | Time for 10 (or 3) oscillation (t) | | | Time Per one oscillation $T = (t/3)$ | | $\frac{l}{T^2}$ |
|------|-----------------------------|------------------------------------|--------|---------|--------------------------------------|-------|-----------------|
| | | Trial1 | Trail2 | Mean(t) | T | T^2 | |
| 1 | 20 | | | | | | |
| 2 | 25 | | | | | | |
| 3 | 30 | | | | | | |
| 4 | 35 | | | | | | |
| 5 | 40 | | | | | | |
| 6 | 45 | | | | | | |
| 7 | 50 | | | | | | |
| 8 | 55 | | | | | | |

To determine the radius of the disc:

| S. No | Main scale reading(a) | Vernier Coincidence | Vernier Reading (b=L.C x V.C) | Total Reading (a+b)cm |
|-------|-----------------------|---------------------|-------------------------------|-----------------------|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |

To determine the radius of the wire:

| S. No | P.S.R (a) | H.S.R | H.S.C | H.S.R (b=L.C x H.S.C) | Total (a+b) (mm) |
|-------|--------------|-------|-------|--------------------------|---------------------|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |

Applications:

1. To study the strength of materials.
2. To find the tensile strength of a wire.
3. To find MI for the girders and metal sheets.

Objectives:

1. Determine (η) for a given wire.
2. Find the relation between L and T^2 from graph.
3. Find the relation between material of a wire and period of oscillation.

Calculations:

Precautions:

1. while using vernier calipers see that the readings must be taken without any parallax error
2. Measure the thickness of wire using screw gauge.
3. Note the disc should be rotated along with its own axis.

Result: The rigidity modulus of the given wire using dynamical method is $\eta =$ dynes/cm²

Conclusion: Course outcomes CO1 to CO6 and Program outcomes PO1, PO2, PO9 & PO12 are attained.

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Viva Questions

1. Define the different types of moduli of Elasticity?

There are three moduli in use.

(i) **Young modulus:** The ratio of longitudinal stress to longitudinal strain, within the elastic limits is called young's modulus of the material. its units are N/m^2 .

(ii) **Bulk modulus:** When a uniform pressure is applied over the whole surface of a body, it produces a uniform compression. The compression is proportional to the pressure, and the ratio of pressure to the volume strain is called bulk modulus. it is measured in N/m^2 .

(iii) **Rigidity Modulus:** The Rigidity Modulus describes an object's tendency to shear (deformation of shape at constant volume) When acted upon by opposing forces.

2. Define stress and strain and state their units?

The magnitude of the attractive or repulsive Forces between molecules of a body per unit Area is called stress. It is measured in N/m^2 . The change of shape or the fractional change Of size of a body by a given set of forces or Couples is called strain. Strain has no unit.

3. List the different stages of elastic properties of Matter?

When a load continuously increased in case Of wire, it reaches different elastic stages

Like: (i) elastic limit (ii) permanent set (iii) breaking stress (iv) yield point

4. State Hooke's law and define modulus of elasticity?

The stress is proportional to the strain within the elastic limits is called Hooke's law. The ratio of any stress to the strain is called modulus of elasticity. It is measured in N/m^2 .

5. What is Poisson's ratio? What is its unit?

Within elastic limits there is a complete proportionality between the lateral strain and the Longitudinal strain is called poisson's ratio. It has no units.

6. What is a cantilever?

When one end of horizontal beam is fixed and the other end is free it is called a cantilever.

7. How is bending of a beam related to young's modulus?

When a beam is bent by an applied couple, its longitudinal filaments are lengthened on the convex side and shortened on the concave and thus which the beam often to bending will depend up on young's modulus for the material

NUMERICAL APERTURE & ACCEPTANCE ANGLE

AIM:

To determine the numerical aperture and the acceptance angle of the optical fiber.

APPARATUS:

Optical Fiber Trainer set, NA measuring Jig, one meter & three meter Optical fiber Cables, Mandrel and in-line SMA adaptor.

FORMULAE:

$$NA = W / (4L^2 + W^2)^{1/2} \quad \& \quad \theta = \sin^{-1} (NA)$$

Where NA is the Numerical Aperture of the fiber, L is the distance of the screen from the fiber end, W is the diameter of the spot and θ is the acceptance angle of the fiber.

WORKING PRINCIPLE: Total Internal Reflection:- "When a ray of light traveling in a medium of higher refractive index n_1 strikes a second medium of lower refractive index n_2 with an angle of incidence $i > \theta_c$ (Critical angle $\theta_c = n_2/n_1$) then the ray is totally reflected into the same medium". This phenomenon is called *Total Internal Reflection*.

THEORY:

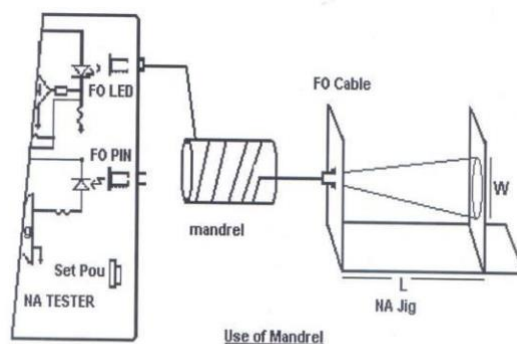
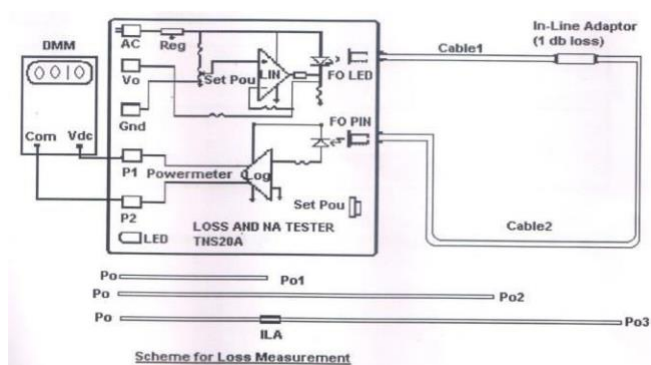
Numerical aperture of any optical system is a measure of how much light can be collected by the optical system. It is the product of the refractive index of the incident medium and the sine of the maximum ray angle.

