Department of Applied Physics

LAB MANUALS

APPLIED PHYSICS LAB II

AP-102

Department of Applied Physics

APPLIED PHYSICS LAB B.Tech 2nd Semester

Paper Code: AP-102

Paper Title: Applied Physics Lab-II

OBJECTIVE: To impart experimental skills which are useful in various branches of Engineering and Technology. The practical course is based on experiments designed to illustrate various phenomena in different areas of physics and hence provides thorough understanding of the subject. This course is also aimed at enhancing the analytical capability of the engineering students.

List of Experiments

1. To determine the Hall coefficient and hence find the density of charge carriers in a semiconductor at room temperature by Hall effect measurement.
2. To determine the Planck's constant by photoelectric effect.
3. To determine the energy band gap of a semiconductor by four probe method.
4. To verify Biot Savrat's law.
5. To determination of Joule's Mechanical Equivalent of Heat.
6. To draw the I-V characteristics for light emitting diode (LED) and determine the value of Planck's constant.
7. To determine the magnetic susceptibility of hydrous manganese chloride ($MnCl_2.4H_2O$) by Quinck's tube method.
8. To study the variation of magnetic field with distance along the axis of a circular coil carrying current and to find 1) the radius of the coil 2) horizontal component of earth's magnetic field.
9. Measurement of high resistance by Ballistic galvanometer.
10. To determine the ratio of charge to mass (e / m) ratio for an electron.

Department of Applied Physics

EXPERIMENT NO.-1

STUDY OF HALL EFFECT EXPERIMENT – HEE -100

INTRODUCTION :

In 1879 physicest E.H. Hall observed that when an electrical current passes through a sample placed in a magnetic field, a potential proportional to the current and to the magnetic field is developed across the material in a direction perpendicular to both the current and to the magnetic field [1.] This effect is known as the Hall effect. And is the basis of many practical applications and devices such as magnetic field measurement, and position and motion detectors.

With the measurement he made, Hall was able to determine for the time the sign of charge carriers in a conductor. Even today Hall effect measurement continue to be a useful technique for characterizing the electrical transport properties of metals and semiconductors.

THEORY :

Static magnetic field has no effect on charges unless they are in motion. When the charges flow, a magnetic field direct perpendicular to the direction of flow produces a mutually perpendicular force on the charges. When this happens, electrons and holes will be separated by opposite forces. They will in turn produce an electric field (E_h) which depends on the cross product of the magnetic intensity, H, and the current density, J. the situation is demonstrated in Fig. I.

$$\overline{Eh} = R \, \overline{J} \times \overline{H} \qquad (1)$$

Where R is called the Hall coefficient.

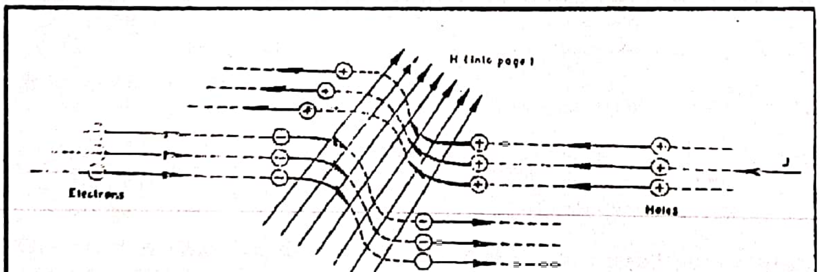

FIG. 1 Carrier Sepration due to Magnetic Field

Now, let us consider a bar of semiconductor, having dimension, x, y and z. let J is directed along X and H along Z them Eh will e along Y, as in Fig. 2.

Then we could write

$$R = \frac{V_h / Y}{J \, H} = \frac{V_h . Z}{I \, H} \qquad (2)$$

Where V_h is the Hall voltage appearing between the two surfaces perpendicular to y and $I = Jyz$.

Generally, the Hall voltage is not a linear function of magnetic field applied, i.e. the Hall coefficient is not generally a constant, but a function of the applied magnetic. Consequently, interpretation of the Hall voltage is not usually a simple matter. However, it is easy to calculate this (Hall) voltage if it is assumed that all carriers have the same drift velocity. We will do this in two steps (a) by assuming that carriers of only one type are present, (b) by assuming that carriers of both types are present.

