UNIVERSITY INSTITUTE OF ENGINEERING

DEPARTMENT OF ACADEMIC UNIT- 1 & 4

PHYSICS FOR ENGINEERS (22SPH-141)

Experiment No. 1

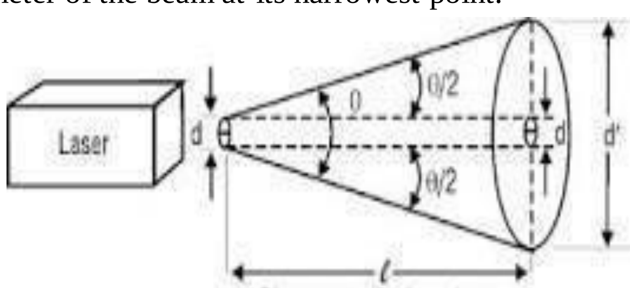
Aim: -To determine the divergence of laser beam.

List of Equipment Used:

Table 1: List of Equipments

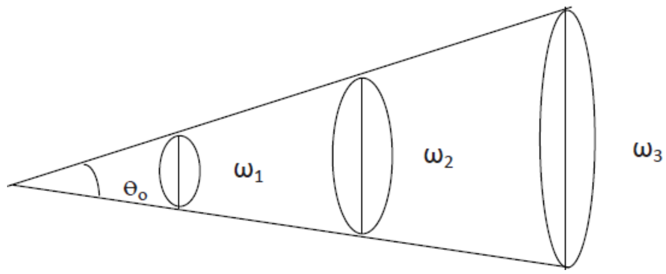
S.N.	**Equipment**	**Range**	**Quantity**
1.	Power supply/Operating voltage	5mV/3-12V	1
2.	Diode laser	650nm	1
3.	Stand	NA	1

Introduction/Theory: The term LASER is the acronym for Light Amplification by Stimulated Emission of radiation. It is a mechanism for emitting electromagnetic radiation via the process of stimulated emission. There are lasers that emit a broad spectrum of light, or emit different wavelengths of light simultaneously. A laser beam with a narrow beam divergence is greatly used to make laser pointer devices. Generally, the beam divergence of laser beam is measured using beam profiler. Like all electromagnetic beams, lasers are subject to divergence, which is measured in mill radians (milliradian) or degrees. For many applications, a lower-divergence beam is preferable. The divergence of a laser beam is proportional to its wavelength and inversely proportional to the diameter of the beam at its narrowest point.



Divergence of a laser beam

One of the chief advantages of a laser is that it produces a beam of light whose edges are parallel. Any deviation from perfect parallelism eventually causes the beam to diverge and spread out its energy, becoming weaker and weaker with distance.



In this figure, Z-axis is chosen as direction of propagation of laser beam and origin is chosen at the point where waist size is minimum. Since Gaussian beam remains Gaussian at all locations, thus the waist size W_1 of the beam at a distance Z is given by the relation:

$$\theta_o = W_1/Z \text{ or } W_1 = \theta_o Z$$

$$W_1^2 = \theta_o^2 Z^2$$

Similarly, W_1, W2 and W_3 are the diameters circles of the laser spot formed at distance (Z+D) and (Z+2D) respectively from the origin, Then

$$\theta_o = W_2 / (Z+D) \text{ or}$$

$$W_2 = \theta_o (Z+D)$$

$$\text{Or } W_2^2 = \theta_o^2 (Z+D)^2$$

$$\text{And} \quad \theta_o = W_3 / (Z+2D)$$

$$\text{OR} \quad W_3 = \theta_o (Z+2D)$$

$$W_3^2 = \theta_o^2 (Z+2D)^2$$

But the laser source cannot be a point source. It has a finite size through small.

Here W_1 = minimum waist size, θ_o is the angle of divergence

To find the angle of divergence θ_o, we set up three equations:

$$W_1^2 = \theta_o^2 Z^2 \text{(i)}$$

$$W_2^2 = \theta_o^2 (Z+D)^2 = \theta_o^2 Z^2 + 2Z\theta_o^2 D + \theta_o^2 D^2 \qquad \text{(ii)}$$

$$W_3^2 = W_o^2 + \theta_o^2 (Z+2D)^2 = \theta_o^2 Z^2 + \theta_o^2 (4D^2) + 4ZD\theta_o^2 \qquad \text{(iii)}$$

From (i), (ii) and (iii), we have

$$W_1^2 - 2W_2^2 + W_3^2 = 2\theta_o^2 Z^2$$

$$\theta = \frac{1}{D}\sqrt{\frac{W_1^2 - 2W_2^2 + W_3^2}{2}}$$

Formula used: The angle of divergence is given by

$$\theta = \frac{1}{D}\sqrt{\frac{W_1^2 - 2W_2^2 + W_3^2}{2}}$$

Precautions:

(i) Spot size should be measured accurately.

(ii) Laser light should not fall directly to the eyes of the observer.

Procedure:

(i) Arrange the apparatus as shown.

(ii) Pencil, draw the circular spot on the paper and measure the vertical and horizontal diameters of the circular spot. Calculate the mean of both values to get the accurate value of the diameter. This is the waist size W_1

(iii) Now distance screen in the direction of beam propagation by a known distance D (total distance from laser becomes Z+D) and measure spot size W_2 as measured in previous step.

(iv) Now displace screen further away by same value D, so the new distance becomes (Z+2D). Measure spot size W_3

(v) Put the values in the formula and calculate laser divergence.

Observations & Calculations:

Table2:

(i) Initial distance between laser and screen Z= .... cm

(ii) Displacement of screen D= ....cm

S. No.	Distance (cm)	Diameter		Mean diameter (cm)	$\theta = \frac{1}{D}\sqrt{\frac{W_1^2 - 2W_2^2 + W_3^2}{2}}$ (milliradian)
		Vertical (cm)	Horizontal (cm)		
1.	Z=			W_1	
	Z+D=			W_2	
	Z+2D=			W_3	

The angle of divergence of the diode laser is_______milliradian

Result(s): The angle of divergence of the diode laser is_______milliradian.

Conclusion: Since this angle is very small (in the range of milliradian), we conclude that laser beam is highly directional as compared to ordinary light source.

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Review Questions

1. What is Divergence of a laser beam?
2. What is LASER?
3. What are the characteristics of laser radiation?
4. What is a Semiconductor Diode Laser?
5. What is the cause of divergence of a laser beam?
6. Why population inversion is essential for stimulated emission?
7. Differentiate between stimulated emission and spontaneous emission.
8. What are the components of laser?
9. What are the examples of two level, three level and four level laser?
10. What are the units of angle of divergence?

Prepared By	Reviewed By	Approved By
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Experiment No. 2

Aim: To determine the diffraction using laser beam and find the grating element of diffraction grating.

List of Equipment Used:

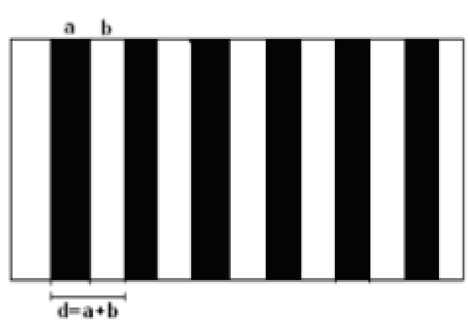
Table 1: List of Equipments

S.N.	Equipment	Range	Quantity
1.	Power supply/Operating voltage	5mV/3-12V	1
2.	Diode laser	650nm	1
3.	Grating element	500,15000 L.P.I.	2
4.	Stand	NA	2

Introduction/Theory:

Diffraction is the slight bending of light as it passes around the edge of an object. The amount of bending depends on the relative size of the wavelength of light to the size of the opening**.**

Diffraction grating is a set of thousands of narrow, closely spaced parallel slits; typically the distance between the lines is comparable to the wavelength of light. Distance between two consecutive slits (lines) of a grating is called grating element (**d**)



Light rays that pass through such a surface are bent as a result of diffraction, related to wave properties of light. The diffraction angle depends upon the wavelength of the light, for a given Grating light with larger wavelength has larger diffraction angle. More precisely a single wavelength can simultaneously have multiple discrete diffraction angles called diffraction orders.