The numerical aperture is given by $NA = n_i \sin \theta_{\max}$, where n_i for air is 1, hence $NA = \sin \theta_{\max}$

For a step-index fiber, as in the present case, the numerical aperture is given by $NA = \sqrt{n_1^2 - n_2^2}$, where Δ is the fractional difference in refractive indices,

The experimenter may refer to the specifications of the optical fiber given in Appendix and record the manufacture's NA, n_1 , n_2 and θ .

Circuit Diagram:



PROCEDURE:

The schematic diagram of the numerical aperture measurement system is shown in Figure and is self explanatory.

Step 1: Connect one end of the Cable 1 (1-metre FO cable) to FO LED of TNS20A and the other end to the NA Jig, as shown.

Step 2: Plug the AC mains. Light should appear at the end of the fiber on the NA Jig, Turn the Set Pout knob clock wise to set to maximum Po. The light intensity should increase.

Step 3: Hold the white screen with the concentric circles (10, 15, 20 and 25 mm diameter) vertically at a suitable distance to make the red spot from the emitting fiber coincide with the 10mm circle. Note that the spot (outermost) must coincide with the circle. A dark room will facilitate good contrast. Record L, the distance of the screen from the fiber end and note the diameter (W) of the spot. You may measure the diameter of the circle accurately with a suitable scale.

Step 4: Compute NA using the above formula. Tabulate the reading and repeat the experiment for 15mm, 20mm and 25mm diameters too.

Step 5: In case the fiber is under filled, the intensity within the spot may not be evenly distributed. To ensure even distribution of light in the fiber, first remove twists on the fiber and then wind 5 turns of the fiber on to the mandrel as shown. Use an adhesive tape to hold the windings in position. Now view the spot. The intensity will be more evenly distributed within the core.

TABLE:

| S.No | Distance b/n the fiber end & the screen L (mm) | Diameter of the spot W (mm) | Numerical Aperture (NA) | Acceptance angle (θ) in degrees |
|------|--|-----------------------------|-------------------------|--|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |

PRECAUTIONS:

1. Take the readings without parallax error.
2. Fiber should be free from all the twists & bendings.
3. The circumference of the spot must coincide with the circle on the NA measuring Jig.

APPLICATIONS:

1. These are used in hospitals in the treatment of eyes surgery, Laparoscopic surgery, angioplasty etc.
2. These are used in defense like army, navy, airplane applications.

3. These are used as sensors in satellite communication system.

4. These are used in many communication systems such as TV, Internet & telecommunication etc.

RESULT:

The numerical aperture of the optical fiber NA =

The acceptance angle of the fiber $\theta =$

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Conclusion: Course outcomes **CO1 to CO5**, Program outcomes **PO1, PO2, PO5, PO6, PO9 & PO12** and Program specific outcome **PSO3** are attained.

VIVA QUESTIONS

1) What is meant by an optical Fiber?

An optical fiber is a flexible, transparent fiber made by drawing glass (silica) or plastic to a diameter slightly thicker than that of a human hair.

2) What is the principle of an optical Fiber?

The principle of an optical fiber is Total Internal Reflection.

3) What is meant by Total Internal Reflection?

When a ray of light traveling in a medium of higher refractive index n_1 strikes a second Medium of lower refractive index n_2 with an angle of incidence $i > \theta_c$ (Critical angle $\theta_c = n_2/n_1$) then the ray is totally reflected into the same medium". This phenomenon is called Total Internal Reflection.

4) What is meant by Numerical Aperture of an optical Fiber?

Numerical aperture is thus considered as a light gathering capacity of an optical fibre. Numerical Aperture is defined as the Sine of half of the angle of fiber's light acceptance cone.

5) What is meant by Acceptance angle of an optical Fiber?

The acceptance angle of an optical fiber is defined based on a purely geometrical consideration (ray optics): it is the maximum angle of a ray (against the fiber axis) hitting the fiber core which allows the incident light to be guided by the core.

6) What is meant by Fiber-optic communication?

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber.

7) What is meant by transmission loss or Attenuation in optical fiber?

Attenuation in fiber optics, also known as transmission loss, is the reduction in intensity of the light beam (or signal) as it travels through the transmission medium.

Experiment No:
Date:

EXPERIMENT No - 10

RESOLVING POWER OF GRATING

AIM: To determine the resolving power of diffraction grating by mercury spectrum in normal incidence position.

APPARATUS: Spectrometer, Mercury lamp, Spirit level, Plane diffraction grating and reading lens.

WORKING PRINCIPLE: *Diffraction of Light:* Bending of the light rays at the transparent spaces between the equidistant parallel lines on the grating plate is the responsible for diffraction pattern and the grating spectrum.

FORMULA: If N is the number of lines per cm of the grating, then the width of the slit $d = 1/N$. When light is incident normally on plane grating and if θ is the angle that the diffracted ray makes with the normal then the path difference between two rays passing through successive slits is ' $d \sin \theta$ ' for maximum of the diffracted beam $d \sin \theta = n\lambda$.

