

MUZAFFARPUR

INSTITUTE OF TECHNOLOGY, MUZAFFARPUR



विज्ञान एवं प्रौद्योगिकी विभाग

Department of Science and Technology

Government of Bihar

**COURSE FILE
OF
PHYSICS
(L-T-P:3-1-3) Credits 5.5**



By:

**S.K. TIWARI & A. DIXIT
ASSISTANT PROFESSOR,
DEPARTMENT OF PHYSICS
MIT, MUZAFFARPUR**



Department of Physics

Vision:

- To serve the nation by providing practical and theoretical knowledge to the students in the field of engineering and experimental research.

Mission :

- To make the laboratory well equipped.
- To arrange new experiment in lab as per syllabus.
- To encourage innovative work to students by undertaking projects, collaboration with industries, institution, and government.

Lab Course Outcomes: [101101P, 102101P, 105101P, 103201P]

Course Outcome 1: Experimental knowledge of fundamental physics and basic engineering principles to include advanced knowledge in one or more engineering disciplines
Course Outcome 2: To design different experimental setup in the field of Optics, Laser, Semiconductor Physics, & Quantum Physics.
Course Outcome 3: The ability to formulate experimental design analyzes, and interprets experiments in engineering physics.
Course Outcome 4: Use of modern engineering devices in Physics experimental work.
Course Outcome 5: To enhance experimental knowledge in optoelectronics, Light and Mechanics.

Program Outcomes: [Physics]

Programm Outcome 1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
Programm Outcome 2: 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.
Programm Outcome 3: 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.
Programm Outcome 4: 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.
Programm Outcome 5: 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.
Programm Outcome 6: 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.
Programm Outcome 7: 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.
Program Outcome 8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
Program Outcome 9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
Program Outcome 10: 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.
Program Outcome 11: 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.
Program Outcome 12: 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.

Mapping – CO – PO :

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO2	2	2	-	1	-	-	-	-	1	1	1	1
CO2	2	2	1	2	-	-	-	-	2	1	-	1
CO3	2	2	-	3	-	-	-	-	1	1	-	-2
CO4	2	2	-	3	1	1	-	-	1	1	-	2
CO5	3	2	2	3	-	1	1	-	1	2	-	2

3 – Excellent; 2 – Good; 1 – Average

Institute / School Name	Muzaffarpur Institute of Technology, Muzaffarpur		
Program Name	B.Tech		
Course Code	[101101P, 102101P, 105101P, 103201P]		
Course Name	Physics Lab		
Labs (per week)	8	Course Credits	2
Course Coordinator Name	Dr. A. Dixit, S.K. Tiwari		

1. Scope and Objectives of the Course

The purpose of this lab is to give the student an understanding of how the basic methods of Physics relate to experiments. The course is designed as per the Bureau of Indian Standard guidelines which is duly approved by Aryabhata Knowledge University which prepares the students for the future.

2. Reference Books

RB1: A Concise laboratory Manual on Engineering Physics by J. W. Charles and K. Sadasivam

3. Other readings and relevant websites

S. No.	Link of Journals, Magazines, websites and Research Papers
1	https://video.search.yahoo.com/search/video?fr=tightropetb&p=To+determine+acceleration+due+to+gravity+by+a+bar+pendulum.+video#id=3&vid=9cb3778d36f12eb7fcdf783f8f8c83a5&action=view
2	https://video.search.yahoo.com/search/video;_ylt=AwrTHRsyHoloQUQAJm5XNyOa;_ylu=X3oDMTB0NjZjZzZhBGNvbG8DZ3ExBHBvcwMxBHZAaWQDBHNIYwNwaXZz?p=To+determine+and+output+characteristics+of+a+PNP+Junction+Transistor+in+CE+Mode+or+Configuration.&fr2=piv-web&fr=tightropetb#id=6&vid=16b37fc2a447ee5cd83c1972c423667f&action=view
3	https://video.search.yahoo.com/search/video;_ylt=A0SO80dqH4laxMMALXRXNyOa;_ylu=X3oDMTB0NjZjZzZhBGNvbG8DZ3ExBHBvcwMxBHZAaWQDBHNIYwNwaXZz?p=To+determine+Planck%27s+Constant.&fr2=piv-web&fr=tightropetb#id=7&vid=e448cb6757b274730e3c77eb8152131a&action=view
4	file:///C:/Users/Puja%20Kumari/Downloads/334933606-to-determine-the-size-of-lycopodium-particle.pdf

4. Lab Plan from July 2018 Onwards:

S. No.	Experiments for ME & LT Branch
1	Experiments on electromagnetic induction and electromagnetic braking
2	LC circuit and LCR circuit
3	Resonance phenomena in lcr circuits;
4	Magnetic field from helmholtz coil;
5	Measurement of lorentz force in a vacuum tube
S. No.	Experiments for IT Branch
1	To determine acceleration due to gravity by a bar pendulum.
2	Forward and Reverse bias characteristics of PN junction diode
3	To determine and output characteristics of a PNP Junction Transistor in CE Mode or Configuration.
4	To determine Planck's Constant.
5	To obtain forbidden energy gap of semiconductor diode.

S. No.	Experiments for Civil Branch
1	Coupled oscillators; experiments on an air-track
2	Experiment on moment of inertia measurement
3	Experiments with gyroscope; resonance phenomena in mechanical oscillators
4	
S. No.	Experiments for EC & EL Branch
1.	To determine acceleration due to gravity by a bar pendulum.
2	To determine Planck's Constant.
3	
4	To obtain forbidden energy gap of semiconductor diode.
5	To obtain dielectric constant.

5. Evaluation Scheme:

Component 1*	Lab Work and attendance	10
Component 2	Lab performance/ File work	10
Component 3**	End Term/ Viva – Voce	30
	total	50

*Lab Performance will be evaluated weekly

**The End Term examination for practical courses is held at the end of semester and includes conduct of experiment and an oral examination (viva voce). The mandatory requirement of 75% attendance in all lab classes is to be met for being eligible to appear in this component

This document is approved by

Designation	Name	Signature
Course Coordinator	Dr. S.K. Tiwari & A Dixit	
HoD	Dr. SK Jha	
Principal	Prof. JN Jha	
Date		

Experiment No.1: Acceleration due to gravity 'g' by Bar Pendulum

Aim of the Experiment: To determine the value of acceleration due to gravity by using bar pendulum.

Apparatus Required: Bar pendulum, stop watch and meter scale.