For normal illumination, the grating equation is given by

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

$$d \sin \theta = n \lambda \quad \text{...} \quad (1)$$

Where θ is the angle of diffraction, (a+b) is the grating element n =0, ±1, ±2,……….and λ is the wavelength of light used.

Diagram:

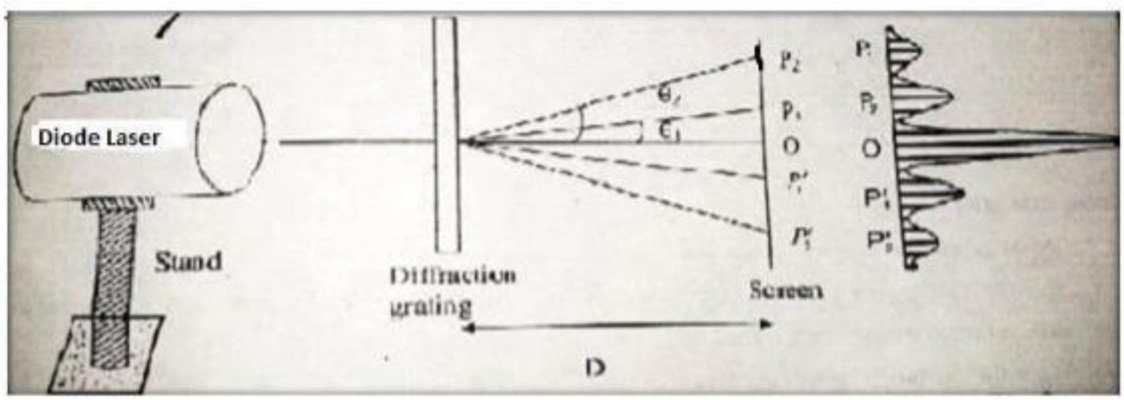


Fig. 1

Fig.2

Formula Used:

$$d = n\lambda / \sin\theta$$

Where, **θ** is the angle of diffraction,

d is the grating element

λ is the wavelength of light incident on grating

n is the order of maxima

Precautions:

1. Laser light should not fall on eyes of observer directly.
2. All lengths should be measured in same unit.
3. Distance between the spots should be measured accurately

Procedure:

1. Arrange the apparatus as shown in fig.1
2. Fix the graph paper on the screen and place it at appreciable distance D from grating so that distinct maxima are seen as in fig 2.
3. Mark the central brightest spot and maxima on both side of central
4. Using a scale find the distance between first maxima on either side of central spot.
5. Find the sine of angle of diffraction θ by formula given in observation table.
6. Repeat the steps 4 and 5 for 2^{nd} and 3^{rd} maxima. Then use these values to calculate grating element d from equation (1).
7. Then calculate % error in grating element d.

Observations &Calculations:

Wavelength of Diode laser, λ=650 nm

Distance between diffraction grating and screen. D=________________cm

Standard Grating element, d (cm) =2.54/N, where N is no. of lines per inch in diffraction grating

a. if we were having diffraction grating of 15000 lines per inch, then standard grating element will be

$$d= 2.54/15000=0.000169 \text{ cm}$$

b. if we were having diffraction grating of 500 lines per inch, then standard grating element will be

$$d=2.54/500=0.00508 \text{ cm}$$

Table 2:

S.No.	**Order of diffraction (n)**	**Position of nth order maxima**		**Mean distanceof n^{th}order maxima from zeroth order OP_n (cm)**	**Distance between Grating and screen (D) (cm)**	**Sinθ $=\frac{OP1}{\sqrt{OP1^2+D^2}}$**	**d=nλ/Sinθ (cm)**
		On left (OP_n) (cm)	**On right (OP_n') (cm)**				
1.							
2.							
3.							

Mean value of grating element, d=______________________cm

Result(s): Grating element, d=______________________cm

Conclusion: - We found out a diffraction grating has a very large number of equally spaced slits. When parallel light is incident on a diffraction grating each slit acts as a source of diffracted waves. Those waves therefore interact with one another. Diffracted lights shine on a distant screen which has a central bright spot labelled m=0 and a higher order bright fringes that can also be observed.

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Review Questions

Q1. What is diffraction?

Q2. Define Grating?

Q3. What is Bragg’s law of diffraction?

Q4. How does diffraction differ from interference?

Q5. Define dispersive and resolving power of grating?

Q6. How many orders of spectra possible for grating of 15000 lines per inch?

Q7. How replica of diffraction grating formed?

Q8. What is the condition for the second order of spectra?

Prepared By	Reviewed By	Approved By
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Experiment No. 3

Aim: - To determine numerical aperture of an optical fibre.

List of Equipment Used:

Table 1: List of Equipments

S.N.	**Equipment**	**Range**	**Quantity**
1.	Power supply	0-12V	1
2.	Diode laser	650nm	1
3.	optical fibre cable	1m	1
4	Stand	NA	2
5	Detector	NA	1
6	Angular deflection	$0\text{-}360^0$	1

Introduction/Theory: Numerical aperture is a basic descriptive characteristic of a specific fiber. It is represents the size or degree of openness of the input acceptance cone. Mathematically it is defined as the sine half angle of the acceptance cone.

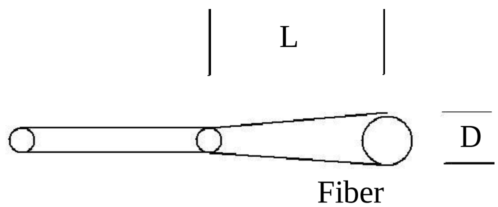
Using Snell's law, the maximum angle within which light will be accepted into and guided through fiber is

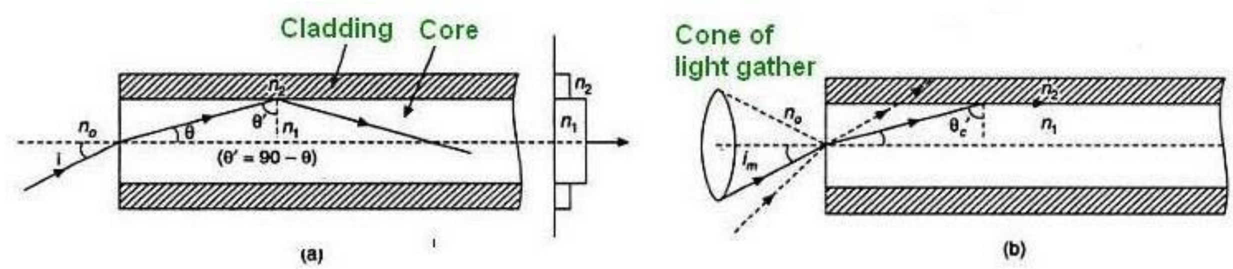
$$NA = \text{Sin}\,(\theta_a) = (n_1^2 - n_2^2)^{1/2}$$

Where θ_a is the numerical aperture and n_1 and n_2 are the refractive indices of the core and the Cladding. If the incident angle $\theta<\theta_a$, the ray undergoes multiple internal reflections at core and cladding interface and it is called the guided ray. If $\theta_a<\theta$, the ray undergoes only partial reflection at core cladding interface.

In short length of straight fiber, ideally a ray launched at angle θ at the input end should come out at the same angle θ from output end. Therefore, the far field at the output end will also appear as a cone of semi angle θ_a emanating from the fiber end.

Diagram:





Formula Used: NA= Sin θ

Precautions:

1. Optical source should be properly aligned with the cable.
2. Distance of the launch point from cable should be properly selected to ensure that maximum amount of optical power is transferred to the cable.
3. The optical fiber provided should be handled carefully so as to prevent cracks.

Procedure:

1. Light from the laser is coupled into the given optical fiber by using microscope objective.
2. Place the output end of the fiber on the rotating stage.