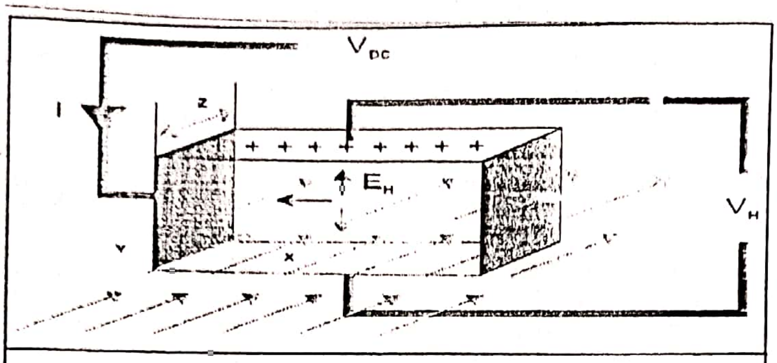

FIG – 2. Geometry of Field and Sample in Hall Effect Exp.

(a) **ONE TYPE OF CARRIER :**

Metals and degenerate (doped) semiconductors are the examples of this type where one carrier dominates.

The magnetic force on the carriers is $\bar{E}m = e(\bar{v} \times \bar{H})$ and is compensated by the Hall Field $F_h = e\,E_h$, where v is the drift velocity of carriers. Assuming the direction of various vectors as before.

$$\bar{v} \times \bar{H} = \bar{E_h}$$

From simple reasoning, the current density J is the charge q multiplied by the number of carriers traversing unit area in unit time, which is equivalent to the carrier density multiplied by the drift velocity i.e. $\bar{J} = q\,n\,\bar{v}$.

By putting these values in equation (2)

$$R = \frac{E_h}{JH} = \frac{v.H}{q\,n\,v\,H} = \frac{1}{nq} \qquad (3)$$

From this equation, it is clear that the sign of Hall Coefficient depend upon the sign of the q. this means, in a p – type specimen the R would be positive, while in n – type it would be negative. Also for a fixed magnetic field and input current, the Hall Voltage is proportional to 1/n or its resistivity. When one carrier dominates, the conductivity of the material is $\sigma = nq\mu$.

Where μ is the mobility of the charges carriers.

Thus $\mu = R\sigma \qquad (4)$

Equation (4) provides an experimental measurement of mobility; R is expressed in cm^3 $coulomb^{-1}$ thus μ is expressed in units, or cm^2, $volt^{-1}$ Sec^{-1}.

(b) **TWO TYPE OF CARRIERS :**

Intrinsic and lightly doped semiconductors are the examples of this type. In such cases, the quantitative interpretation of Hall coefficient is more difficult since both type of carriers contribute to the Hall field. It is also clear that for the same electric filed, the Hall voltage of p – carriers will be opposite sign from the n – .

carriers. As a result, both mobilities enter into any calculation of Hall coefficient and weighted average is the result** i.e.

$$R = \frac{\mu_h^2 P - \mu_e^2 n}{2 (\mu_h P + \mu_e n)^2} \qquad (5)$$

** (Modern Physics by Adrian C. Melissions (Academic Press) P.86.)

Where μ_h and μ_h are the mobilities of holes and electrons; p and n are the carrier densities of holes and electron. correctly reduces to equation (3) when only one type of carriers is present ***.

Since the mobilities μ_h and μ_h are not constants but function of temperature (T) the Hall coefficient given by Eq. (5). is also a function of T and it may become zero. even change sign. In general $\mu_h > \mu_h$ so that inversion may happen only if $p > n$: thus Hall coefficient inversion is characteristic only of p-type semiconductors.

At the point of zero Hall coefficient, it is possible to determine the ratio of mobilities and their relative concentration.

Thus we see that the Hall coefficient, in conjunction with resistivity measurements, can provide information on carrier densities, mobilities, impurity concentration and other values. It must be noted, however, that mobilities obtained from Hall Effect measurements $\mu = R\sigma$ do not always agree with directly measured values. The reason being that carriers are distributed in energy, and those with higher velocities will be deviated to a greater extent for a given field. As μ we know varies with carrier velocity.