Therefore the resolving power of given grating is given by

$$\lambda / d\lambda = nN$$

Where,

λ is the wavelength of the light source

$d\lambda$ is difference in two wavelengths ,

N is the number of lines per cm on the grating (**15000 LPI = 5905.511 lines/cm**)

n is the order of the spectrum

PROCEDURE:

i. Find the least count of the spectrometer:

Least count = Value of one M.S.D / No of Vernier scale divisions.

ii. Preliminary adjustments of the spectrometer:

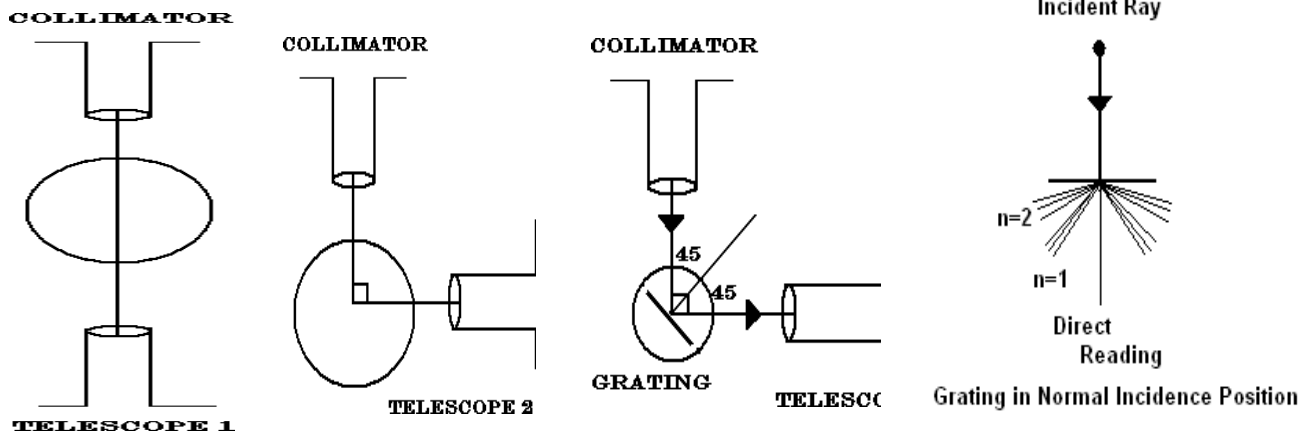
Turn the telescope towards a white surface. Move the eye-piece in or out until the cross wires are seen distinctly. Now focus the telescope to a distant object and by the turning the pinion screw adjusts the distance of the eye-piece from the object until the distant object is clearly seen in the plane of the cross-wires. Now the telescope is adjusted to receive the parallel rays.

The slit of the collimator is illuminated with mercury light and the telescope is brought in line with the collimator. Set the slit of the collimator vertical. Observing through the telescope, the width of the slit and the distance of the slit from the collimator lens are adjusted until a clear image of the slit with well-defined edges is formed in the plane of the cross-wires.

iii. To set the grating in normal incidence position:

Turn the telescope exactly in line with the collimator and observe the image of the slit. Clamp the Vernier table to the prism table. Adjust the position of the telescope so that the vertical cross-wire exactly coincides with the image of the slit and note down the direct reading on both the vernier (Fig 1). Release the telescope and rotate it exactly through 90° from the direct reading position and fix it. At this position the axis of the collimator and telescope are perpendicular to each other (Fig 2).

Ray Diagram



Mount the grating on the prism table such that the ruled surfaces the collimator. Then release the prism table and looking through the telescope. Rotate the prism table slowly until the reflected image of the slit from the grating exactly coincides with the vertical cross-wire. Keeping the prism table and telescope fixed, release the Vernier table and rotate it exactly through 45° towards the collimator such that the ruled surface of the grating is towards the collimator. Release the telescope and bring it in line with the collimator. Now the grating is said to be in normal incidence position and the light rays from the collimator will be incident on the grating surface perpendicularly. (Fig 3)

iv. Diffracted lines of mercury spectrum:

Now turn the telescope to each the diffracted spectral lines of the mercury spectrum on one side, say to the left. Starting from the extreme left coincide the vertical cross-wire with yellow-2 and note the reading. Similarly note the readings for all lines on the right side of the direct position (Fig 3). The difference between the readings corresponding to any line on left side (L) and right side (R) gives twice the angle of diffraction (2θ) for that line.

Half the difference in the readings corresponding to any line gives the angle of diffraction (θ) for that line in the first order spectrum. Tabulate your results as shown in table.

Ray Diagram

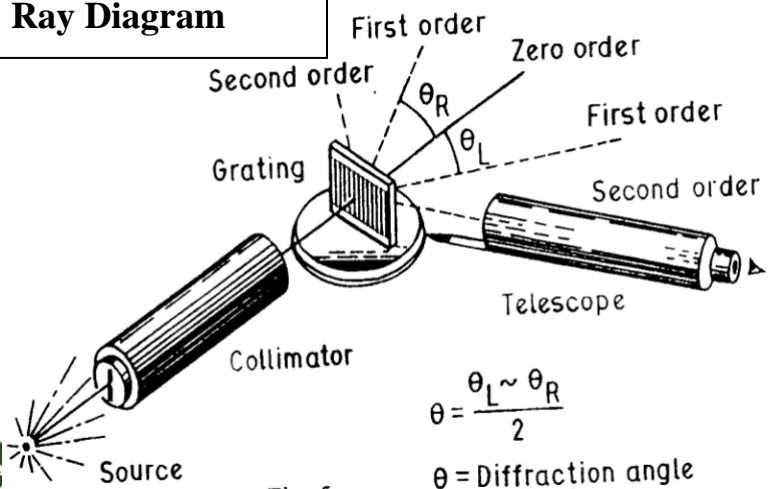


Fig. 5

OBSERVATIONS:

Note down the number of lines per inch marked on the grating and calculate the number of lines N per cm by using the formula