3. A detector, whose output is connected to the voltmeter, is mounted on the base and aligns it for maximum intensity (I_{max}) such that the pinhole is at the same horizontal level as the fiber end.
4. Connect the output of the detector to Multimeter using wire provided with the apparatus having BNC socket at one end and banana plugs at other end (with red wire V+ socket and black wire to Com socket) and select I_{max} mode.
5. Without disturbing the input coupling, rotate the output fiber end spot in suitable steps and at each angular position the detector output is recorded.
6. Plot and extrapolate graph showing the output of detector vs. angular position.
7. From the graph, find out the angle $2\theta_a$ corresponding to the 0.05 I_{max} below from the maximum detector reading and hence obtain θ_a..
8. Find NA = Sin (θ_a)

Observations & Calculations:
Table2:

S.No.	Angular Deflection	Detector Reading
1		
2		
3		

Numerical aperture of Optical fiber = _________

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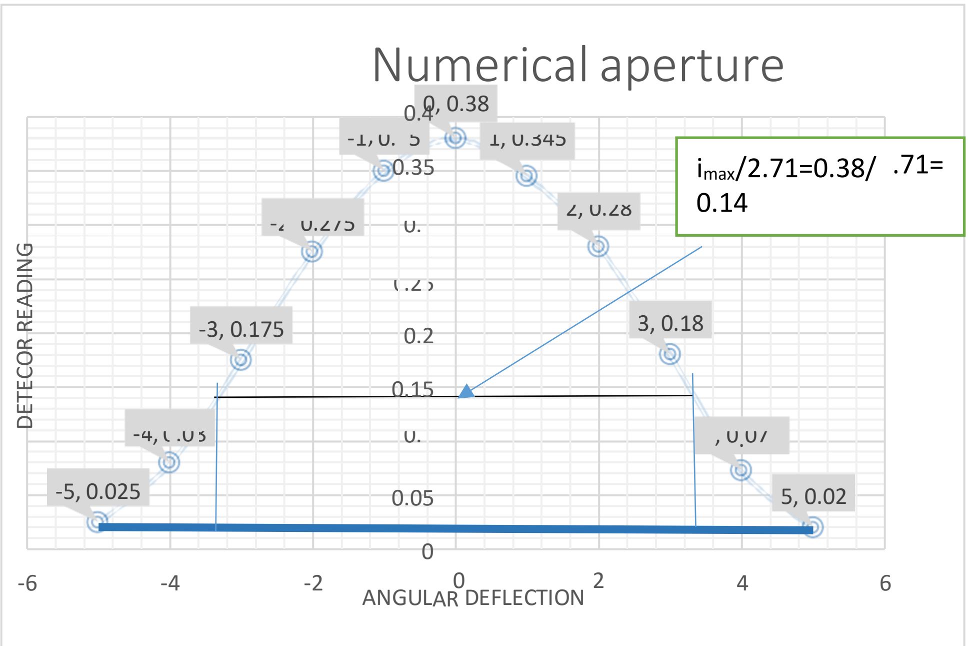
Graph:



Result(s): Numerical aperture of the given Optical fiber =

Conclusion: - A high numerical aperture allows light to propagate down the fiber in rays both close to the axis and at various angles, allowing efficient coupling of light into the fiber. However, a high numerical aperture increases the amount of dispersion as rays at different angles have different path lengths and therefore take different times to traverse the fiber. A low numerical aperture may therefore be desirable.

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Review Questions

1. What do you mean by numerical aperture?
2. What could be the maximum value of numerical aperture?
3. What should be the numerical aperture of the fiber used for short distance communication?
4. What are the advantages of using optical fiber over conventional communication systems?
5. Is numerical aperture always constant for a particular optical fiber?
6. What are the different components of an optical fiber?
7. What is the relation between acceptance angle and numerical aperture of an optical fiber?
8. What do you understand by the term LASER?
9. What is the principle of light propagation in an optical fiber?
10. Is it possible to find numerical aperture of an optical fiber with any ordinary source of light?

Prepared By	**Reviewed By**	**Approved By**
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Experiment No. 4

Aim: -To find the resistivity of a semiconductor material using four probe methods.

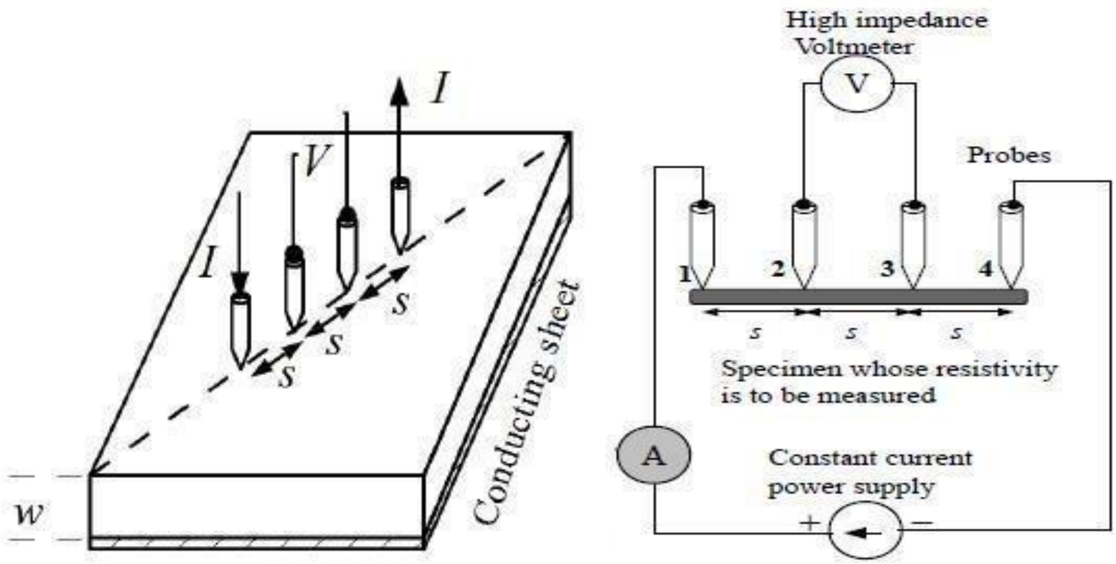
List of Equipment Used:

Table 1: List of Equipments

S.N.	**Equipment**	**Range**	**Quantity**
1.	Power supply	220V	1
2.	Oven	0-200°C	1
3.	n-Type crystal	NA	1
4	milliAmmeter & milliVoltmeter	0-20mA &0-250mV	1

Introduction/Theory: In its useful form, the four probes are collinear. The error due to contact resistance, which is especially serious in the electrical measurement on semiconductors, is avoided by the use of two extra contacts (probes) between the current contacts. In this arrangement the contact resistance may all be high compare to the sample resistance, but as long as the resistance of the sample and contact resistances are small compared with the effective resistance of the voltage measuring device (potentiometer, electrometer or electronic voltmeter), the measured value will remain unaffected. Because of pressure contacts, the arrangement is also especially useful for quick measurement on different samples or sampling different parts of the same sample. Four probe apparatus is one of the standard and most widely used apparatus for the measurement of band gap of semiconductors. This method is employed when the sample is in the form of a thin wafer, such as a thin semiconductor material deposited on a substrate. The sample is millimetre in size and having a thickness w. It consists of four probe arranged linearly in a straight line at equal distance S from each other. A constant current is passed through the two probes and the potential drop V across the middle two probes is measured. An oven is provided with a heater to heat the sample so that behaviour of the sample is studied with increase in temperature.

Diagram:



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

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.

$$R = \rho \frac{L}{A} \qquad \text{- (1)}$$

Where ρ is the resistivity of the conductor and its unit is ohmmeter.
We assume that the size of the metal tip is infinitesimal and sample thickness is greater than the distance between the probes,

$$\rho = \frac{\rho_0}{f\left(\frac{w}{s}\right)}$$

$$\rho_0 = \frac{V}{I} \times 2\pi S \qquad \text{- (2)}$$

Where V - the potential difference between inner probes in volts.
I -Current through the outer pair of probes.
S - Spacing between the probes in meter.
So in order to measure band gap the required formula is given as

Precautions:

1. The resistivity of the material should be uniform in the area of measurement.
2. The surface on which the probes rest should be flat with no surface leakage.
3. The diameter of the contact between the metallic probes and the semiconductor crystal chip should be small compared to the distance between the probes.