Theory:

A. The general formula of the time period for bar pendulum is given by following equation:

$$T = 2\pi\sqrt{\frac{\frac{k^2}{l} + l}{g}} = 2\pi\sqrt{\frac{l_1 + l_2}{g}}$$
$$g = \frac{4\pi^2(l_1 + l_2)}{T^2} = \frac{4\pi^2L}{T^2} \quad (1)$$

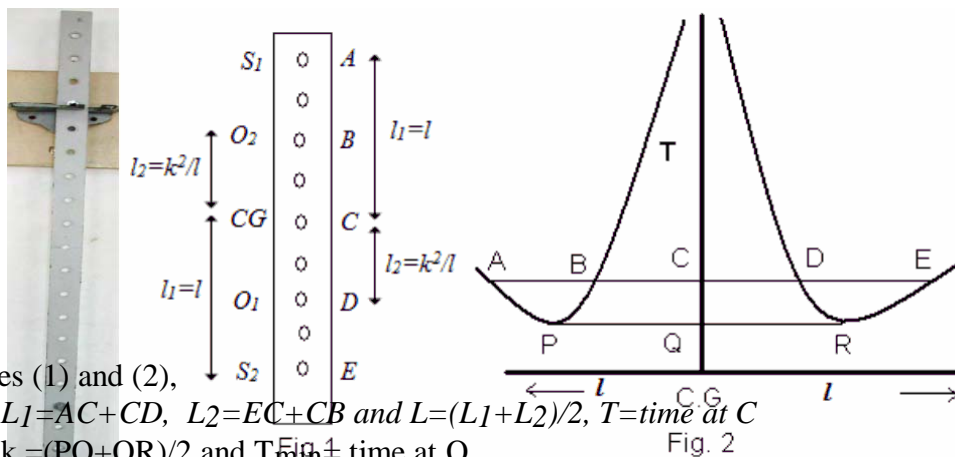
where l: distance between C.G. and suspension point, L: distance between suspension and oscillation points, $L = l_1 + l_2 = l + \frac{k^2}{l}$ g: Acceleration due to gravity T: time period

B. Time period is minimum when $l = \pm k$, in this situation the equation (1) becomes as:

$$T_{\min} = 2\pi\sqrt{\frac{k}{g}}$$
$$g = \frac{8\pi^2k}{T_{\min}^2} \quad (2)$$

where k is the radius of gyration, T_{\min} : minimum time period.

The value of g can be calculated by using equation (1) and (2). The values of L, T, k and T_{\min} are obtained using graph between T and L for bar pendulum which is shown in following figure:



C. The radius of gyration can be obtained by using this formula:

$$k = \sqrt{l_1 l_2} \quad (3)$$

Where $l_1 = (AC + CE)/2$, $l_2 = (BC + CD)/2$

Procedure:

- (1) Place the knife-edges at the first hole of the bar.
- (2) Suspend the pendulum through rigid support with the knife-edge.
- (3) Oscillate the pendulum for small amplitude ($\theta = 3 \sim 4^\circ$).
- (4) Note the time taken for 20 oscillations and measure the distance of the hole from the C.G. of the bar.
- (5) Repeat the observations (2)-(4) for knife-edges at first half side holes of bar.
- (6) Repeat the process (1)-(5) for the second half side of the bar.
- (7) Plot the graph between T and L.

Observations:

1. Least count of the stop watch = sec
2. Least count of the meter scale = cm

3. Table for l and T

S. No.	l (cm)	t (time taken for 20 oscillations)	T = t/20
For first half side of the bar			
1	45		
2	40		
3	35		
4	30		
5	25		
6	20		
7	15		
8	10		
9	5		
For second half side of the bar			
1	-5		
2	-10		
3	-15		
4	-20		
5	-25		

6	-30		
7	-35		
8	-40		
9	-45		

Calculations: from graph, $L = (AD + EB)/2 = \dots$, $T = \dots \text{sec}$,
 $k = PR/2 = \dots$

$T_{\min} = \dots$
 $\text{sec } l_1 = (AC + CE)/2 = \dots$,
 $l_2 = (BC + CD)/2$

Result: The acceleration due to gravity (g) = $\dots \text{m/s}^2$
Radius of gyration (k) = $\dots \text{cm}$ (from calculation)
= $\dots \text{cm}$ (from graph)

Precautions:

1. The motion of the pendulum should be in a vertical plane. While taking the time, start taking observations after two oscillations to avoid any irregularity of motion.
2. The amplitude of oscillation should be small.

Viva Questions:

1: Define 'g'?

Ans. Acceleration due to gravity.

2: What is the difference between 'g' and 'G'?

Ans. The value of G (gravitational constant) remains constant throughout the universe, whereas the value of 'g' decreases with the increase in the height.

3: What is the value of 'g' at the C.G. of the earth?

Ans. Zero.

4: How the value of 'g' changes as we move from the surface towards the C.G. of the earth?

Ans. As a rule it should decrease gradually but due to variable density of the earth, it increases up to a small depth and then decreases.

5: Where the 'g' is greater, at equator or poles?

Ans. At the poles (where the earth is slightly compressed).

6: Where 'g' will be smaller, at Karachi or at Muree?

Ans. At Muree (7000 ft. above sea level).

7: What is the value of 'g' at sea level?

Ans. $g = 9.781 \text{ m/s}^2$ at equator.

$g = 9.832 \text{ m/s}^2$ at poles.

8: Why the amplitude of the pendulum is kept small (2cm or about 5 cm)?

Ans. If the amplitude is large the motion of the simple pendulum will not be simple harmonic. If θ will not be small $\sin \theta \neq \theta$ and $T \neq 2\sqrt{L/g}$.

9: Define simple harmonic motion (S.H.M).

Ans. The motion of the vibrating body is S.H.M. when

- (a) The magnitude of its acceleration is directly proportional to the displacement x from the mean position.
- (b) The direction of acceleration is always towards the mean position (that is opposite to x) mathematically: $a \propto -x$

10: Time period will increase or decrease if we use a heavier bob.

Ans. There will be no change in the time period. EXPLANATION: The relation $T = 2\pi\sqrt{L/g}$ shows that there is no effect of mass on the time period.

Experiment No.2: I-V Characteristics of PN Junction Diode

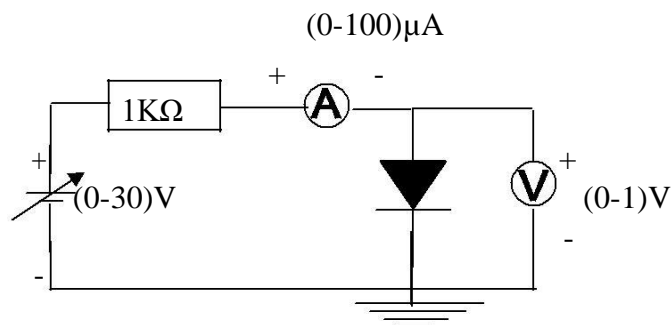
Aim of the Experiment: To study the PN junction diode characteristics under Forward & Reverse bias conditions.

Apparatus Required: R.P.S(0-30)V, Ammeter(0–100) μ A, Voltmeter(0–1)V, Diode IN4001, Resistor 1k Ω , Wires

Theory: A PN junction diode is a two terminal junction device. It conducts only in one direction .

Forward Bias: On forward biasing, initially no current flows due to barrier potential. As the applied potential exceeds the barrier potential the charge carriers gain sufficient energy to cross the potential barrier and hence enter the other region. The holes, which are majority carriers in the P-region, become minority carriers on entering the N-regions, and electrons, which are the majority carriers in the N-region, become minority carriers on entering the P-region. This injection of Minority carriers results in the current flow, opposite to the direction of electron movement

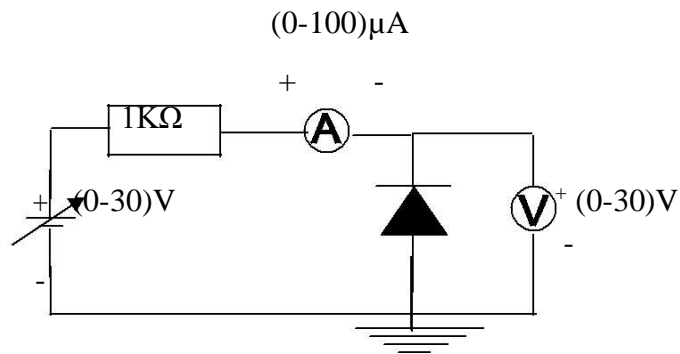
Circuit Diagram:



Reverse Bias: On reverse biasing, the majority charge carriers are attracted towards the terminals due to the applied potential resulting in the widening of the depletion region. Since the charge carriers are pushed towards the terminals no current flows in the device due to majority charge carriers. There will be some current in the device due to the thermally generated minority carriers. The generation of such carriers is independent of the applied potential and hence the current is constant for all increasing reverse potential. This current is referred to as

Reverse Saturation Current (I_o) and it increases with temperature. When the applied reverse voltage is increased beyond the certain limit, it results in breakdown. During breakdown, the diode current increases tremendously.