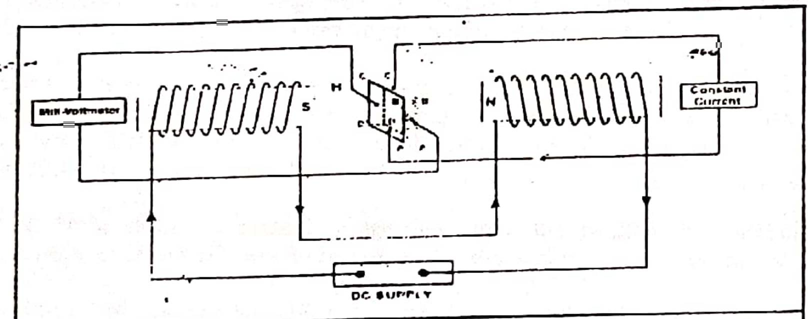

Fig – 3. Basic Hall Effect Set up

EXPERIMENTAL TECHNIQUE :

(a) EXPERIMENTAL CONSIDERATION RELEVANT TO ALL MEASUREMENT ON SEMICONDUCTORS :

1. In single crystal material the resistivity may vary smoothly from point to point. In fact this is generally the case. The question is the amount of the amount of this variation rather than its presence. Often however, it is conventionally stated that it is constant within some percentage and when the variation does in fact all within this tolerance, it is ignored.

2. High resistance or rectification action appears fairly often in electrical contacts to semiconductors and in fact is one the major problem.

3. Soldered probe contacts, through very much desirable may disturb the current flow (shorting out part of the sample). Soldering directly to the body of the sample can affect the sample properties due to heat and by contamination unless care is taken. These problems can be avoided by using pressure contacts an in the present

set-up. The principle draw back of this type of contacts is that they may be noisy. This problem can, how be managed by keeping the contacts clean and firm.

*** Both Eq.(3) and Eq.(5) have been derived on the assumption that all carriers have same velocity: this is not true, bu exact calculation modifies the results obtained here by a factor of only $3\pi/8$

4. The current through the sample should not be large enough to cause heating. A further precaution is neces to prevent 'injecting effect' from affecting the measurement. Even good contacts to germanium for exan may have this effect. This can be mininized by keeping the voltage drop at the contacts low. If the sur near the contacts is rough and the electric flow in the crystal is low, these injected carriers will recom before reaching the measuring probes.

Since Hall coefficient is independent of current, it is possible to determine whether or not any of these eff are interfering by measuring the Hall coefficient at different values of current.

(b) EXPERIMENTAL CONSIDERATION WITH THE MEASUREMENT OF HALL COEFFICIEN

1. The voltage appearing between the Hall Probes is not generally, the Hall voltage alone. There are ot galvanomagnetic and thermomagnetic effects (Nearest effect, Rhighleduc effect and Ettingshausen effect) wh can produce voltages between the Hall Probes. In addition, IR drop due to probe misalignment (zero magn field potential) and thermoelectric voltage due to transverse thermal gradient may be present. All these exc the Ettingshausen effect are eliminated by the method at averaging four readings.

   The Ettingshausen effect is negligible in materials in which a high thermal conductivity is primarily due lattice conductivity or in which the thermoelectric power is small.

   When the voltage between the Hall Probes is measured for both directions of current, only the Hall volta and IR drop reverse. Therefore, the average of these readings eliminates the influence of the other effe Further, when Hall Voltage is measured for bother the directions of the magnetic field, the IR drop does r reverse and may therefore be eliminated.

2. The Hall Probe must be rotated in the field unitl the position of maximum voltage is reached. This is t position when direction of current in the probe and magnetic field would be perpendicular to each other.

3. The resistance of the sample changes when the magnetic field is turned on. This phenomena called magnet resistance is due to the fact that the drift velocity of all carriers is not the same, with magnetic field on, t Hall voltage compensates exactly the Lorentz force for carriers with average velocity. Slower carriers will over compensated and faster ones under compensated, resulting in trajectories that are not along the appli external field. This results in effective decrease of the man free path and hence an increase in resistivity.