Procedure:

1. Put the sample on the base plate of the four probe arrangement. Unscrew the pipe holding the four probes and let the four probes rest in the middle of the sample. Apply a very gentle pressure on the probes and tighten the pipe in this position. Check the continuity between the probes for proper electrical contacts.
2. Connect the outer pair of probes (yellow/green) leads to the constant current power supply and the inner pair (red/black leads) to the probe voltage terminals.
3. Place the four probe arrangement in the oven and fix the thermometer in the oven through the hole provided.
4. Switch on the ac mains of Four Probe Set-up and put the digital panel meter in the current measuring mode through the selector switch. In this position LED facing mA would glow. Adjust the current to a desired value (Say 5 mA).
5. Now put the digital panel meter in voltage measuring mode. In this position LED facing mV would glow and the meter would read the voltage between the probes.
6. Connect the oven power supply. Rate of heating may be selected with the help of a switch - Low or High as desired. Switch on the power to the Oven. The glowing LED indicates the power to the oven is 'ON'.

Figure:-Four Probe set-up

Observations & Calculations:

Table 2:

(i) Distance between probes (s) = 0.2cm

(ii) Thickness of the crystal chip (W) = 0.05cm

(iii)Current (I) =..........mA (constant)

S. No.	Temperature in ˚C	Temperature in Kelvin	Voltage V in volts	ρ́(ohm cm)
1.				
2.				
3.				

First find resistivity, ρ, corresponding to temperatures in K using the relation:

$$\rho = \rho_o / f(W/s),$$

Where $\rho_o = \frac{V}{I} \times 2\pi s =$ ….ohm.cm.

$$\rho_0 = \frac{V}{I} \times 1.256$$

$$f(W/s) = 5.89$$

Result(s): Resistivity of a semiconductor material =................ ohm cm.

Conclusion: The resistivity decreases exponentially with the increase in T. That is as at low temperatures resistivity is more and at high temperatures the resistivity is less.

Review Questions

1. What is energy gap?
2. How do you differentiate between a conductor, an insulator and a semiconductor in relation to energy gap?
3. What is intrinsic and extrinsic semi-conductor?
4. Why a semi-conductor behaves as an insulator at zero degree Kelvin?
5. What is the advantage of four probe method over other methods of measuring resistivity?

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Experiment No. 5

Aim: - To draw the reverse characteristics of Zener diode.

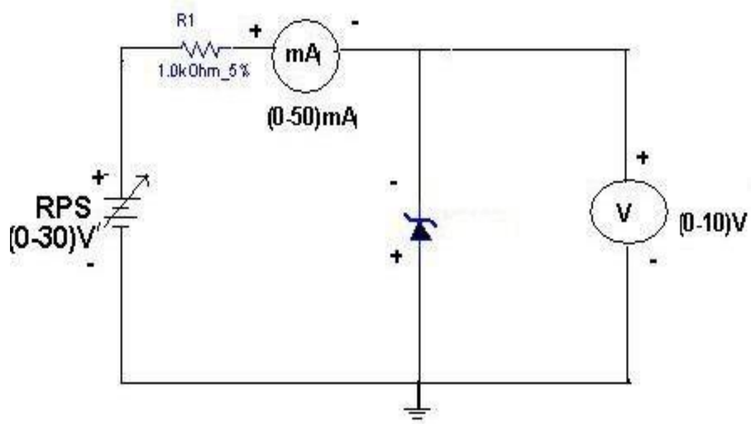
List of Equipment Used:

Table 1: List of Equipments

S.N.	**Equipment**	**Range**	**Quantity**
1.	Regulated Power Supply	0-30V	1
2.	Zener diode	3v/5V/9V	3
3.	Voltmeter	0-30V	1
4.	Ammeter	250mA	1
5.	Connecting wires	NA	4
6.	Resistance	1Kohm	3

Introduction/Theory: -A Zener diode is heavily doped p-n junction diode, specially made to operate in the break down region. A p-n junction diode normally does not conduct when reverse biased. But if the reverse bias is increased, at a particular voltage it starts conducting heavily. This voltage is called Break down Voltage. High current through the diode can permanently damage the device. To avoid high current, we connect a resistor in series with zener diode. Once the diode starts conducting it maintains almost constant voltage across the terminals whatever may be the current through it, i.e., it has very low dynamic resistance. It is used in voltage regulators.

Circuit Diagram:-



Zener diode reverse characteristic circuit diagram

Precautions:

1. Excessive flow of current may damage the diode.
2. Current for sufficiently long time may change the characteristics.
3. Connections should be made neat and clean.

Procedure:-

1. Connect the circuit as shown in figure.
2. Vary RPS gradually in steps and note down the corresponding readings of V_{zr} and I_{zr}.
3. Tabulate different reverse currents obtained for different reverse voltages.
4. Plot graph between voltage and current.

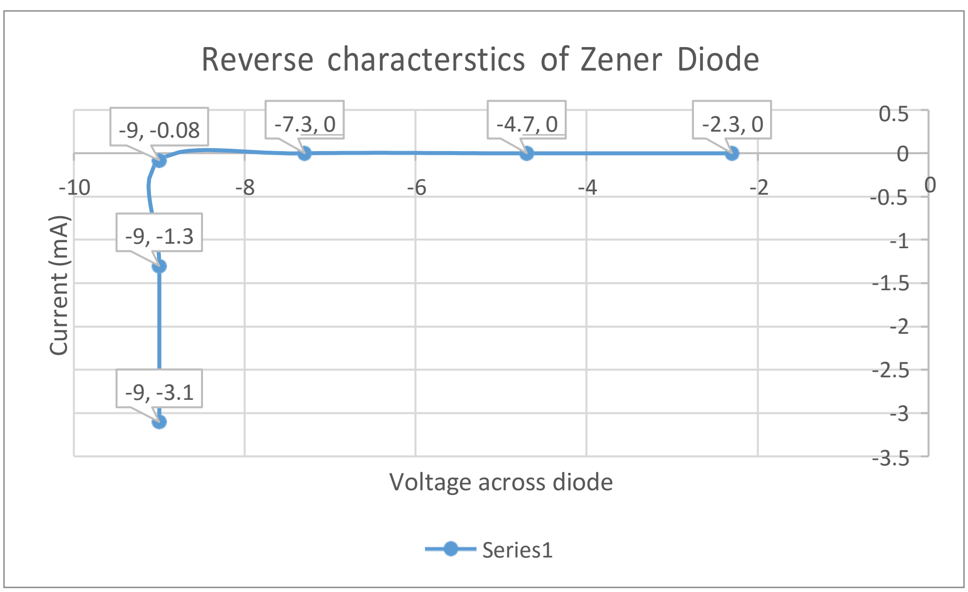
Observations & Calculations:

Table2:

Sr. No.	Reverse Voltage Across the diode V_{zr} (Volts)	Reverse Current through the diode I_{zr} (mA)
1		
2		
3		
4		

From graph breakdown voltage =.............V.

Graph:



Result (s): The value of breakdown voltage from graph is…

Conclusion: The Zener diode, with its accurate and specific reverse breakdown voltage, allows for a simple, inexpensive voltage regulator. Combined with the right resistor, fine control over both the voltage and the supply current can be attained. However, the low power ratings of standard Zener diodes and resistors make this solution impractical for high power devices.

Review Questions

1. Which diode is operated in the reverse biasing mode?
2. What is meant by reverse bias?
3. What is zener diode?
4. What is the cause of reverse breakdown voltage?
5. What is zener voltage?
6. Give one application of zener diode.

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Experiment No. 6

Aim:-To determine Hall Voltage and Hall Coefficient using Hall Effect.