Circuit Diagram:



Procedure:

Forward Bias:

1. Connect the circuit as per the diagram.
2. Vary the applied voltage V in steps of 0.1V.
3. Note down the corresponding Ammeter readings I_f .
4. Plot a graph between V_f & I_f

Reverse Bias:

1. Connect the circuit as per the diagram.
2. Vary the applied voltage V_r in steps of 0.5V.
3. Note down the corresponding Ammeter readings I_r .
4. Plot a graph between V_r & I_r
5. Find the dynamic resistance $r = \delta V / \delta I$.

Observation:

Forward Bias:

Serial Number	Voltage(V_f) In Volts	Current (I_f) In mA
1.		
2.		
3.		
4.		
5.		

Serial Number	Voltage(V_r) In Volts	Current (I_r) In μA

1.		
2.		
3.		
4.		

1. Find the d. c. static current

2. Find the a.c. (dynamic) resistance $r = \delta V / \delta I$ ($r = V/I$) = $\frac{V_2 - V_1}{I_2 - I_1}$

3. Find the forward voltage drop = [Hint: it is equal to 0.7 for Si and 0.3 for Ge]=

Formula for Reverse Saturation Current (I_0):

$$I_0 = \frac{A q n_i^2}{N_A} \left[\exp\left(\frac{V}{\eta V_T}\right) - 1 \right]$$

Where V_T is the voltage equivalent of Temperature = kT/q

k is Boltzmann's constant, q is the charge of the electron and T is the temperature in degrees Kelvin.

$\eta = 1$ for Silicon and 2 for Germanium

Results:

Forward and Reverse bias characteristics of the PN junction diode was Studied and the dynamic resistance under

Forward bias = -----

Reverse bias = -----

Reverse Saturation Current = -----

PRECAUTIONS:-

1. Make sure that the connections are tight.
2. Take care to apply suitable forward and reverse voltages across the diode so that suitable forward and reverse currents flow through the diode. Otherwise the diode may be damaged.

Viva Questions:

1.What are Semiconductors? Give examples?

Ans:The materials whose electrical property lies between those of conductors and insulators are known as Semiconductors. Ex germanium, silicon.

2.What are the types of Semiconductor?

Ans: 1. Intrinsic semiconductor 2. Extrinsic semiconductor.

3. What is Intrinsic Semiconductor?

Ans: Pure form of semiconductors are said to be intrinsic semiconductor. Ex: germanium, silicon.

4. What is Extrinsic Semiconductor?

Ans: If certain amount of impurity atom is added to intrinsic semiconductor the resulting semiconductor is Extrinsic or impure Semiconductor.

5. What are the types of Extrinsic Semiconductor?

Ans: 1. P-type Semiconductor 2. N-Type Semiconductor.

6. What is P-type Semiconductor?

Ans: The Semiconductor which are obtained by introducing trivalent impurity atom (gallium, indium) are known as P-type Semiconductor.

7. What is N-type Semiconductor?

Ans: The Semiconductor which is obtained by introducing pentavalent impurity atom (phosphorus, Antimony) are known as N-type Semiconductor.

8. What is doping?

Ans: Process of adding impurity to a intrinsic semiconductor atom is doping. The impurity is called dopant.

9. Why n - type or pentavalent impurities are called as Donor impurities?

Ans: n- type impurities will donate the excess negative charge carriers (Electrons) and therefore they are referred to as donor impurities.

10. Why P – type or trivalent impurities are called as acceptor impurity?

Ans: p- type impurities make available positive carriers because they create holes which can accept electron, so these impurities are said to be as acceptor impurity.

11. What is depletion region in PN junction?

Ans: The region around the junction from which the mobile charge carriers (electrons and holes) are depleted is called as depletion region. Since this region has immobile ions, which are electrically charged, the depletion region is also known as space charge region.

12. Give the other names of depletion region?

Ans: i. space charge region ii. Transition region

13. What is barrier potential?

Ans: Because of the oppositely charged ions present on both sides of PN junction an electric potential is established across the junction even without any external voltage source which is termed as barrier potential.

14. What is meant by biasing a PN junction?

Ans: Connecting a PN junction to an external voltage source is biasing a PN junction.

15. What are the types of biasing a PN junction?

Ans: 1. Forward bias 2. Reverse bias.

16. What is forward bias and reverse bias in a PN junction?

Ans: When positive terminal of the external supply is connected to P region and negative terminal to N region, the PN junction is said to be forward biased. Under forward biased condition the PN region offers a very low resistance and a large amount of current flows through it.

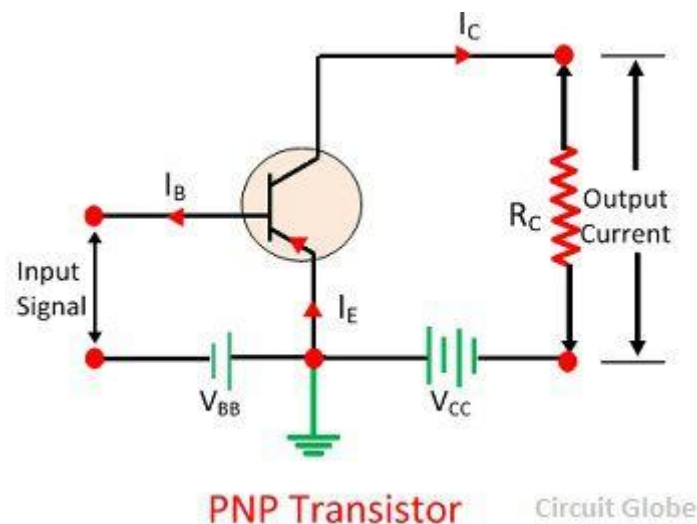
Experiment No.3: Determination of output characteristics of a PNP Junction Transistor in CE Mode

Aim of the Experiment: To determine the output characteristics of a PNP Junction transistor in CE Mode

Apparatus Required: Transistor BC 107, Resistors ($1K\Omega$, $100K\Omega$), Bread board, Dual DC Regulated Power supply (0 - 30 V), Digital Ammeters (0 - 200 mA, 0-200 μ A), Digital Voltmeter (0 - 20V), Connecting wires (Single Strand)

Theory:

Output characteristics are obtained between the output voltage and output current at constant input current. It is plotted between V_{CE} and I_C at constant I_B in CE configuration.