No. of lines per inch/2.54 (N) = 15000 / 2.54 = lines/cm

Order of the spectrum (n) =

L.C of the spectrometer = Value of one M.S.D /total No of Vernier scale divisions

| Order of the spectrum (n) | Colour of the line | Telescope Reading | | | | | | Angle of Diffraction $\theta = (L \sim R)/2$ | $\lambda = \frac{\text{Sin } \theta}{n N} A^0$ |
|---------------------------|--------------------|-------------------|----|--|-----------|----|--|---|--|
| | | Left (L) | | | Right (R) | | | | |
| | | MSR | VC | Total Reading= MSR+(VC X LC) (L) | MSR | VC | Total Reading= MSR+(VC X LC) (R) | | |
| 1 | Green1 | | | | | | | | |
| 1 | Green2 | | | | | | | | |
| 1 | Yellow1 | | | | | | | | |
| 1 | Yellow2 | | | | | | | | |
| 1 | Red1 | | | | | | | | |
| 1 | Red2 | | | | | | | | |

For green color $n=1$

For yellow color $n=1$

For red color $n=1$

Applications:

1. Diffraction of light plays a dominant role in limiting the resolving power of cameras, binoculars, telescopes, microscopes and the eyes.
2. Diffraction gratings are used in the production of holograms.
3. Diffraction gratings are used in the laser shows which are popularly used in opening and closing ceremonies of film fare awards, IPL and Olympic games, etc.
4. Spectra produced by diffraction gratings are extremely useful in applications from studying the structure of atoms and molecules to investigating the composition of stars.
5. Diffraction grating is an immensely useful tool for the separation of the spectral lines associated with atomic transitions
6. Diffraction grating leads to application for measuring atomic spectra in both laboratory instruments and telescopes.
7. The hologram on a credit card and the closely spaced tracks of a CD or DVD act as a diffraction grating for producing a separation of the colors of white light.
8. Diffraction grating is used in ICPAES (Inductively Coupled Plasma Auger Electron Spectroscopy).

RESULT: The resolving power of diffraction grating is determined by using diffraction grating in normal incidence position.

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Conclusion: Course outcomes **CO1 to CO5**, Program outcomes **PO1, PO2, PO9 & PO12** and Program specific outcome **PSO3** are attained.

Viva Questions

1. What is diffraction grating?

A plate of glass or metal ruled with very close parallel lines, producing a spectrum by diffraction grating and interference of light.

2. What are the essential parts of the spectrometer?

The essential parts of the spectrometer are Eye-piece, telescope, objective lens, prism table, collimator, slit.

3. How many types of spectra are available?

The familiar spectrum colors are easy to remember with the mnemonic "VIBGYOR" for Red, Orange, Yellow, Green, Blue, Indigo, and Violet. Different light sources have different amounts of these colors.

4. What is dispersive power of grating?

Dispersive power is defined as the rate of change of angle of diffraction with the change of wavelength in a particular order of spectrum.

5. Define grating element?

The distance b/w two adjacent slits is known as grating element/its value is obtained by dividing the length of grating by total number of lines ruled on the grating.

$$d = L/N$$

L=length of the grating

N=number of lines ruled on the grating

6. What is plane transmission diffraction grating?

A plane transmission diffraction grating is an optically plane parallel glass plate on which equidistant, extremely close grooves are made by ruling with a diamond point.

7. In our experiment, what class of diffraction occur and how?

Fraunhofer class of diffraction occurs. Since the spectrometer is focused for parallel rays, the source and the image are effectively at infinite distances from the grating.

8. What type of diffraction occurs in this experiment?

Fraunhofer diffraction

9. What are maximum numbers of possible orders with the given grating?

Three ($n=3$).

10. Among the three possible orders which order you are observing?

First order ($n=1$)

BREWSTER'S ANGLE DETERMINATION

Aim:

To verify the Brewster's law and to find the Brewster's angle.

Theory & Introduction:

An ordinary light source consists of a very large number of randomly oriented atomic emitters. They radiate polarized wave trains for roughly 10^{-8} s. These wave trains combine to form a single resultant polarized wave which persists for a short time, not more than 10^{-8} s. Since natural light composes of a large number of rapidly varying succession of the different polarization states it is said to be an unpolarised or randomly polarized light.

The natural light can be expressed in terms of two arbitrary, incoherent, orthogonal, linearly polarized of equal amplitude. Figure (a) shows randomly polarized natural light and figure (b) shows the at 50% horizontal and 50% vertical states.



Figure (a)

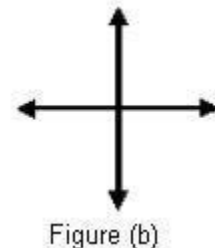


Figure (b)

waves
splitting

A light is said to be a plane polarized light, if all the vibrations are confined to a single plane. Consider an unpolarised light incident on a transparent surface. If the angle of incidence is equal to a particular angle of incidence, the reflected light produced will be completely plane polarized. This particular angle is called the Brewster's angle or the polarizing angle θ_B .

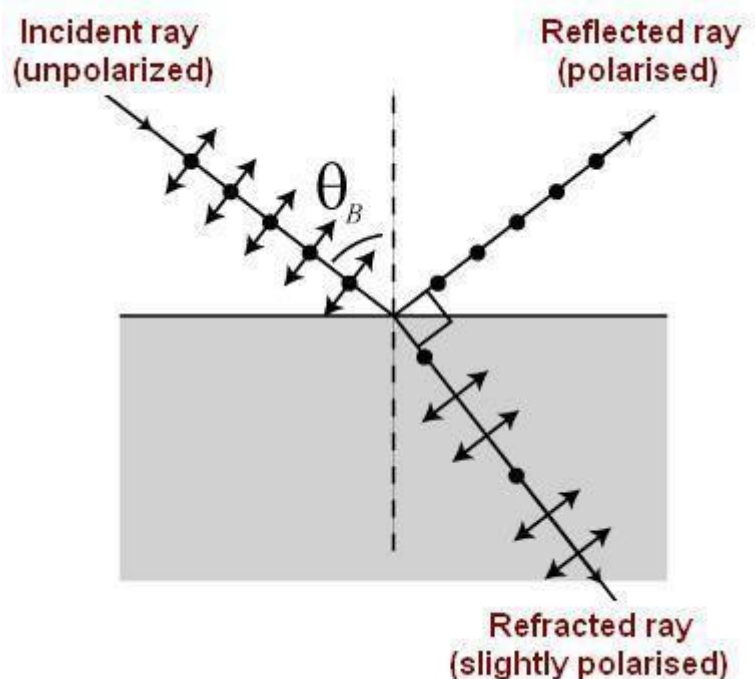
Sir David Brewster, in 1892, found that the maximum polarization of the reflected ray occurs when the reflected ray is perpendicular to the refracted ray. This is called the Brewster's law.