List of Equipment Used:

Table 1: List of Equipments

S.N.	Equipment	Range	Quantity
1.	Constant current Power supply	4A &50V	1
2.	Hall probe	NA	1
3.	Digital gauss meter	2-20K gauss	1
4	n-type Germanium crystal	0.7eV	1
5	Electromagnet	NA	1
6	Power supply for crystal	0-8mA &0-200mV	1

Introduction/Theory:- Hall Effect: 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

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

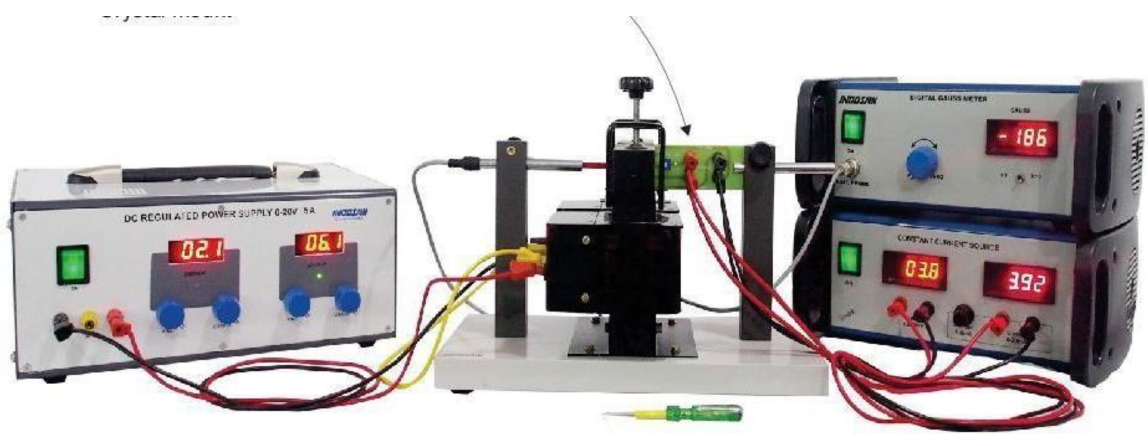
If the magnetic field is applied along negative z-axis, the Lorentz force moves the charge carriers (say electrons) toward the y-direction. This results in accumulation of charge carriers at the top edge of the sample. This set up a transverse electric field $\mathbf{E_y}$ in the sample. This develop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

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, $F_m = q(vxB)$ 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

$$eE = evB \qquad (2)$$

Diagram:-



Circuit diagram:-

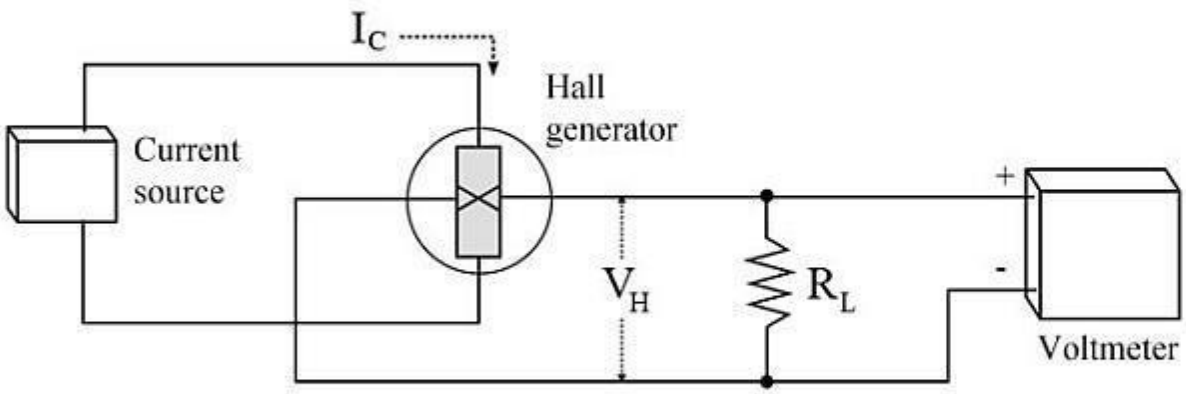


Fig.1:- Schematic representation of Hall Effect in a conductor.

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,

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

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,

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

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

By rearranging equation (4) we get

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

Where R_H is called the Hall coefficient.

Formula Used:

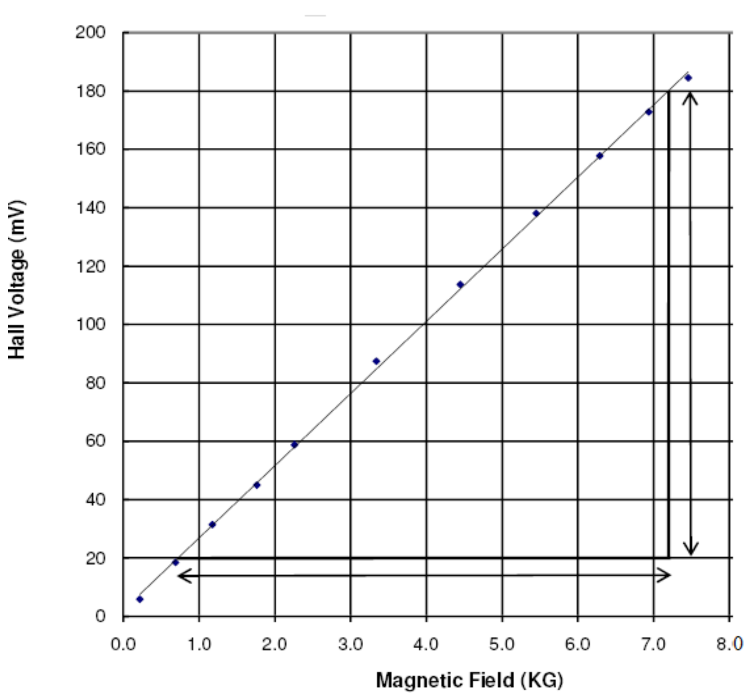
Hall voltage

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

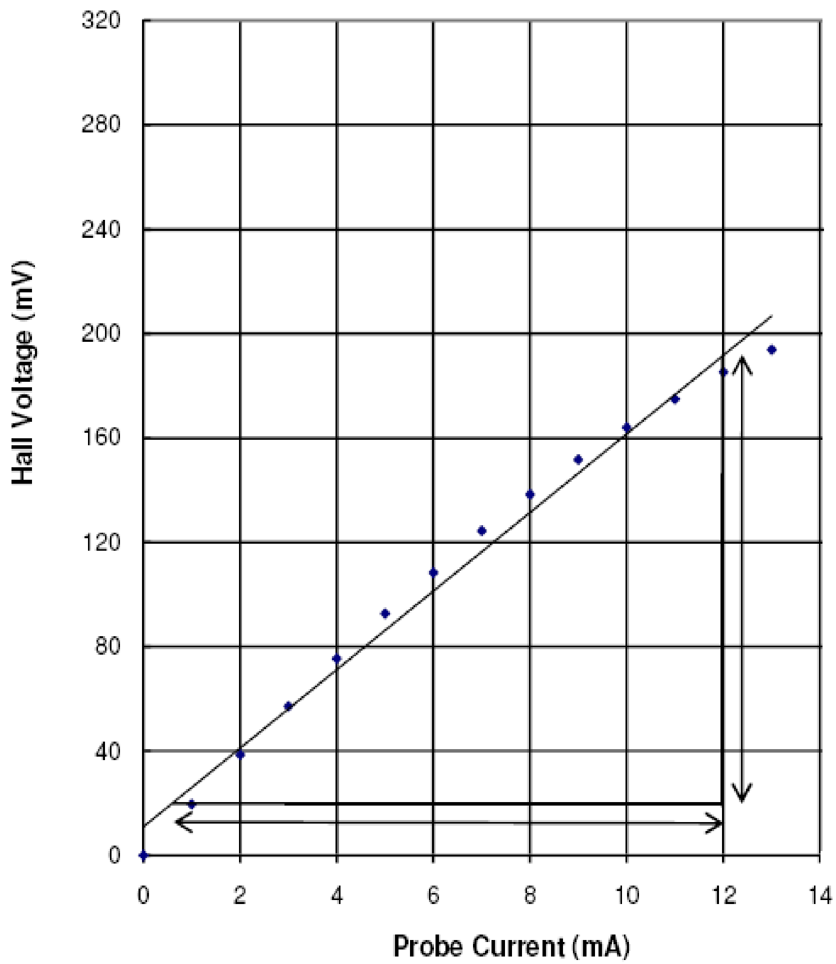
$$R_H = \frac{V_H * t}{I * B}$$

Where R_H is called the Hall coefficient.