Procedure:

1. Connect the circuit as shown in the circuit diagram.
2. Keep emitter current $I_B = 20\mu A$ by varying V_{BB} .

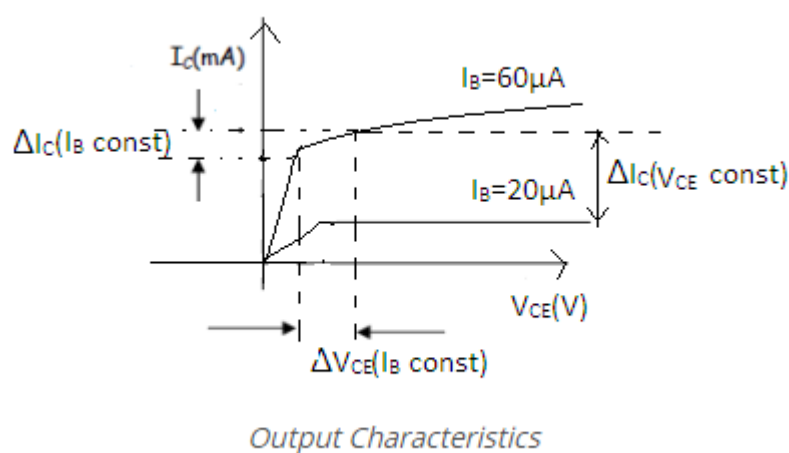
3. Varying V_{CC} gradually in steps of 1V up to 12V and note down collector current I_C and Collector-Emitter Voltage(V_{CE}).
4. Repeat above procedure (step 3) for $I_B = 60\mu A, 0\mu A$.

Observations:

Output Characteristics						
$V_{CC}(\text{volts})$	$I_B = 0 \mu A$		$I_B = 20 \mu A$		$I_B = 40 \mu A$	
	$V_{CE}(\text{Volts})$	$I_C(\text{mA})$	$V_{CE}(\text{Volts})$	$I_C(\text{mA})$	$V_{CE}(\text{Volts})$	$I_C(\text{mA})$

Graph:

1. Plot the output characteristics by taking V_{CE} on X-axis and taking I_C on Y-axis taking I_B as a constant parameter.



Calculations from Graph:

Output Characteristics: To obtain output resistance find ΔI_C and ΔV_{CE} at a constant I_B .

Output admittance $1/h_{oe} = R_o = \Delta I_C / \Delta V_{CE}$ (I_B is constant)

Forward current gain = $h_{fe} = \Delta I_C / \Delta I_B$ ($V_{CE} = \text{constant}$)

Precautions:

1. While performing the experiment do not exceed the ratings of the transistor. This may lead to damage the transistor.

2. Connect voltmeter and ammeter in correct polarities as shown in the circuit diagram.
3. Do not switch ON the power supply unless you have checked the circuit connections as per the circuit diagram.
4. Make sure while selecting the emitter, base and collector terminals of the transistor.

Viva Questions:

1. Can transistor be replaced by two back to back connected diodes?

Ans: No, because the doping levels of emitter(heavily doped), base(lightly doped) and collector(doping level greater than base and less than emitter) terminals are different from p and n terminals in diode.

2. For amplification CE is preferred, why?

Ans: Because amplification factor beta is usually ranges from 20-500 hence this configuration gives appreciable current gain as well as voltage gain at its output on the other hand in the Common Collector configuration has very high input resistance($\sim 750K \Omega$) & very low output resistance($\sim 25 \Omega$) so the voltage gain is always less than one & its most important application is for impedance matching for driving from low impedance load to high impedance source.

3. To operate a transistor as amplifier, emitter junction is forward biased and collector junction is reverse biased. Why?

Ans: Voltage is directly proportional to Resistance. Forward bias resistance is very less compared to reverse bias. In amplifier input forward biased and output reverse biased so voltage at output increases with reverse bias resistance.

4. Which transistor configuration provides a phase reversal between the input and output signals?

Ans: Common emitter configuration.

5. What is the range β of a BJT?

Ans: Beta is usually ranges from 20 - 500.

6. What is transistor? what are the types of transistors?

Ans: Transistor is a three terminal semiconductor device.

There are two types of semiconductor i.e., n-p-n and p-n-p.

7. Define n-type and p-type semiconductors.

Ans: If an intrinsic semiconductor is doped with pentavalent impurity. Then it is called n-type semiconductors.

If it is doped with trivalent impurity then it is called p-type semiconductor.

8. What is doping?

Ans: Adding trivalent or pentavalent impurity to an intrinsic semiconductor is called doping.

9. What are three basic transistor connection modes? Which mode is most preferred? Why?

Ans: Common-Emitter, Common-Base & Common-Collector connections.

CE mode is most preferred because CE modes gives Highest voltage gain.

10. Define current amplification factor of a transistor?

Ans: It is defined as ratio of change in collector current to change in base current.

11. What is the biasing rule of transistor?

Ans: Emitter base junction should be forward biased and collector base junction should be reversed biased.

12. What is semiconductor?

Ans: Semiconductor is a substance which has the resistivity in between that of conductor and insulator. semiconductor has negative temperature coefficient of resistance.

13. Which are the commonly used semiconductors?

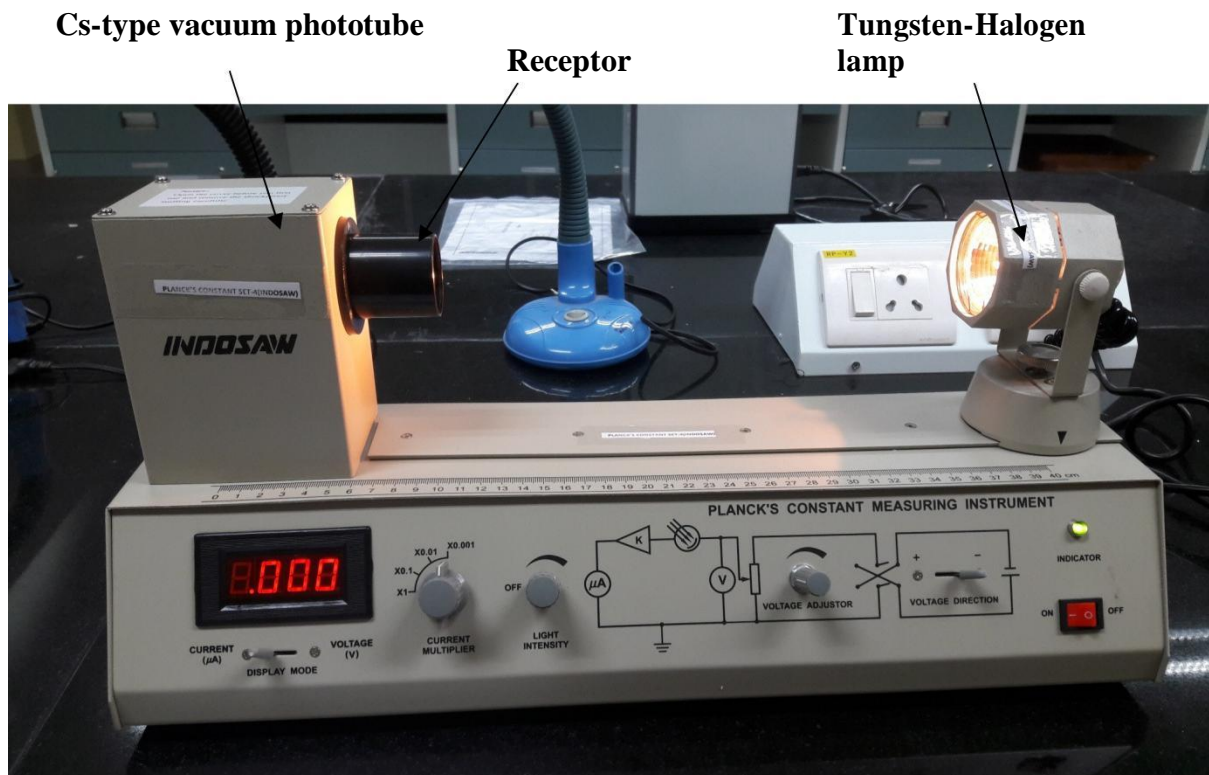
Ans: Germanium & Silicon

Experiment No.4: Determination of Planck's Constant

Aim of the Experiment: To determine the Planck's constant 'h'.