   There, while taking readings with a varying magnetic field at a particular current value, it is necessary th current value should be adjusted, every time. The problem can be eliminated by using a constant curre power supply, which would keep the current constant irrespective of the resistance of the sample.

4. In general, the resistance of the sample is very high and the Hall Voltages are very low. This means th practically there is hardly any current – not more than few micro amperes. Therefore, the Hall Voltages shou only be measured with a high input impedance (≅ 1 M) devices such as electrometer, electronic Millivoltmete or good potentiometers preferably with lamp and scale arrangements.

5. Although the dimensions of the crystal do not appear in the formula except the thickness, but the theor assumes that all the carriers are moving only lengthwise. Practically it has been found that a closer to ide situation may be obtained if the length may be taken three times the width of the crystal.

APPARATUS REQUIRED

1. (a) Hall Probe (Ge Crystal) (P or N type)

(b) Hall Probe (In As)
2. Digital Hall Effect Set, Model – DHE – 21.
3. Electromagnet, Model – EMU – 35, EMU – 50 OR EMU – 75.
4. Constant Current Power Supply, Model – CC – 35, CC – 50 OR CC – 75/BPCC - 75
5. Digital Gauss Meter, Model – DGM – 100.

1. (a) **HALL PROBE (Ge Crystal) :**

'Ge' Single Crystal with four spring type pressure contacts of pure silver is mounted on a glass epoxy strip. Four leads are provided for connections with measuring devices.

Contacts	:	Spring type
Hall Voltage	:	0.1 – 1 Volt / 100 mA / Kilogauss
Thickness of Ge Crystal	:	0.4 – 0.5, m.m.
Resistivity	:	≅ 10, ohm c.m.

The exact value of thickness and resistivity is provided in the test report of the Hall Probe (Ge) supplied with the set-up. The student after calculating the Hall Coefficient from this experiment and using the given value of resistivity can also get valuable information about carrier density and carrier mobilities. A typical example is provided in the appendix. A minor draw back of this arrangement is that it may require zero adjustment from time to time. This type of probes are specially designed and recommended for Hall Effect Experiment.

(b) **HALL PROBE (Indium Arsenide) :**

Indium arsenite Crystal (Rectangular) is mounted on a phenolic strip with four soldered contacts for connections with measuring devices. The crystal is covered by a protective layer of paint. The whole system is mounted in a pen-type case for further protection.

Contacts	:	Soldered.
Hall Voltage	:	8 – 10 mV / 100 mA / KG.

The value of the thickness and resistivity of the sample given for these probes are not very reliable as these are not given for a specific probe and may vary from probe as is usually the case with all semiconductor devices. These are essentially meant to be used as transducers.

2. **DIGITAL HALL EFFECT SET - UP, MODEL – DHE – 21.**

The set-up consists of an electronic Digital Millivometer and a constant current power supply. The Hall Voltage and probe current can be read on digital panel meter through the selector switch.

(a) **DIGITAL MILLIVOLTMETER :**

A/D Converter ICL – 7107 have been used. It has high accuracy like, auto zero to less than 10 μV. zero drift less than 1 μV/°C, input bias current of 10 pA and roll over error of less than one count. Since the use of internal reference causes the degradation in performance due to internal heating. an external reference has been used. This voltmeter is much more convenient to use in Hall Experiment. because the input of either polarity can be measured.

SPECIFICATIONS :

Range	:	0 – 200.0. mVolt.
Resolution	:	100. μVolt.
Accuracy	:	± 0.1% of reading ± 1 Digit.
Impedance	:	1, M ohm.
Special Features	:	Auto zero and polarity indicator.
Overload Indicator	:	Sign of 1 on the left and blanking of other digits.

(b) **CONSTANT CURRENT POWER SUPPLY :**

This power supply specially designed for Hall Probe provided 100 percent protection against crystal burn-out due to excessive current. The basic scheme is to use the feed-back principle to limit the load current of the supply to a preset maximum value. Variations in the current are achieved by a potentiometer. The supply is highly regulated and practica ripple free D.C. Source. The current is measured by the digital panel meter.