$$r = 90^\circ - \theta_B$$

Brewster's equation:

$$\tan \theta_B = \frac{\mu_2}{\mu_1}$$

Where, μ_2 is the refractive index of the reflecting surface and μ_1 is the refractive index of the surrounding medium. The refracted ray so produced will be partially polarized. As the refractive index changes the polarizing angle differs but it is independent of the wavelength of light used.



Procedure for Performing the Simulation:

Drag the components from the right panel and place them correctly in the optic bench.

Start: This button enables the user to start the experiment.

Side view/Top view: Using this, different views of the experimental arrangement can be seen.

Choose light: Using this combo box, one can select different lasers.

Choose medium: The medium of different refractive index can be selected using this combo box.

Choose material: Different materials can be selected using this combo box.

Switch on light: The user can make the laser source ON/OFF using this button.

Angle of the polarizer: Using this slider, one can change the angle of the polarizer from zero to 360 degrees.

Angle of incidence: This slider helps one to change the angle of incidence, which can be varied from zero to 360 degrees.

Observations & Readings:-

| S.No | Name of the Medium | Refractive index of medium (μ_1) | Name of the Material | Refractive index of material (μ_2) | Current | Brewster's Angle |
|------|--------------------|--|----------------------|--|---------|------------------|
| 1 | Air | 1 | Topaz | 1.607 | | |
| 2 | Air | 1 | Crown Glass | 1.52 | | |
| 3 | Air | 1 | Flint Glass | 1.57 | | |
| 4 | Helium | 1.00003 | Topaz | 1.607 | | |
| 5 | Helium | 1.00003 | Crown Glass | 1.52 | | |
| 6 | Helium | 1.00003 | Flint Glass | 1.57 | | |
| 7 | Hydrogen | 1.00013 | Topaz | 1.607 | | |
| 8 | Hydrogen | 1.00013 | Crown Glass | 1.52 | | |
| 9 | Hydrogen | 1.00013 | Flint Glass | 1.57 | | |
| 10 | Carbon dioxide | 1.0 | Topaz | 1.607 | | |
| 11 | Carbon dioxide | 1.0 | Crown Glass | 1.52 | | |
| 12 | Carbon dioxide | 1.0 | Flint Glass | 1.57 | | |

Result: Brewster's law is verified by determining the Brewster's angles for various materials in different media.

Conclusion: Course outcomes **CO1 to CO5**, Program outcomes **PO1, PO2, PO9 & PO12** are attained.

Experiment No:
Date:

EXPERIMENT No – 12 HALL EFFECT EXPERIMENT

Aim:

1. To determine the Hall voltage developed across the given sample material.
2. To determine the Hall coefficient & the carrier concentration of charge carriers in the given sample material

Apparatus:

Two solenoids, Constant current supply, four probe, Digital gauss meter, Hall Effect apparatus (which consist of Constant Current Generator (CCG), digital milli voltmeter and Hall probe).

Theory:

If a current carrying conductor placed in a perpendicular magnetic field, a potential difference will generate in the conductor which is perpendicular to both magnetic field and current. This phenomenon is called Hall Effect. In solid state physics, Hall Effect is an important tool to characterize the materials especially semiconductors. It directly determines both the sign and density of charge carriers in a given sample.

Consider a rectangular conductor of thickness t kept in XY plane. An electric field is applied in X-direction using Constant Current Generator (CCG), so that current I flow through the sample. If w is the width of the sample and t is the thickness. There for current density is given by

$$J_x = I/wt \quad (1)$$

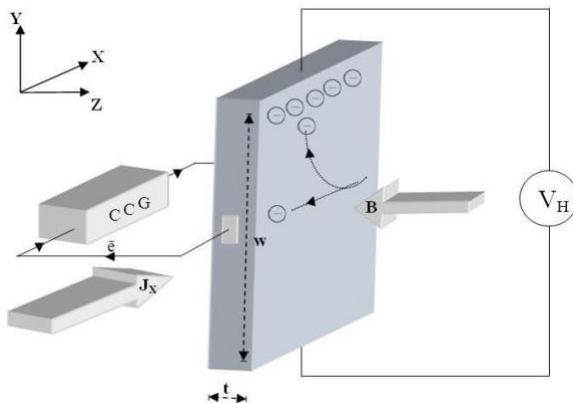


Fig.1 Schematic representation of Hall Effect in a conductor. **CCG** - Constant Current Generator, **J_x** - current density, **\bar{e}** - electron, **B** - applied magnetic field, **t** - thickness, **w** - width, **V_H** - Hall voltage

If the magnetic field is applied along negative z-axis, the Lorentz force moves the charge carriers (say electrons) toward the y-direction. This results in accumulation of charge carriers at the top edge of the sample. This set up a transverse electric field E_y in the sample. This develop a potential difference along y-axis is known as Hall voltage V_H and this effect is called Hall Effect.

A current is made to flow through the sample material and the voltage difference between its top and bottom is measured using a volt-meter. When the applied magnetic field $B=0$, the voltage difference will be zero.