Experimental Set up:

The present experimental set-up comprises of a tungsten-halogen light source with five different colour filters, a Cesium-type vacuum phototube, a built-in power supply and a current multiplier. The base of the phototube is built into a dark room and in front of it a receptor (pipe) is installed to mount filters.



Theory:

An electron in a metal can be modelled as a particle in an average potential well due to the net attraction and repulsion of protons and electrons. The minimum depth that an electron is

located in the potential well is called the work function of the metal, Φ (see Fig. 1). In other words, it is a measure of the amount of work that must be done on the electrons (located in the well) to make it free from the metal. Since different metal atoms have different number of protons, it is reasonable to assume that the work function (Φ) depends on the metal. This is also supported by the fact that different metals have different values for electrical properties that should depend on the electron binding including conductivity. The electron in the potential well of a metal is shown below in Fig. 1. It is analogous to a marble trapped in a water-well. The shallower the well (i.e. the lower the work function “ Φ ”), less is the energy is required to cause the emission of the electron. If we shine a light with sufficient energy then an electron is emitted.

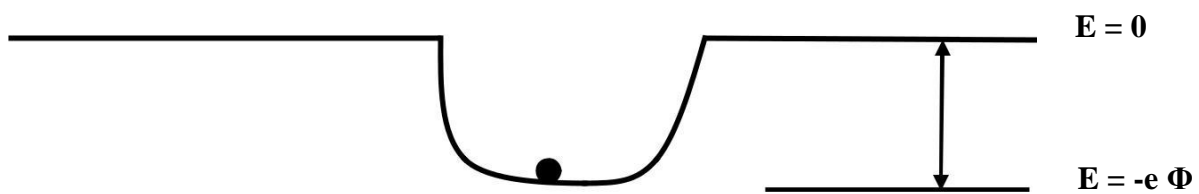


Figure 1: Electron in a potential well at a depth “ Φ ”

When a photon with frequency “ ν ” strikes the surface of a metal, it imparts all of its energy to a conduction electron near the surface of the metal. If the energy of the photon ($h\nu$) is greater than the work function (Φ), the electron may be ejected from the metal. If the energy is less than the work function, the electron will simply acquire some kinetic energy that will dissipate almost immediately in subsequent collisions with other particles in the metal. By conservation of energy, the maximum kinetic energy with which the electron could be emitted from the metal surface T_{\max} , is related to the energy of the absorbed photon $h\nu$, and the work function Φ , by the relation,

$$T_{\max} = \frac{1}{2}mv_{\max}^2 = h\nu - e\phi \quad (1)$$

Eq. 1 can be rewritten as in terms of stopping potential,

$$eV_0 = h\nu - e\phi \quad (2)$$

$$V_0 = \frac{h\nu}{e} - \phi \quad (3)$$

It is worth noting here that, since the anode and cathode surfaces are different, an additional contact potential “A” comes into the picture which simply gets added to the work function “ Φ ”. Eq. (3) can be written in terms of wavelength as

$$V_0 = \frac{hc}{e\lambda} - (\phi + A) \quad (4)$$

Standard value of **h** is known to be 6.626×10^{-34} J-s.

Procedure:

1. Plug in and switch on the apparatus using the red button at the bottom right corner of the set up.
2. Before the lamp is switched on, put the toggle switch in current mode and check that the dark current is zero.
3. Turn on the lamp source (it may take 5-10 mins. to warm up). Set the light intensity near to maximum. Note that the intensity should be such that the value of current should not exceed the display range. In case it happens, you need to reduce the intensity. You should not change intensity while taking data.
4. Insert one of the five specified filters into the drawtube of the receptor.
5. Set the voltage direction switch to “+ve” polarity. Adjust the voltage knob at minimum and current multiplier at X 0.1. Vary the voltage and record the current till the value of current becomes relatively constant. Use the display mode switch to record the values of voltage and the corresponding current each time
6. Now, set the voltage direction switch to “-ve” polarity. Adjust the voltage knob at minimum and current multiplier at X 0.001. Vary the voltage and record the current till the value of current becomes 0. Use the display mode switch to record the values of voltage and the corresponding current each time.
7. The above steps 5 and 6 provides data to plot the I-V characteristics of the phototube for the wavelength (or frequency) selected by the filter.
8. Repeat the steps 5-7 for all the filters provided.
9. Fill up the observation tables and draw necessary plots. Determine the values of planck’s constant and work function of the metal used in the phototube.

Observations:

Colour	Blue	Green	Yellow	Orange	Red
--------	------	-------	--------	--------	-----

Wavelength (nm)	460	500	540	570	635
-----------------	-----	-----	-----	-----	-----

Table 1 : For I-V Characteristics

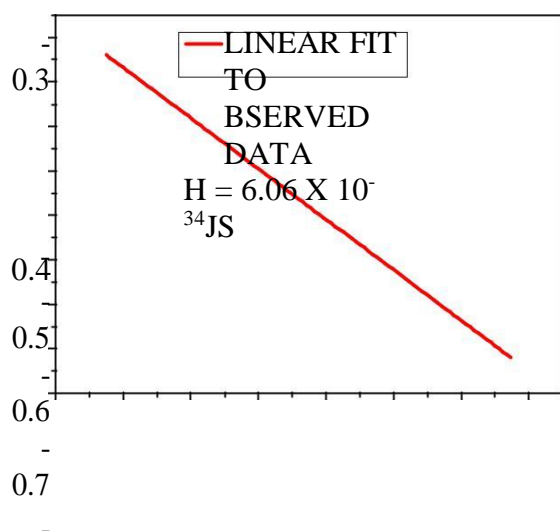
Voltage (+ve Polarity)					
Current (μA)					

Table 2: Data for stopping potential ~ wavelength

Stopping Potential(V)					
Wavelength (nm)					

Graph:

1. Plot I~ V characteristics for different wavelengths.
2. Plot Stopping potential ~ (1/wavelength) and calculate slope and intercept using Eq. 4. A sample graph is shown in Fig.4.



0.8
-
0.9
-
1.0
-
1.1

Precautions:

1. Rotate all the knobs very slowly.
2. Handle the filters with utmost care and avoid touching their surfaces

Viva Questions

1. What is Planck's Law?

Ans: Planck's law describes the electromagnetic radiation emitted by a black body in thermal equilibrium at a definite temperature.

2. What is Rayleigh-Jeans law?

Ans: Rayleigh-Jeans law attempts to describe the spectral radiance of electromagnetic radiation at all wavelengths from a black body at a given temperature through classical arguments.

3. What is the standard value of Planck's constant?

Ans: $h = 6.626 \times 10^{-34}$ Joule-sec

4. Define photoelectric effect?

Ans: When light falls on a metal surface, an electron is emitted from the metal if the energy of the photon is greater than the work function of the metal.