SPECIFICATIONS :

Current Range	:	(0 – 20 mA) or as required for the particular Hall Probe.
Resolution	:	10 μA.
Accuracy	:	± 0.2% of the reading ± 1 Digit.
Load Regulation	:	0.03% for 0 to full load.
Line Regulation	:	0.05% for 10% changes.

3. (a) **ELECTROMAGNET, MODEL – EMU – 75.**

Field Intensity	:	12.500gauss ± 5% Gauss at an air-gap of 10 mm. Air-gap is continusouly varial upto 75 mm.
Pole Pieces	:	75.mm diameter. Normally flat faced pole pieces are supplied with the magnet.
Engineering Coils	:	Two each coil has a resistance of 10. ohms. Approx.
Power Require	:	0 – 5 Amps. Continuously variable

(b) **ELECTROMAGNET, MODEL – EMU – 50.**

Field Intensity	:	7.5 K Gauss ± 5% at 10. mm. air-gap The air-gap is continuously variable.
Pole Pieces	:	50.mm diameter. Normally flat faced pole pieces are supplied with the magnet.
Engineering Coils	:	Two each coil and has a resistance of about 3.0. ohm/coil
Power Require	:	0 – 4 Amp.

(c) **ELECTROMAGNET, MODEL – EMU – 35.**

Field Intensity	:	5.0 K Gauss at 10. mm air -gap. The air-gap is adjustable from 0 -60 mm.
Pole Pieces	:	35.mm flat faced pole.
Engineering Coils	:	Two each coil has a resistance of about 4.0. ohm.
Power Require	:	0 – 2.5Amps.

4. (a) **CONSTANT CURRENT POWER SUPPLY, MODEL – CC – 75.**

SPECIFICATIONS :

Current	:	Smoothly adjustable from 0 to 5 Amp
Regulation (Line)	:	± 0.1% for 10% mains variation.
Regulation (Load)	:	± 0.1% for load resistance variation from 0 to full load.
Metering	:	3 ½ Digit, 7 segment panel meter.
Protection	:	Electronically protected against over loading & short circuiting
Input	:	220Volt ±10% , 50Hz

5. **BIPOLAR MAGNET POWER SUPPLY MODEL: BCC- 75**

BCC-75, Bipolar power supplies are micro controlled based highly regulated constant current sources , speciall designed for Electromagnets . The BCC- 75 Power Supply maintain tight control over the entire output range including zero output . This achieved without reversal contactor or relays , which are not suitable for this purpos because they produce , unintended field spikes , and other discontinuities , as a result field hysteresis or other biases are avoided in experimental data.

Features:

- Built-in spikes , surge , noise and transient suppressor
- Bipolar variable constant output
- Over Load and short circuit protection
- Low ripples
- High regulation
- Advance technology

- Output is controllable by push buttons provided on panel

Specification :

Output	:	-5 Amps. through zero '0' to +5 Amps. Through a microcontroller provided.
Regulation	:	Better than ± .05% from no load to full load.
Stabilization	:	Better than ± .05% for ± 10% variation in Mains
Display	:	3½ digit, LED Meter (Two nos. one for current and other for %)
Protection	:	The unit is fully protected electronically against short circuiting and over loading. Spikes , surge, noise and transients, in addition to a suitable fuse and a miniature circuit breaker in input.
Input	:	220V ± 10% , 50Hz

(b) **<u>CONSTANT CURRENT POWER SUPPLY,</u> MODEL – CC – 50.**

<u>Specifications :</u>

Current	:	0 – 4, Amp.
Regulation (Line)	:	± 0.1% for 10% variation in mains.
Regulation (Load)	:	± 0.1% no load to full load.
Protected	:	Electronically protected against overload or short circuit.
Metering	:	3 ½ Digit, 7 segment LCD Digital Panel Meter.
Input	:	220Volt ± 10% , 50Hz