Graph1:



Graph2:



Precautions:

1. There should be no magnet, magnetic substances and current carrying conductors near the apparatus.
2. The plane of the coil should be set in the magnetic meridian.
3. Current should remain constant and should be reversed for each observations

4. To avoid error due to parallax, the eye should be placed such a way that pointer covers its image in the mirror below.

Procedure:

1. Connect 'Constant current source' to the solenoids.
2. Four probes is connected to the Gauss meter and placed at the middle of the two solenoids.
3. Switch ON the Gauss meter and Constant current source.
4. Vary the current through the solenoid from 1A to 5A with the interval of 0.5A, and note the corresponding Gauss meter readings.
5. Switch OFF the Gauss meter and constant current source and turn the knob of constant current source towards minimum current.
6. Fix the Hall probe on a wooden stand. Connect Constant Current Generator and milli voltmeter in the Hall Effect apparatus
7. Replace the Four probes with Hall probe and place the sample material at the middle of the two solenoids.
8. Switch ON the constant current source and CCG.
9. Carefully increase the current I from CCG and measure the corresponding Hall voltage V_H. Repeat this step for different magnetic field B.
10. Thickness t of the sample is measured using screw gauge.
11. Hence calculate the Hall coefficient R_H

Observations & Calculations:-

Thickness of the sample (t) = 0.70 (mm)

Table 2:

Sr. No.	Current I, (A)	Magnetic Field H, (Tesla)
1		
2		
3		

Table 3:

Sr. No.	Magnetic Field (Tesla)	Hall current, (mA)	Hall Voltage (mV)	$R_H = \frac{V_H * t}{I * B}$ (volt m/amp tesla)
1				
2				

The observed Hall voltage $\mathbf{V_H}$**=...............** volt

Hall coefficient of the material $\mathbf{R_H}$ =………volt m/amp tesla

Result (s): The observed Hall voltage $\mathbf{V_H}$**=..............** volt

Hall coefficient of the material, $\mathbf{R_H}$ =..........volt m/amp tesla

Conclusion: In conclusion, the Hall effect was verified. As long as the magnetic field and the current stayed below some threshold, there was a linear relationship between the voltage measured, and the current and B field applied.

Review Questions

1. How is Hall's Coefficient related to carrier concentration?
2. On what factors do the sign of the Hall Coefficient depend?
3. Is it possible to measure Hall's coefficient for metal?
4. In what units is hall's coefficient measured?

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Experiment No. 7

Aim: To measure the value of ‘g’ using kater’s pendulum.

List of Equipment Used:

Table 1: List of Equipments

S.N.	Equipment	Range	Quantity
1	Kater’s pendulum	120cm	1
2	Stop watch	NA	1
3	Meter rod	100cm	1

Introduction/Theory: Kater’s pendulum consists of a long metallic rod R of circular cross section weighted at one end so that the centre of mass is much nearer to one end. To do this, a heavy metallic cylinder W_1 and an identical wooden cylinder W_2 are placed at the two ends of the rod. It has two movable knife edges K_1 and K_2. A much smaller metallic cylinder W is kept at the middle of the rod. All the five can be moved along the rod and fixed at any position using screws. This configuration ensures that the centre of gravity lies near one of the knife edges.

Kater’s pendulum is a compound pendulum based on the principle that the centre of suspension and centre of oscillation are interchangeable. The movable cylinders, knife edges and the metallic weight are so adjusted such that the time periods of the pendulum about the two knife edges situated asymmetrically with respect to the centre of gravity are exactly equal. Then, the distance between the knife edges is equal to the length of equivalent simple pendulum whose time period is given by

$$T=2\pi\sqrt{l/g}$$

And hence, g may be calculated. We resort to Bessel's approximation where we do not require making the two time periods to be exactly equal because it is quite difficult and time-consuming to set the Kater's pendulum for this configuration.

If T_1 and T_2 represent two nearly equal time periods (in sec) for positions of K_1 and K_2 distant l_1 and l_2 (in cm) from C.G.

$$g = \frac{8\pi^2}{\frac{T1^2+T2^2}{l1+l2}+\frac{T1^2-T2^2}{l1-l2}}$$

Formula Used: The following formula is used for the determination of acceleration due to gravity 'g':

$$g = \frac{8\pi^2}{\frac{T1^2+T2^2}{l1+l2}+\frac{T1^2-T2^2}{l1-l2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Here, T_1: time periods of the oscillating pendulum from knife-edge K_1

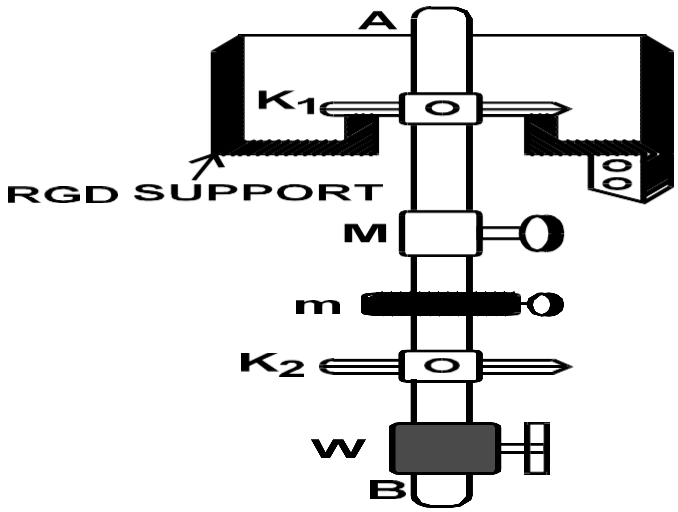
T_2: time periods of the oscillating pendulum from knife-edge K_2

l_1: distances between knife-edges K_1 and CG of the pendulum

l_2: distances between knife-edges K_2 and CG of the pendulum

When T_1 and T_2 are very close to each other (difference less than 1 percent),

The above expression becomes as: $\frac{8\pi^2}{\frac{T1^2+T2^2}{l1+l2}}$ ……………………………….(2)



Precautions:

1. The two knife-edges should be parallel to each other.

2. The amplitude of vibration should be small so that the motion of the pendulum satisfies the condition of simple harmonic motion.

3. To avoid any irregularity of motion the time period should be noted after the pendulum has made a few oscillations.

4. To avoid friction there should be glass surface on rigid support.

Procedure:

1. Suspend the pendulum from the knife edges K_1 and K_2 in turn and oscillate it. Find for 20 oscillations and obtain the time periods.

2. The time periods are made nearly equal as much as possible by moving M either upward or downward and finally using the micrometre screw for the final adjustment of mass m.

3. Measure the time periods T_1 and T_2 about K_1 and K_2.

4. Measure the distance $(l_1 + l_2)$ between the two knife edges K_1 and K_2.

5. by knowing the value of ($l_1 + l_2$) and time periods T_1 and T_2 the value of g can be calculated by applying the formula in equation (1).