Experiment No.5: Determination of Wavelength by using grating

1. Aim of the Experiment: To obtain the wavelength of a laser source by using diffraction grating

2. Objective:

- To understand the physical processes that are occurring that give rise to the diffraction phenomenon
- To learn about the characteristics of Lasers
- To determine the wavelength of the given source
- To study the various types of Lasers

3. Apparatus required: Laser source; Grating; Meter Scale; Screen

4. Theory: A diffraction grating consists of a transparent material into which a very large number of uniformly spaced wires have been embedded. As the light impinges on the grating, the light waves that fall between the wires propagate straight on through. The light that impinges on the wires, however, is absorbed or reflected backward. At certain points in the forward direction the light passing through the spaces (or slits) in between the wires will be in phase, and will constructively interfere. Whenever the difference in pathlength between the light passing through different slits is an integral number of wavelengths of the incident light, the light from each of these slits will be in phase, and then it will form an image at the specified location. Mathematically, the relation is simple:

$$d \sin \theta = m\lambda$$

where d is the distance between adjacent slits (which is the same as the distance between adjacent wires), θ is the angle the re-created image makes with the normal to the grating surface, λ is the wavelength of the light, and $m = 0, 1, 2, \dots$ is an integer.

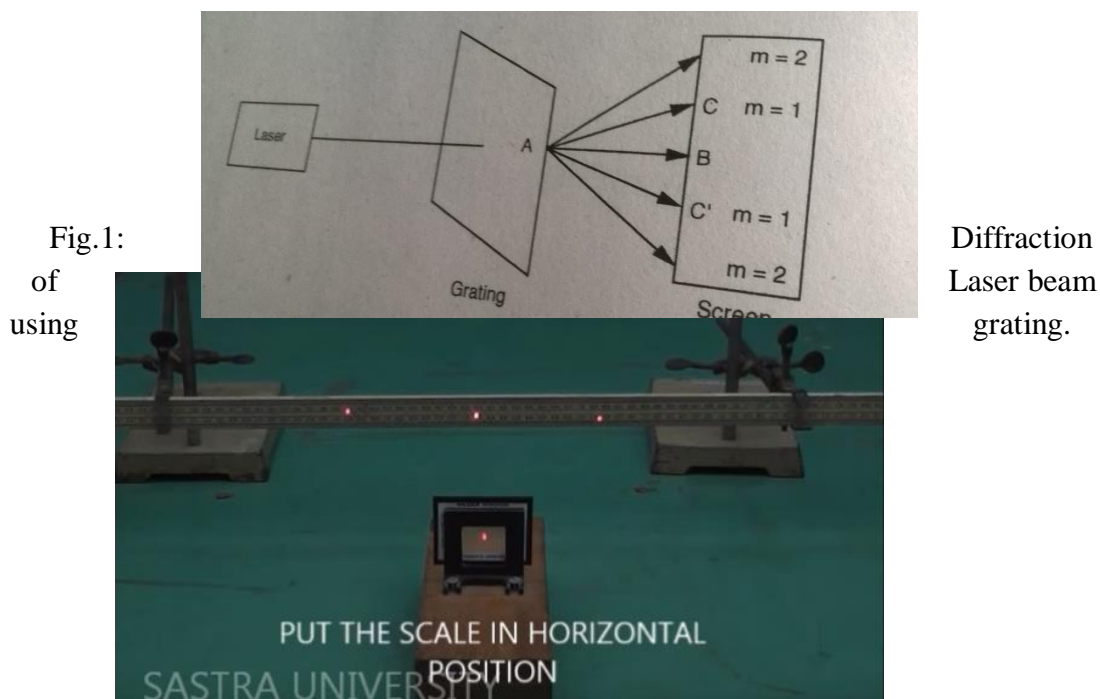


Fig.2: Experimental set-up for measuring the wavelength using a diffraction grating

5. Procedure:

- Put the scale in the horizontal position.
- Grating is placed between the screen and the source.
- Measure the distance between the scale and grating.
- Keep the laser, Grating, 50th mark on the scale in the straight line.
- Note down the distance between the scale (screen) and the Grating as X .
- Laser gets diffracted and two spots are observed on the scale on the both side of the center mark.
- Measure the length of the first spot to the right and the first spot to left from the center mark.

- Also, measure the length of the second spot on both sides from the center mark.
- Repeat the Experiments for various values of X.

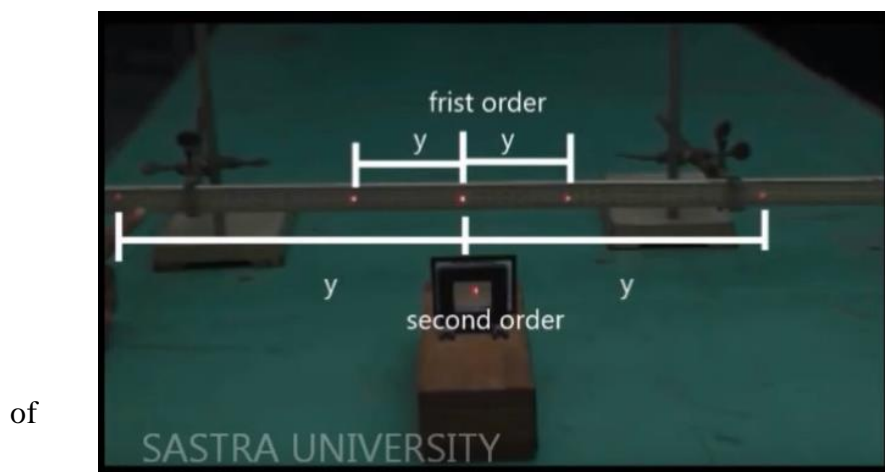


Fig.3:
Measurement
First and
Second Order

Calculate the angle of Diffraction using the following formula

6. Formula:

$$\tan \theta = \frac{Y}{X}$$

$$\theta = \tan^{-1} \left(\frac{Y}{X} \right)$$

where Y = average distance between the orders of spots
X = Distance between screen and the grating

$$\lambda = \frac{\sin \theta}{mN} \text{ nm}$$

where θ is the angle of diffraction in degrees

m is the order of spectrum

N is the no. of lines per meter in the grating

λ is the wavelength of the laser source

7. Observations and Table:

S.No.	Distance between the grating and centre spot AB (10^{-2} m)	Distance between the central spot and first order BC (10^{-2} m)	AC=sqrt(AB^2+BC^2) (10^{-2} m)	Sin θ = BC/AC
1				
2				
3				
4				
5				

Mean Sin θ =

8. Calculations:

Distance of the spot from the central maximum (x_n)	=	m
Perpendicular distance between grating and the scale (X)	=	m
Number of lines per metre in the grating (N)	=	lines/m
Angle of Diffraction, $\theta = \tan^{-1} \left(\frac{Y}{X} \right)$	=	
Wavelength of laser light, $\lambda = \frac{\sin \theta}{mN} \text{ nm}$		

9. Result:

Wavelength of the laser $\lambda =$ m

10.Expected Result:

The wavelength of the laser is found to be **632.8 nm**.

11. Precautions:

It is dangerous to view the laser light directly. So, direct exposure of eye to laser should be avoided.

The distance between the central spot and the nth fringe should be carefully measured.

12.Expected Questions

- What do mean by Diffraction of light?
- The condition required to obtain Diffraction in the case of light.
- What are characteristics of Laser?
- Name some source of Laser?