(c) **<u>CONSTANT CURRENT POWER SUPPLY,</u> MODEL – CC – 35.**

<u>Specifications :</u>

Current	:	0 –2.5, Amp.
Regulation (Line)	:	± 0.1% for No load to full load.
Regulation (Load)	:	± 0.1% for ± 10% mains variation..
Protection	:	Electronically protected against overload or short circuiting.
Metering	:	3 ½ Digit, 7 segment LCD Digital Panel Meter.
Range	:	220V ± 10% 50 Hz

6. **<u>DIGITAL GAUSS METER,</u> MODEL – DGM – 100.**

<u>Specifications :</u>

Range	:	0 – 2, K Gauss and 0 – 20 k Gauss.
Resolution	:	1 Gauss at 0 – 2 K Gauss Range.
Accuracy	:	± 0.5%.
Display	:	3 ½ Digit, 7 segment LED.
Detector	:	Hall Probe with an Imported Hall Element.
Input	:	220 Volt, 50 Hz.
Special	:	Indicates the direction of the magnetic field.

<u>PROCEDURE :</u>

1. Connect the widthwise contacts wires of the Hall Probe to the terminals marked "Voltage" and lengthwise contacts to terminals marked "Current".
2. Switch 'ON' the Hall Effect Set – Up and adjustment current (say few mA).
3. Switch over the display to voltage side. There may be some voltage reading even outside the magnetic field. This is due to imperfect alignment of the four contacts of the Hall Probes and is generally known as the 'Zero field Potential". In case its value is comparable to the Hall Voltage it should be adjusted to a minimum possible (for Hall Probe "Ge" only). In all cases, this error should be subtracted from the Hall Voltage reading.
4. Now place the probe in the magnetic field as shown in Fig.3 and switch on the electromagnet power supply and adjust the current to any desired value. Rotate the Hall Probe till it become perpendicular to magnetic field. Hall voltage will be maximum in this adjustment.

5. Measure Hall voltage for both the directions of the current and magnetic field (i.e. four observations particular value of current and magnetic field).
6. Measure the Hall Voltage as a function of current keeping the magnetic field constant Plot a graph.
7. Measure the Hall Voltage as a function of magnetic field keeping a suitable value of current as constan graph.
8. Measure the magnetic field by the Gauss Meter.

CALCULATIONS :

1. From the graph Hall Voltage Vs. Magnetic field calculate Hall coefficient.
2. Determine the type of majority charge carriers, i.e. whether the crystal in n-type or p-type.
3. Calculate charge carrier density from the relation.

$$R = \frac{1}{nq} \Rightarrow n = \frac{1}{Rq}$$

4. Calculate carrier mobility, using, the formula

$$\mu_n \text{ (or } \mu_p) = R\sigma$$

using the specified value of resistivity ($1/\sigma$) given by the supplier or obtained by some other method Probe Method). Typical calculations are shown in appendix.

QUESTIONS :

1. What is Hall Effect ?
2. What are n – type and p – type semiconductors ?
3. What is the effect of temperature on Hall coefficient of a lightly doped semiconductors.
4. Do the holes actually move ?
5. Why the resistance of the sample magnetic field ?
6. Why a high input impedance device is generally needed to measure the Hall voltage.
7. Why the Hall Voltage should be measured for both the directions of current as well as of magnetic field

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(iii) CARRIER MOBILITY :

For degenerate semiconductor i.e. when one carrier dominates.

$$\text{Carrier Mobility} \quad \mu = R\sigma$$

$$= 33 \times 10^{-3} \times 0.1$$

$$= 3300 \ cm^2 \ volt^{-1} \ sec^{-1}$$

Thus we see that Hall Coefficient in conjunction with resistivity measurement can provide valuable informati on carrier density, mobilities and other values. It must be noted however. that mobilities obtained from Hall Effe Measurement $\mu = R\sigma$ do not always agree with directly measured values. The reason is explained in the booklet.

OBSERVATION TABLE

1. CONSTANT Magnetic Field ....Gauss.

FORWARDED		REVERSE	
I (mA) Current (mA)	V (mV) Volts (mV)	I (mA) Current (mA)	V (mV) Volts (mV)

2. CURRENT CONSTANT.............mA.

Current	Milli Volt

APPENDIX

Sample calculation for Hall Coefficient; Carrier Density and Mobility taking Hall Probe as sample.