6. Change the distance between two knife edges and again repeat the experiment.

Observations &Calculations:

1. Least count of stop watch=…….sec
2. Distance between K_1 and CG (l_1) =…….cm
3. Distance between K_2 and CG (l_2) =…….cm
4. Table for time period T_1(oscillation about K_1)

Table 2:

For the determination of T_1 and T_2

S. No.	No. of oscillations	Time about the knife edge K1			Time of one oscillation T_1 secs.	Mean T_1 Secs.	Time about the knife edge K_2			Time of one oscillation T_2 secs.	Mean T_2 Secs.	Distance between two knife edges i.e. $\ell_1+\ell_2$ meter
		Min.	Secs.	Total			Min.	Secs.	Total			
1 2	20 25	… …	… …	… …	… …	…	… …	… …	… …	… …	…	… …
1 2	20 25	… …	… …	… …	… …	…	… …	… …	… …	… …	…	… …
1 2	20 25	… …	… …	… …	… …	…	… …	… …	… …	… …	…	… …

Acceleration due to gravity ‘g’=............m/s^2

Standard value of ‘g’ = 9.8 m/s^2

Result (s): Acceleration due to gravity ‘g’=............m/s^2

Conclusion: kater’s pendulum gives a very accurate value of gravity.

Review Questions:

1. What is a kater's pendulum?

2. Why do you place heavy mass at one end?

3. How will you find the value of g if the two time periods are not exactly equal?

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Experiment No. 8

Aim: **To calculate the velocity of ultrasonic sound through different liquid media.**

List of Equipment Used:

Table1: List of Equipments

S.N.	Equipment	Range	Quantity
1.	Ultrasonic interferometer	2MHz	1
2.	Sample liquids	20ml	1
3.	Power supply	220V	1

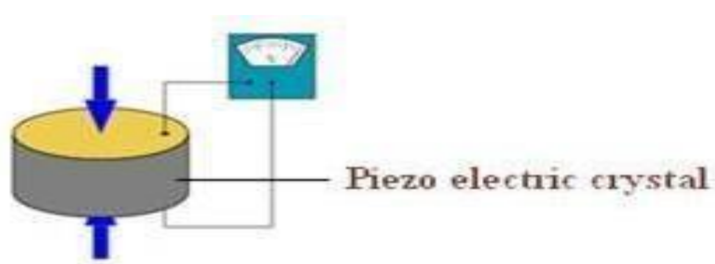
Introduction/Theory:

Ultrasonic interferometer is a simple device which yields accurate and consistent data, from which one can determine the velocity of ultrasonic sound in a liquid medium. Ultrasonic sound refers to sound pressure with a frequency greater than the human audible range (20Hz to 20 KHz). When an ultrasonic wave propagates through a medium, the molecules in that medium vibrate over very short distance in a direction parallel to the longitudinal wave. During this vibration, momentum is transferred among molecules. This causes the wave to pass through the medium.

Generation of ultrasound:

Ultrasonic can be produced by different methods. The most common methods include

Piezoelectric generator: This is the most common method used for the production of ultrasound. When mechanical pressure is applied to opposite faces of certain crystals which are cut suitably, electric fields are produced. Similarly,

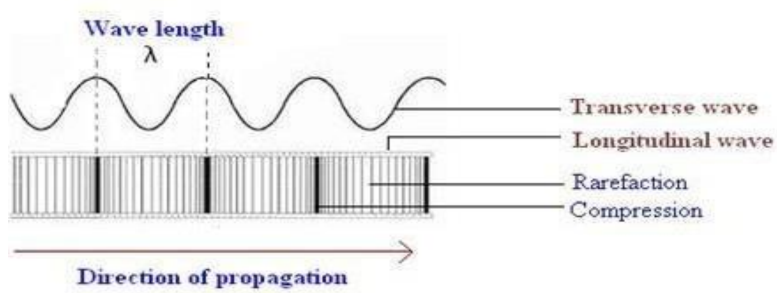


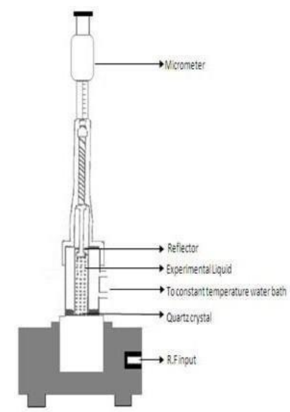
when subjected to an electric field, these crystals contract or expand, depending on the direction of the field. Thus, a properly oriented rapid alternating electric field causes a piezoelectric crystal to vibrate mechanically. This vibration, largest when the crystal is at resonance, is used to produce a longitudinal wave, *i.e.*, a sound wave.

Magnetostriction generator**:** In this method, the magnetostriction method is used for the production of ultrasonic. Frequencies ranging from 8000 Hz to 20,000Hz can be produced by this method.

Ultrasonic Interferometer:

The schematic diagram of an ultrasonic interferometer is shown in the figure.





In an ultrasonic interferometer, the ultrasonic waves are produced by the piezoelectric method. In a fixed frequency variable path interferometer, the wavelength of the sound in an experimental liquid medium is measured, and from this one can calculate its velocity through that medium. The apparatus consists of an ultrasonic cell, which is a double walled brass cell with chromium plated surfaces having a capacity of 10ml. The double wall allows water circulation around the experimental medium to maintain it at a known constant temperature. The micrometre scale is marked in units of 0.01mm and has an overall length of 25mm. Ultrasonic waves of known frequency are produced by a quartz crystal which is fixed at the bottom of the cell. There is a movable metallic plate parallel to the quartz plate, which reflects the waves. The waves interfere with their reflections, and if the separation between the plates is exactly an integer multiple of half-wavelengths of sound, standing waves are produced in the liquid medium. Under these circumstances, acoustic resonance occurs. The resonant waves are a maximum in amplitude, causing a corresponding maximum in the anode current of the piezoelectric generator. If we increase or decrease the distance by exactly one half of the wavelength ($\lambda/2$) or an integer multiple of one half wavelength, the anode current again becomes maximum. If *d* is the separation between successive adjacent maxima of anode current, then,

$$d=\lambda/2$$

The velocity (v) of a wave is related to its wavelength (λ) by the relation $v=\lambda f$, where f is the frequency of the wave.

$$\text{Then } v=\lambda f=2df$$

The velocity of ultrasound is determined principally by the compressibility of the material of the medium. For a medium with high compressibility, the velocity will be less.

Formula Used: The velocity (v) of a wave is related to its wavelength (λ) by the relation

$$v=\lambda f=2df$$

Where, *d* is the separation between successive adjacent maxima of anode current

Precautions:

1. The middle portion of the ultrasonic interferometer should be thoroughly cleaned and filled with the liquid, say water.
2. Do not use acidic medium for performing the experiment.
3. Wait for five minutes, after the instrument is switched ON, and then start making the adjustments, and noting down readings with the apparatus.
4. Lower side reading is to be taken on the micrometer scale.

Procedure:

1. Insert the quartz crystal in the socket at the base and clamp it tightly with the help of a screw provided on one side of the instrument.
2. Unscrew the knurled cap of the cell and lift it away. Fill the middle portion with the experimental liquid and screw the knurled cap tightly.
3. Then connect the high frequency generator with the cell. The cell is filled with the given liquid and the frequency of the generator is set at a desired value.
4. There are two knobs on the instrument- “Adj” and “Gain”. With “Adj”, position of the needle on the ammeter is adjusted. The knob “Gain” is used to increase the sensitivity of the instrument.
5. Then ultrasonic waves are reflected back from the movable plate, and standing waves are formed between the quartz crystal and the reflector plate.
6. The micrometer screw is moved till the anode current reaches maximum.
   Micro ammeter readings are noted for ‘n’ number of maxima / minima.
7. The distance ‘d’ between two successive maxima and minima is obtained from the readings taken.
8. The wavelength of the ultrasound is calculated using the ‘d’ value and hence velocity of the ultrasonic wave can be calculated using the known frequency.

Observations and Calculations:

Least count of the main scale = ……… mm

Least count of circular scale = ……… mm

Least count of vernier scale = ……… mm

Frequency of the ultrasound used (f) = 2MHz

Table 2:

S.NO	Micrometre Reading Corresponding to maxima/minima(mm)	Difference between consecutive Maxima/Minima $d=\lambda/2$ (mm)
1	N1	N2-N1
2	N2	N3-N2
3	N3	N4-N3
4	N4	N5-N4
5	N5	Mean d=

The velocity of ultrasonic waves is calculated as $v=\lambda f=2df$ =………ms^{-1}

Standard velocity of ultrasonic waves is =1480m/s

Result (s): The velocity of ultrasonic waves is = ………ms^{-1}

Conclusion: Ultrasonic waves move with a very high speed.