Experiment No.6: Particle Size Determination by using laser source

1. Aim of the Experiment: To obtain the particle size by laser

2. Objective:

- To determine the concept of diffraction
- To determine the size of the particles using the given laser source
- To learn about the characteristics of Lasers
- To study the various type of Lasers

3. Apparatus required: laser source; Screen; Meter Scale; Glass Plate; particle (Lycopodium Powder)

4. Formula:

Particle Size “a” is given by

$$a = 1.22n\lambda D/x_n(\text{in metre})$$

where

“n” is the order of diffraction

“λ” is the wavelength of laser light in metre

“D” is the distance between glass plate and the screen in metre

“ x_n ” is the distance between central bright spot and the n th fringe in metre

5. Theory:

Figure 1:
set-up for the
measurement of



Experiment
particle size

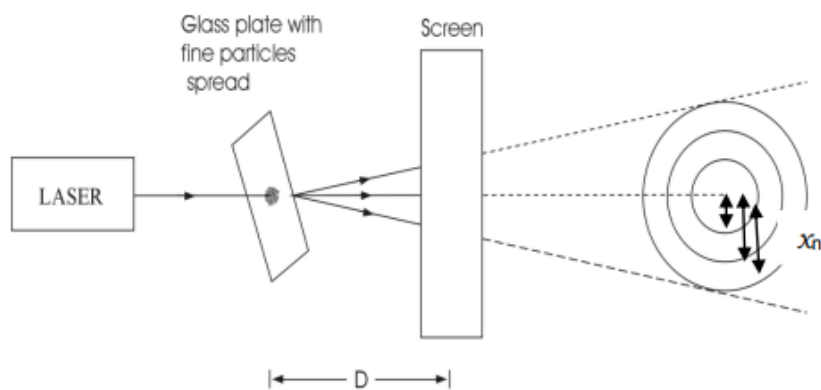
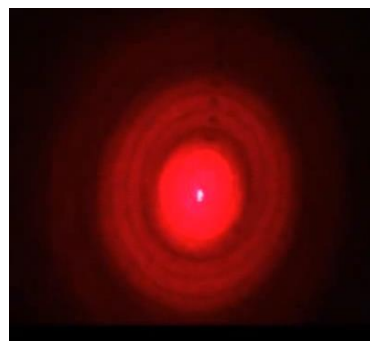


Figure 2: Schematic diagram of set-up

When LASER is passed through a glass plate spread with fine microparticles, the beam gets diffracted by the particles and circular rings are obtained on the screen as shown in Figure 2 and 3. By measuring the radii of the rings and the distance between the glass plate and the screen, the size of the particle can be determined.

Figure 3: Diffraction pattern on
Due to the diffraction of laser by
spectrum are obtained. The
order, 2nd order upto n th order



the screen
particle different order of
position of the fringe 1st
are noted.

1. Sprinkle the fine micro particles (Lycopodium) on the clean transparent glass plate. It should be uniformly spread over a glass plate.
2. Mount the LASER source on a stand
3. Place a screen in front of the LASER source at some distance
4. Mount the glass plate on a separate stand and place it between the LASER source and the screen.
5. Switch ON the laser source and allow the beam to pass through the glass plate.

6. Adjust the distance (D) between the glass plate and the screen to get a clear circular fringe pattern (diffraction pattern) on the screen. The intensity is found to decrease from zeroth order (central spot) to higher orders.
7. Measure the distance (D) between the glass plate and the screen using metre scale.
8. Measure the distance (x_n) of the first order, second order and so on from the central bright spot (radii of the rings).
9. Repeat the experiment by varying the distance (D) between the glass plate and the screen and the readings are tabulated.

6. Observations and Table:

To determine the particle size “a”

Order m	Distance between screen and glass plate D (10^{-2} m)	Radius of the ring r (10^{-2} m)	Particle size a (m)
1			
2			
1			
2			
1			
2			

Mean (a) =

7. Calculations:

Order of diffraction (n) =
Wave length of laser light (λ) = m
Distance between the glass plate and the screen (D) = m
Distance between the central spot and the nth fringe (x_n) =
The size of the microparticle using laser diffraction, a = $1.22n\lambda D/x_n$

8. Result:

The size of the micro-particle using diffraction of laser light, a = μm

9. Expected Result:

The size of the particle Lycopodium Powder is **27.22** μm . Standard value is **30** μm .

10. Precaution:

It is dangerous to view the laser light directly. So, direct exposure of eye to laser should be avoided.

The distance between the central spot and the nth fringe should be carefully measured.

11. Expected Questions:

- a) Define Coherence.
- b) Identify two types of Coherence.
- c) Can we use X-rays instead of Laser Source in this experiment?
- d) Why do we get rings in the particle size determination instead of spot?

Experiment No. 7: Band gap determination of semiconductor

1. Aim of the Experiment

To obtain forbidden energy gap of a semiconductor by using Four Probe Method

2. Objective

To determine the energy band gap of a given semiconductor by measuring its electrical resistivity as a function of temperature by a four probe method.

3. Apparatus Required

- A semiconductor crystal piece mounted on a non-conducting bottom surface is placed under four spring loaded contact probes spaced equally.
Dimensions are:
Sample thickness (w): 0.5mm,
Probe separation (s): 2mm
- Oven (0-200°C) with a thermocouple
- PID temperature controller with display.
- Constant current source.
- Microvolt meter.

4. Theory

This method is used when the sample is in the form of a thin wafer, such as a thin semiconductor material deposited on a substrate. The sample is millimeter in size and having a thickness w as per the above description. It consists of four probe arranged linearly in a straight line at equal distance S from each other as shown in the Fig.1. A constant current is passed through the two probes and the potential drop V across the middle two probes is measured as shown in Fig.2. An oven is provided with a heater to heat the sample so that behavior of the sample is studied with increase in temperature.

At a constant temperature, the resistance, R of a conductor is proportional to its length L and inversely proportional to its area of cross section A .

$$R = \rho \frac{L}{A}$$

Where ρ is the resistivity of the conductor and its unit is ohmmeter.

A semiconductor has electrical conductivity intermediate in magnitude between that of a conductor and insulator. Semiconductor differs from metals in their characteristic property of decreasing electrical resistivity with increasing temperature.

According to band theory, the energy levels of semiconductors can be grouped into two bands, valence band and the conduction band. In the presence of an external electric field it is electrons in the valence band that can move freely, thereby responsible for the electrical conductivity of semiconductors. In case of intrinsic semiconductors, the Fermi level lies in between the conduction band minimum and

valence band maximum. Since conduction band lies above the Fermi level at 0K, when no thermal excitations are available, the conduction band remains unoccupied. So conduction is not possible at 0K, and resistance is infinite. As temperature increases, the occupancy of conduction band goes up, thereby resulting in decrease of electrical resistivity of semiconductor.