We know that a current flows in response to an applied electric field with its direction as conventional and it is either due to the flow of holes in the direction of current or the movement of electrons backward. In both cases, under the application of magnetic field the magnetic Lorentz

force, $F_m = q(v \times B)$ causes the carriers to curve upwards. Since the charges cannot escape from the material, a vertical charge imbalance builds up. This charge imbalance produces an electric field which counteracts with the magnetic force and a steady state is established. The vertical electric field can be measured as a transverse voltage difference using a voltmeter.

In steady state condition, the magnetic force is balanced by the electric force. Mathematically we can express it as

$$eE = evB$$

(2)

Where 'e' the electric charge, 'E' the hall electric field developed, 'B' the applied magnetic field and 'v' is the drift velocity of charge carriers. And the current 'I' can be expressed as,

$$I = neAv \quad (3)$$

Where 'n' is the number density of electrons in the conductor of length l, breadth 'w' and thickness 't'.

Using (1) and (2) the Hall voltage V_H can be written as,

$$V_H = Ew = vBw = \frac{IB}{net}$$

$$V_H = R_H \frac{IB}{t} \quad (4)$$

by rearranging eq(4) we get

$$R_H = \frac{V_H * t}{I * B} \quad (5)$$

Where R_H is called the Hall coefficient.

$$R_H = 1/ne \quad (6)$$

Procedure: Controls

Combo box

Select procedure: This is used to select the part of the experiment to perform.

- 1) Magnetic field Vs Current.
- 2) Hall effect setup.

Select Material: This slider activate only if Hall Effect setup is selected. And this is used to select the material for finding Hall coefficient and carrier concentration.

Button

Insert Probe/ Remove Probe: This button used to insert/remove the probe in between the solenoid.

Show Voltage/ Current: This will activate only if Hall Effect setup selected and it used to display the Hall voltage/ current in the digital meter.

Reset: This button is used to repeat the experiment.

Slider

Current: This slider used to vary the current flowing through the Solenoid.

Hall Current: This slider used to change the hall current

Thickness: This slider used to change the thickness of the material selected.

Procedure for doing the simulation:

Part-1. To measure the magnetic field generated in the solenoid

- Select **Magnetic field Vs Current** from the procedure combo-box.
- Click **Insert Probe** button
- Placing the probe in between the solenoid by clicking the wooden stand in the simulator.

Using Current slider, varying the current through the solenoid and corresponding magnetic field is to be noted from Gauss meter.

| Trial No: | Current through solenoid | Magnetic field generated |
|-----------|--------------------------|--------------------------|
| 1 | 1 A | |
| 2 | 1.5 A | |
| 3 | 2 A | |
| 4 | 2.5 A | |
| 5 | 3 A | |
| 6 | 3.5 A | |
| 7 | 4 A | |
| 8 | 4.5 A | |
| 9 | 5 A | |

Table(1)

Part-2. Hall Effect apparatus

Select **Hall Effect Setup** from the **Select the procedure** combo box

Click Insert **Hall Probe** button

Placing the probe in between the solenoid by clicking the wooden stand in the simulator.

Set "**current slider**" value to minimum.

Select the material from "**Select Material**" combo-box.

Select the Thickness of the material using the slider **Thickness**.

Vary the Hall current using the slider **Hall current**.

Note down the corresponding Hall voltage by clicking "**show voltage**" button.

Then calculate Hall coefficient and carrier concentration of that material using the equation

$$R_H = V_H t / (I \times B)$$

Where R_H is the Hall coefficient $R_H = 1/ne$

And n is the carrier concentration Repeat the experiment with different magnetic field.

Observations & Readings: - Name of the Material==Germanium

| S.No | Thickness in (m) | Hall | Hall Voltage in (V) | | | | |
|------|------------------|-----------------|---------------------|--------------|--------------|--------------|--------------|
| | | Current in (mA) | Current 1(A) | Current 2(A) | Current 3(A) | Current 4(A) | Current 5(A) |
| 1 | 0.0001 | 1 | | | | | |
| 2 | 0.0001 | 2 | | | | | |
| 3 | 0.0001 | 3 | | | | | |
| 4 | 0.0001 | 4 | | | | | |
| 5 | 0.0001 | 5 | | | | | |
| 6 | 0.0002 | 1 | | | | | |
| 7 | 0.0002 | 2 | | | | | |
| 8 | 0.0002 | 3 | | | | | |
| 9 | 0.0002 | 4 | | | | | |
| 10 | 0.0002 | 5 | | | | | |
| 11 | 0.0003 | 1 | | | | | |
| 12 | 0.0003 | 2 | | | | | |
| 13 | 0.0003 | 3 | | | | | |
| 14 | 0.0003 | 4 | | | | | |
| 15 | 0.0003 | 5 | | | | | |
| 16 | 0.0004 | 1 | | | | | |
| 17 | 0.0004 | 2 | | | | | |
| 18 | 0.0004 | 3 | | | | | |
| 19 | 0.0004 | 4 | | | | | |

| | | | | | | | |
|----|--------|---|--|--|--|--|--|
| 20 | 0.0004 | 5 | | | | | |
| 21 | 0.0005 | 1 | | | | | |
| 22 | 0.0005 | 2 | | | | | |
| 23 | 0.0005 | 3 | | | | | |
| 24 | 0.0005 | 4 | | | | | |
| 25 | 0.0005 | 5 | | | | | |
| 26 | 0.0006 | 1 | | | | | |
| 27 | 0.0006 | 2 | | | | | |
| 28 | 0.0006 | 3 | | | | | |
| 29 | 0.0006 | 4 | | | | | |
| 30 | 0.0006 | 5 | | | | | |
| 31 | 0.0007 | 1 | | | | | |
| 32 | 0.0007 | 2 | | | | | |
| 33 | 0.0007 | 3 | | | | | |
| 34 | 0.0007 | 4 | | | | | |
| 35 | 0.0007 | 5 | | | | | |
| 36 | 0.0008 | 1 | | | | | |
| 37 | 0.0008 | 2 | | | | | |
| 38 | 0.0008 | 3 | | | | | |
| 39 | 0.0008 | 4 | | | | | |
| 40 | 0.0008 | 5 | | | | | |
| 41 | 0.0009 | 1 | | | | | |
| 42 | 0.0009 | 2 | | | | | |
| 43 | 0.0009 | 3 | | | | | |
| 44 | 0.0009 | 4 | | | | | |
| 45 | 0.0009 | 5 | | | | | |