Review Questions

(i) What is ultrasonic wave?

(ii) Why ultrasonic waves are inaudible to humans?

(iii) Give important applications of ultrasound.

(iv) What is the principle used for finding ultrasonic velocity using acoustic grille?

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Experiment No. 9

Aim: Determination of value of Planck's constant 'h' using photo cell.

List of Equipment Used:

Table 1: List of Equipments

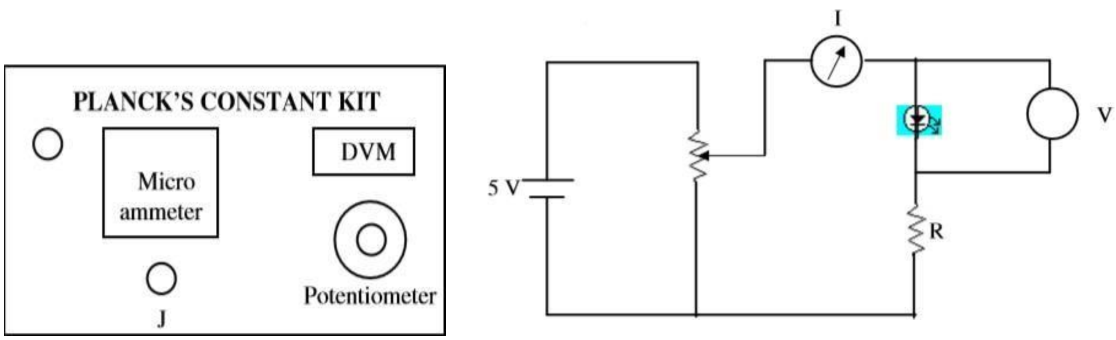
S.N.	**Equipment**	**Range**	**Quantity**
1	Digital Voltmeter (DVM) to measure the voltage across the L.E. D. s	0-20V	1
2	Micro-ammeter to determine the current through L.E.D.s.	30MA	1
3	Jack J to connect the L.E.D.s	Different colors	4

Introduction/Theory: The objective of this experiment is to determine Planck's constant using light emitting diodes (LED's) by observing the 'reverse photo-electric effect'. In the case of the photoelectric effect, an electron is emitted from a metal if the energy of the photon is greater than the work function of the metal. If the energy of said photon is greater than the work function of a given material then the electron emitted possesses a voltage, which equals the difference in these energies. In the case of an LED's the opposite is true. If an electron of sufficient voltage is passed across a material, then a photon is emitted whose energy is equivalent to the work function of that material. The voltage at which this effect is first observed is the 'turn on voltage'.

When a semiconductor is doped with impurities of the III periodic group elements it then has a lack of electrons in the valance band. Similarly doped semiconductors with V periodic group elements so as to have excess electrons, which then overpopulate the valance band and form a conduction band. These are P and N type semiconductors respectively, P for positive, and N for negative. When coupled we have what is called a P-N junction. In this system the bands don't always line up and there then exists a barrier potential. If a bias voltage is passed across the diode, which is equal or greater than the difference in the energy of the bands, i.e. the barrier

potential, then the bands will 'line up' and a current will flow. When current flows, electrons flow from the conduction band of the N type conductor and are forced up into the conduction band of the P type. Since the P type conductor's valance band is lacking in electrons and we are overpopulating its conduction band with the bias voltage the electrons readily fall into the 'holes' in the valance band of the P type conductor. When they fall this energy is released in the form of a photon. The energy of this photon is equal to the band gap energy of the diode. It follows that if the linear portion of the voltage vs. current graph is extrapolated back to the x-axis the intercept should be the point at which the voltage equals the barrier potential. The energy of the photons emitted should then be the same as the energy of a given electron.

Diagram:



Formula Used:

$E = h\upsilon$ (1)

$E = eV$ (2)

Where $e = 1.6 \times 10^{-19}$ C

We then solve equation (1) for h and replace the E term with the equivalent of E in equation (2), as well as replace υ with:

$\upsilon = c/\lambda$

Where $c = 3 \times 10^8$ m/sec

We then get:

$h = eV\lambda/c$ (3)

this equation can be rewritten as

$V = hc/e\lambda$ (4)

It is this equation that we will use to determine Planck's constant.

Where h is Planck's Constant

υ is the frequency of light

Precautions: -

1. The experiment should be performed such that the glow of LEDs is properly visible.

2. Smooth graphs should be plotted.

Procedure: 1. Connect the L.E.D. to the jack provided on the front panel and switch ON the unit.

2. Take the different voltage and current measurement of LED (as tabulated below) for V-I characteristic of LED:

3. Take different LEDs and follow step 2.

4. Now plot the V-I characteristics of all the LEDs on graph paper and take voltages corresponding to a constant current as shown on graph in next page.

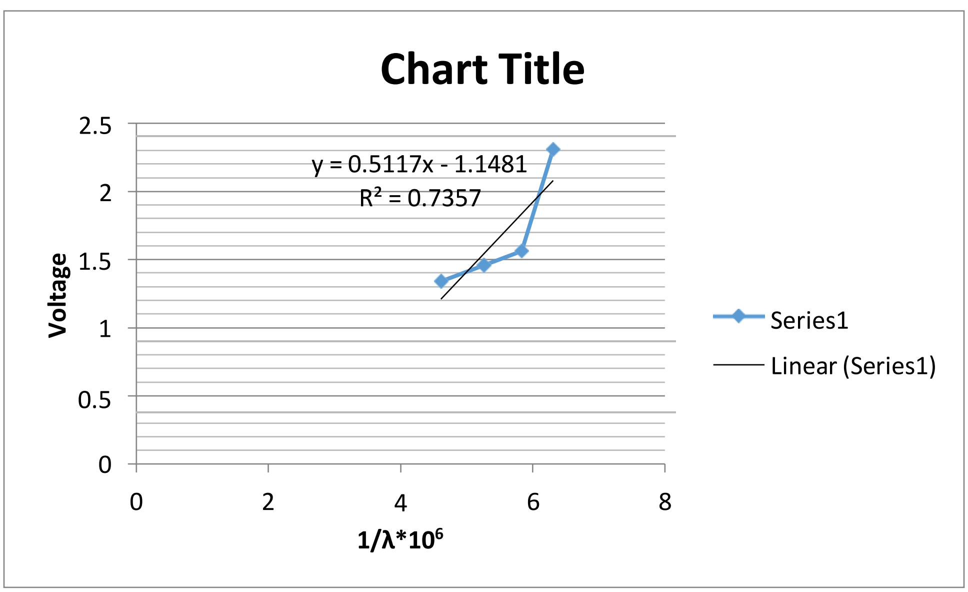
Observations & Calculations:

Table 2:

S. No	L.E.D. Colour	Wavelength λ (nm)	1/ λ	Stoppage Voltage V (volts)	Energy(J) E=eV	Frequency υ = c/ λ	h= eV λ/c
1	Red	650					
2	Green	510					
3	Yellow	570					
4	Blue	475					

Now plot a graph between voltage (V) vs. 1/λ and determine the slope of the line.

Graph:



Slope of the curve between V vs. 1/λ =hc/e.

Substitute the values of c = (3×10^{8} m/s) and e = (1.6×10^{-19} C) and determine the value of Planck's constant h.

Standard value of Planck's constant' h' is = 6.63×10^{-34}Js

Result (s): The value of Planck's constant 'h'= Js

Conclusion: Our experimental value of Planck's constant was well within the limits set by experimental uncertainty.

Review Questions

1. What is the value of Planck's constant?
2. What is the relation between energy of a photon and its wavelength?
3. What are the units of Planck's constant?
4. Does the violet light have more energy or the red light?

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