Resistivity of semiconductor by four probe method

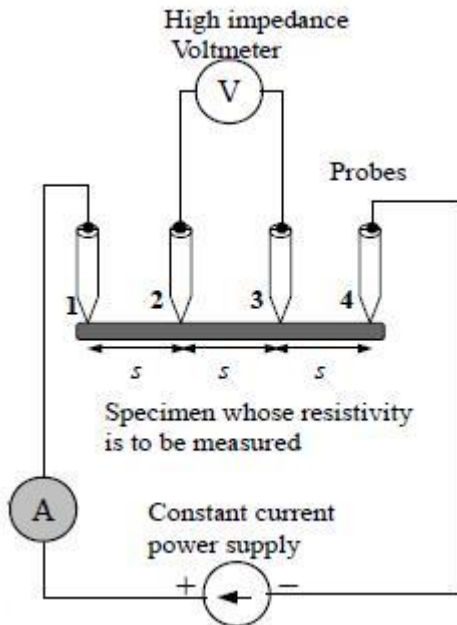


Figure 1

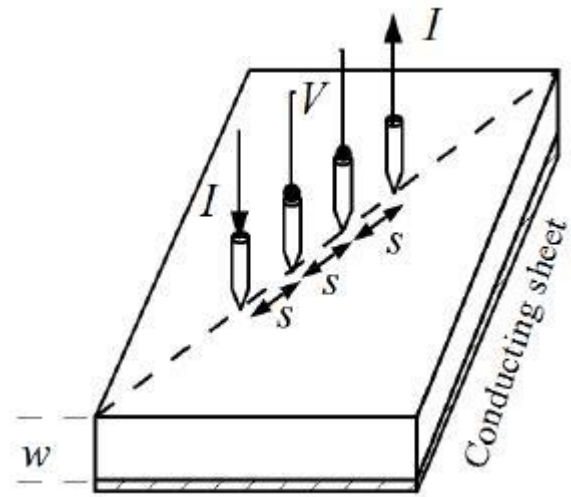


Figure 2

The figure shows the arrangements of four probes that measure voltage (V) and supply current (A) to the surface of the crystal.

5. Formula

Calculate the electrical resistivity (ρ_0) using the relation:

$$\rho_0 = \frac{V}{I} \times 2\pi s$$

where 's' is the probe separation.

Use to determine the electrical resistivity from relation

$$\rho = \frac{\rho_0}{G}$$

where G is a function dependent on the (W/S) ratio and known as correction factor when measurements are carried out on a thin slice non conducting bottom. Take the value of 'G' as 6.

Temperature dependence of resistivity of semiconductor

Total electrical conductivity of a semiconductor is the sum of the conductivities of the valence band and conduction band carriers. Resistivity is the reciprocal of conductivity and its temperature dependence is given by

$$\rho = A \exp \frac{E_g}{2kT}$$

Where E_g – band gap of the material

T – Temperature in kelvin

K – Boltzmann constant, $K = 8.6 \times 10^{-5} \text{ eV/K}$

The resistivity of a semiconductor rises exponentially on decreasing the temperature.

Plot $\ln \rho$ Vs $1000/T$ curve and find out the energy band gap (E_g) of the semiconductor. The electrical resistivity follows the relation where A is the pre-exponential factor and 'k' is the Boltzmann constant.

6. Procedure

- (1) Gently remove the sample holder out the oven and carefully check the sample position, contacts of the leads, separation between the leads and the thickness of the sample.
- (2) Identify the voltage and the current leads.
- (3) Having placed the sample holder inside the oven, switch on the current source and the voltmeter.
- (4) Set a constant current (e.g. 5 mA) to flow through two outer probes and turn on the oven power supply. The sample heating begins automatically with temperature indication on the display. Measure the voltage drop across the middle two probes at the temperature interval of $\sim 5^\circ\text{C}$ up to 180°C .

7. Observations and Table

S.No.	Temperature ($^\circ\text{C}$)	Temperature ($^\circ\text{K}$)	$\rho_0 = \frac{V}{I} \times 2\pi S$	$\ln \rho$	$1000/T$

8. Calculation

- i) Plot $\ln \rho$ Vs $1000/T$ from the above table.
- ii) The band gap of the semiconductor material is given by $E_g = (\text{Slope of the line}) \times (2k) \times 1000$

9. Results

The band gap of the semiconductor sample= eV

10. Expected Result

The band gap of the Semiconductor Material = 1.1eV

11. Precaution

- 2) Maximum temperature should not exceed 70°C.
- 3) Reading of the temperature and corresponding reading of the microvolt meter should be taken carefully.

12. Expected Questions

- i. Why is four probe method is preferred over two probe measurement system? Discuss briefly.
- ii. Can you measure resistivity of the material by this technique placed on a conducting surface?
- iii. How you measure the activation energy and band gap of an extrinsic semiconductor by this method?
- iv. Can you determine the band gap of the material by measuring the resistivity at low temperatures? What temperature range you think as most appropriate to measure the band gap of the material you worked on.

Experiment No. 8: To obtain dielectric constant

1. Aim of the Experiment: To obtain dielectric constant

2. Objective: To measure the Dielectric constant using a parallel plate capacitor configuration

3. Apparatus Required:

- a. Digital Voltmeter
- b. Dielectric cell – 1. Having two gold plated discs (75mm), used for plywood, glass, card board.
2. Having two gold plated brass discs (25mm) used for PZT material

c. Given samples

4. Formula:

The capacitance of a parallel plate capacitor is given by

$$C = \frac{k\epsilon_0 A}{d}$$

where “C” is the capacitance, “k” is the dielectric constant, “ ϵ_0 ” is the permittivity of free space, “A” is the area of the plates, and “d” is separation.



Fig.1: Experimental set-up for dielectric measurement of the given sample.
 SC1 is used for materials of low dielectric constant (eg – glass, plywood, etc)
 SC2 is used for materials of high dielectric constant (eg – PZT sample)

5. Procedure:

- Connect the disc to the respective terminals keeping the glass material between them.
- Switch on the Digital Voltmeter. Put the switch at SC1 terminal.
- Note down the voltage reading.
- Now, switch off the Digital Voltmeter and replace the glass material by Plywood and switch it on.
- Now, connect the Discs of 25 mm to find the Dielectric Voltage of PZT.
- Place the positive side of the PZT on the Disc connected with the positive terminal and negative terminal on the negative side.
- As PZT has high Dielectric Constant Material the switch must be set to SC2.
- Now, switch the selector switch to standard cell and find out V_{sc} .
- Then, switch it to dielectric cell and find V_{dc} of PZT.

6. Observations and Table:

S.No.	V_{dc}	$C_{dc}(\text{nF})$	$K = C_{dc}/C_0$

7. Calculation:

Dielectric cell capacitance $C_{dc} = C_{sc}V_{sc}/V_{dc}\text{nF}$

Capacitance of Dielectric Cell without sample $C = \frac{k\epsilon_0 A}{d}\text{nF}$

where C_{sc} – Standard Cell Capacitance

V_{sc} – Standard Cell Voltage

V_{dc} – Dielectric Cell Voltage

ϵ_0 – Permittivity of free space

A – Area of the Sample

d – Thickness of the Sample

The dielectric constant of the sample is given by

$$k = C_{dc}/C_0$$

8. Result:

The Dielectric Constant of the given sample =

9. Expected Result:

The Dielectric Constant Value of the Material

Material	Dielectric Constant
Air (1 atm)	1.00059
Glass	3.8–14.5
Wood	1.4 - 2.9
PZT	300 - 3850

10. Precaution:

- Do not apply extra pressure as “PZT” sample and glass are brittle may be damage.
- Never place the Discs one above the other without Dielectric material within them.

11. Expected Questions:

- a. What do mean by Dielectric Constant of the Material?
- b. What determines the Dielectric Properties of the Material? Hint: Effect of Electric field on Atomic structure of the Material.
- c. Name some Material with lowest and highest value of Dielectric Constant?
- d. Name some Applications of Dielectric Material?