Hall Coefficient of Germanium=

; & Charge Carrier Concentration in Germanium=

Observations & Readings: - Name of the Material== Gold

| S.No | Thickness in (m) | Hall Current in (mA) | Current 1(A) | Hall Voltage in (V) | Current 2(A) | Current 3(A) | Current 4(A) | Current 5(A) |
|------|---------------------|----------------------------|-----------------|---------------------|-----------------|-----------------|-----------------|-----------------|
| 1 | 0.0001 | 1 | | | | | | |
| 2 | 0.0001 | 2 | | | | | | |
| 3 | 0.0001 | 3 | | | | | | |
| 4 | 0.0001 | 4 | | | | | | |
| 5 | 0.0001 | 5 | | | | | | |
| 6 | 0.0002 | 1 | | | | | | |
| 7 | 0.0002 | 2 | | | | | | |
| 8 | 0.0002 | 3 | | | | | | |
| 9 | 0.0002 | 4 | | | | | | |
| 10 | 0.0002 | 5 | | | | | | |
| 11 | 0.0003 | 1 | | | | | | |
| 12 | 0.0003 | 2 | | | | | | |
| 13 | 0.0003 | 3 | | | | | | |
| 14 | 0.0003 | 4 | | | | | | |
| | 0.0003 | 5 | | | | | | |
| 16 | 0.0004 | 1 | | | | | | |
| 17 | 0.0004 | 2 | | | | | | |
| 18 | 0.0004 | 3 | | | | | | |

| | | | | | | | |
|----|--------|---|--|--|--|--|--|
| 19 | 0.0004 | 4 | | | | | |
| 20 | 0.0004 | 5 | | | | | |
| 21 | 0.0005 | 1 | | | | | |
| 22 | 0.0005 | 2 | | | | | |
| 23 | 0.0005 | 3 | | | | | |
| 24 | 0.0005 | 4 | | | | | |
| 25 | 0.0005 | 5 | | | | | |
| 26 | 0.0006 | 1 | | | | | |
| 27 | 0.0006 | 2 | | | | | |
| 28 | 0.0006 | 3 | | | | | |
| 29 | 0.0006 | 4 | | | | | |
| 30 | 0.0006 | 5 | | | | | |
| 31 | 0.0007 | 1 | | | | | |
| 32 | 0.0007 | 2 | | | | | |
| 33 | 0.0007 | 3 | | | | | |
| 34 | 0.0007 | 4 | | | | | |
| 35 | 0.0007 | 5 | | | | | |
| 36 | 0.0008 | 1 | | | | | |
| 37 | 0.0008 | 2 | | | | | |
| 38 | 0.0008 | 3 | | | | | |
| 39 | 0.0008 | 4 | | | | | |
| 40 | 0.0008 | 5 | | | | | |
| 41 | 0.0009 | 1 | | | | | |
| 42 | 0.0009 | 2 | | | | | |
| 43 | 0.0009 | 3 | | | | | |
| 44 | 0.0009 | 4 | | | | | |
| 45 | 0.0009 | 5 | | | | | |

Hall Coefficient of Gold= ; & Charge Carrier Concentration in Gold=

Observations & Readings: - Name of the Material==Copper

| S.No | Thickness in (m) | Hall Current in (mA) | Hall Voltage in (mV) | | | | |
|------|---------------------|----------------------------|----------------------|-----------------|-----------------|-----------------|-----------------|
| | | | Current 1(A) | Current 2(A) | Current 3(A) | Current 4(A) | Current 5(A) |
| 1 | 0.0001 | 1 | | | | | |
| 2 | 0.0001 | 2 | | | | | |
| 3 | 0.0001 | 3 | | | | | |
| 4 | 0.0001 | 4 | | | | | |
| 5 | 0.0001 | 5 | | | | | |
| 6 | 0.0002 | 1 | | | | | |
| 7 | 0.0002 | 2 | | | | | |
| 8 | 0.0002 | 3 | | | | | |
| 9 | 0.0002 | 4 | | | | | |
| 10 | 0.0002 | 5 | | | | | |
| 11 | 0.0003 | 1 | | | | | |
| 12 | 0.0003 | 2 | | | | | |
| 13 | 0.0003 | 3 | | | | | |
| 14 | 0.0003 | 4 | | | | | |
| 15 | 0.0003 | 5 | | | | | |
| 16 | 0.0004 | 1 | | | | | |
| 17 | 0.0004 | 2 | | | | | |

| | | | | | | | |
|----|--------|---|--|--|--|--|--|
| 18 | 0.0004 | 3 | | | | | |
| 19 | 0.0004 | 4 | | | | | |
| 20 | 0.0004 | 5 | | | | | |
| 21 | 0.0005 | 1 | | | | | |
| 22 | 0.0005 | 2 | | | | | |
| 23 | 0.0005 | 3 | | | | | |
| 24 | 0.0005 | 4 | | | | | |
| 25 | 0.0005 | 5 | | | | | |
| 26 | 0.0006 | 1 | | | | | |
| 27 | 0.0006 | 2 | | | | | |
| 28 | 0.0006 | 3 | | | | | |
| 29 | 0.0006 | 4 | | | | | |
| 30 | 0.0006 | 5 | | | | | |
| 31 | 0.0007 | 1 | | | | | |
| 32 | 0.0007 | 2 | | | | | |
| 33 | 0.0007 | 3 | | | | | |
| 34 | 0.0007 | 4 | | | | | |
| 35 | 0.0007 | 5 | | | | | |
| 36 | 0.0008 | 1 | | | | | |
| 37 | 0.0008 | 2 | | | | | |
| 38 | 0.0008 | 3 | | | | | |
| 39 | 0.0008 | 4 | | | | | |
| 40 | 0.0008 | 5 | | | | | |
| 41 | 0.0009 | 1 | | | | | |
| 42 | 0.0009 | 2 | | | | | |
| 43 | 0.0009 | 3 | | | | | |
| 44 | 0.0009 | 4 | | | | | |
| 45 | 0.0009 | 5 | | | | | |

Result:- Hall coefficient for different materials & their Charge Carrier Concentrations are determined and are given in the below table.

| S.No | Name of the Material | Hall coefficient (R_H) | Carrier Concentration |
|------|----------------------|----------------------------|-----------------------|
| 1 | Germanium | | |
| 2 | Gold | | |
| 3 | Copper | | |

Conclusion: Course outcomes **CO1 to CO5**, Program outcomes **PO1, PO2, PO9 & PO12** are attained

Signature of Facultywith
date & Remark

APPENDIX- I

Fundamental Physical constants

| Name | Symbol | Constant Value |
|------------------------|------------------------|--|
| Speed of light | c | $2.99792458 \times 10^8 \text{ m/s}$ |
| Planck constant | h | $6.6260755 \times 10^{-34} \text{ J}\cdot\text{s}$ |
| Planck constant | h | $4.1356692 \times 10^{-15} \text{ eV}\cdot\text{s}$ |
| Gravitation constant | G | $6.67259 \times 10^{-11} \text{ m}^3 \cdot \text{kg}^{-1} \cdot \text{s}^{-2}$ |
| Boltzmann constant | k | $1.380658 \times 10^{-23} \text{ J/K}$ |
| Avogadro's number | N_A | $6.0221 \times 10^{23} \text{ mol}^{-1}$ |
| Charge of electron | e | $1.60217733 \times 10^{-19} \text{ C}$ |
| Permeability of vacuum | μ_0 | $4\pi \times 10^{-7} \text{ N/A}^2$ |
| Permittivity of vacuum | ϵ_0 | $8.854187817 \times 10^{-12} \text{ F/m}$ |
| Coulomb constant | $1/4\pi\epsilon_0 = K$ | $8.987552 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2$ |
| Faraday constant | F | 96485.309 C/mol |
| Mass of electron | m_e | $9.1093897 \times 10^{-31} \text{ kg}$ |
| Mass of electron | m_e | $0.51099906 \text{ MeV}/c^2$ |
| Mass of proton | m_p | $938.27231 \text{ MeV}/c^2$ |
| Mass of neutron | m_n | $1.6749286 \times 10^{-27} \text{ kg}$ |
| Mass of neutron | m_n | $939.56563 \text{ MeV}/c^2$ |
| Bohr magneton | μ_B | $9.2740154 \times 10^{-24} \text{ J/T}$ |
| Flux quantum | Φ_0 | $2.067834 \times 10^{-15} \text{ T}\cdot\text{m}^2$ |
| Bohr radius | a_0 | $0.529177249 \times 10^{-10} \text{ m}$ |
| Earth's magnetic field | H | 0.38 oersted |

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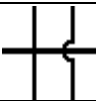

















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APPENDIX –II
Physical Density of Metal's & Alloy's

| S.No. | Metal or Alloy | Density (kg/m^3) |
|--------------|-----------------------|---|
| 1. | Actinium | 10070 |
| 2. | Aluminum | 2712 |
| 3. | Barium | 3594 |
| 4. | Beryllium | 1840 |
| 5. | Bismuth | 9750 |
| 6. | Brass 60/40 | 8520 |
| 7. | Bronze (8-14% Sn) | 7400 - 8900 |
| 8. | Brass - casting | 8400 - 8700 |
| 9. | Cadmium | 8640 |
| 10. | Cast iron | 6800 - 7800 |
| 11. | Chromium | 7190 |
| 12. | Cobalt | 8746 |
| 13. | Copper | 8940 |
| 14. | Iron | 7850 |
| 15. | Nichrome | 8400 |
| 16. | Nickel | 8908 |
| 17. | Gold | 19320 |
| 18. | Red Brass | 8746 |
| 19. | Silver | 10490 |
| 20. | Stainless Steel | 7480 - 8000 |
| 21. | Steel | 7850 |
| 22. | Tin | 7280 |

APPENDIX –III

| Symbol | Component name | Physical Meaning |
|---|----------------------------|---|
|  | Not Connected Wire | Wires are not connected |
|  | Earth Ground | Used for zero potential reference and electrical shock protection. |
|  | Resistor | Resistor reduces the current flow. |
|  | Variable Resistor/Rheostat | Adjustable resistor - has 2 terminals. |
|  | Capacitor | Capacitor is used to store electric charge. It acts as short circuit with AC and open circuit with DC. |
|  | Capacitor | |
|  | Variable Capacitor | Adjustable capacitance |
|  | Inductor | Coil / solenoid that generates magnetic field |
|  | Voltage Source | Generates constant voltage |
|  | Current Source | Generates constant current. |
|  | AC Voltage Source | AC voltage source |
|  | Generator | Electrical voltage is generated by mechanical rotation of the generator |
|  | Battery Cell | Generates constant voltage |
|  | Battery | Generates constant voltage |
|  | Voltmeter | Measures voltage. Has very high resistance. Connected in parallel. |
|  | Ammeter | Measures electric current. Has near zero resistance. Connected serially. |
|  | Diode | Diode allows current flow in one direction only (left to right). |
|  | Zener Diode | Allows current flow in one direction, but also can flow in the reverse direction when above breakdown voltage |