SAMPLE DETAILS :

Sample	:	'Ge' Crystal n – type.
Thickness (z)	:	5×10^{-2} cm.
Resistivity (ρ)	:	10 ohm cm or
		10 Volt coulomb^{-1} sec cm.
Conductivity (σ)	:	0.1 coulomb volt–1 sec–1 cm–1

$$\text{ohm} = \frac{V}{I} = \frac{V}{\frac{dQ}{dt}} = \text{V.coulomb}^{-1}\text{. sec}$$

EXPERIMENTAL DATA :

Current	:	8×10^{3} Amp.
Magnetic Field (H)	:	1000, G.
Hall Voltage (V_h)	:	53×10^{-3} Volt.

(i) HALL COEFFICIENT (R) :

We know from equation 2 of the text.

$$R = \frac{V_h . z}{I\,H}$$

$$= \frac{53 \times 10^{-3} \times 5 \times 10^{-2}}{8 \times 10^{-3} \times 10^{3}}$$

$$= 33 \times 10^{-3} \text{ volt cm amp}^{-1} \text{ G}^{-1}$$

or

$$= 33 \times 10^{-5} \times 10^{8} \text{ cm}^3 \text{ coulomb}$$

$$= 33 \times 10^{3} \text{ cm}^3 \text{ coulomb}^{-1}$$

(ii) CARRIER DENSITY (n) :

We know from equation 3 of the text.

$$R = \frac{1}{nq} \Rightarrow n = \frac{1}{Rq}$$

$$= \frac{1}{33 \times 10^{3} \times 1.6 \times 10^{-19}}$$

$$= 1.9 \times 10^{14} \text{ cm}^{-3}$$

EXPERIMENT NO.-2

Determination of Plank's Constant by Photoelectric Effect

Theory:

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

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

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

Further it is assumed that electrons are bound inside the metal surface with an energy $e\phi$, where ϕ is called work function. It then follows that if the frequency of the light is such that

$$h\nu > e\phi$$

it will be possible to eject photoelectron, while if $h\nu < e\phi$, it would be impossible. In the former case, the excess energy of quantum appears as kinetic energy of the electron, so that

$$h\nu = \frac{1}{2}mv^2 + e\phi \qquad (1)$$

which is the famous photoelectrons equation formulated by Einstein in 1905.

The energy of emitted photoelectrons can be measured by simple retarding potential techniques as is done in this experiment. Retarding potential at which the photo current stop, we call it stopping potential V_s and is used to measure kinetic energy of electrons E_e, we have,

$$E_e = \frac{1}{2}mv^2 = eV_s \qquad \text{or} \qquad V_s = \frac{h}{e}\nu - \phi$$

So when we plot a graph V_s as a function of ν, the slope of the straight line yields $\frac{h}{e}$ and the intercept of extrapolated point $\nu=0$ can give work function ϕ.

PROCEDURE

1. Insert the red color filter (635 nm), set light intensity switch (12) at strong light, voltage direction switch (14) at '-', display mode switch (10) at current display.
2. Adjust to de-accelerating voltage to 0 V and set current range selector (4) at X 0.001. Increase the de-accelerating to decrease the photo current to zero. Take down the de-accelerating voltage (V_s) corresponding to zero current of 635 nm wavelength. Get the Vs of other wave lengths, in the same way.

OBSERVATIONS

S. No	Filters	ν (sec^{-1} x 10^{14})	Stopping Voltage (V)
1	Red (635 nm)		
2	Yellow I (585 nm)		
3	Yellow II (540 nm)		
4	Green (500 nm)		
5	Blue (460 nm)		

CALCULATIONS

Planck's Constant: $h = e\dfrac{\Delta V_s}{\Delta \nu}$

Where e is the charge of electron

By putting the value of ΔV_s & $\Delta\nu$ from graph

$$h = 1.602\times10^{-19}\times\frac{0.825}{2.00\times10^{14}}$$

$$= 1.602 \times 10^{-19} \times 0.413 \times 10^{-14}$$

$$= 6.61 \times 10^{-34} \text{ Joules sec.}$$

From Graph 1 intercept at $\nu = 0$ the value of

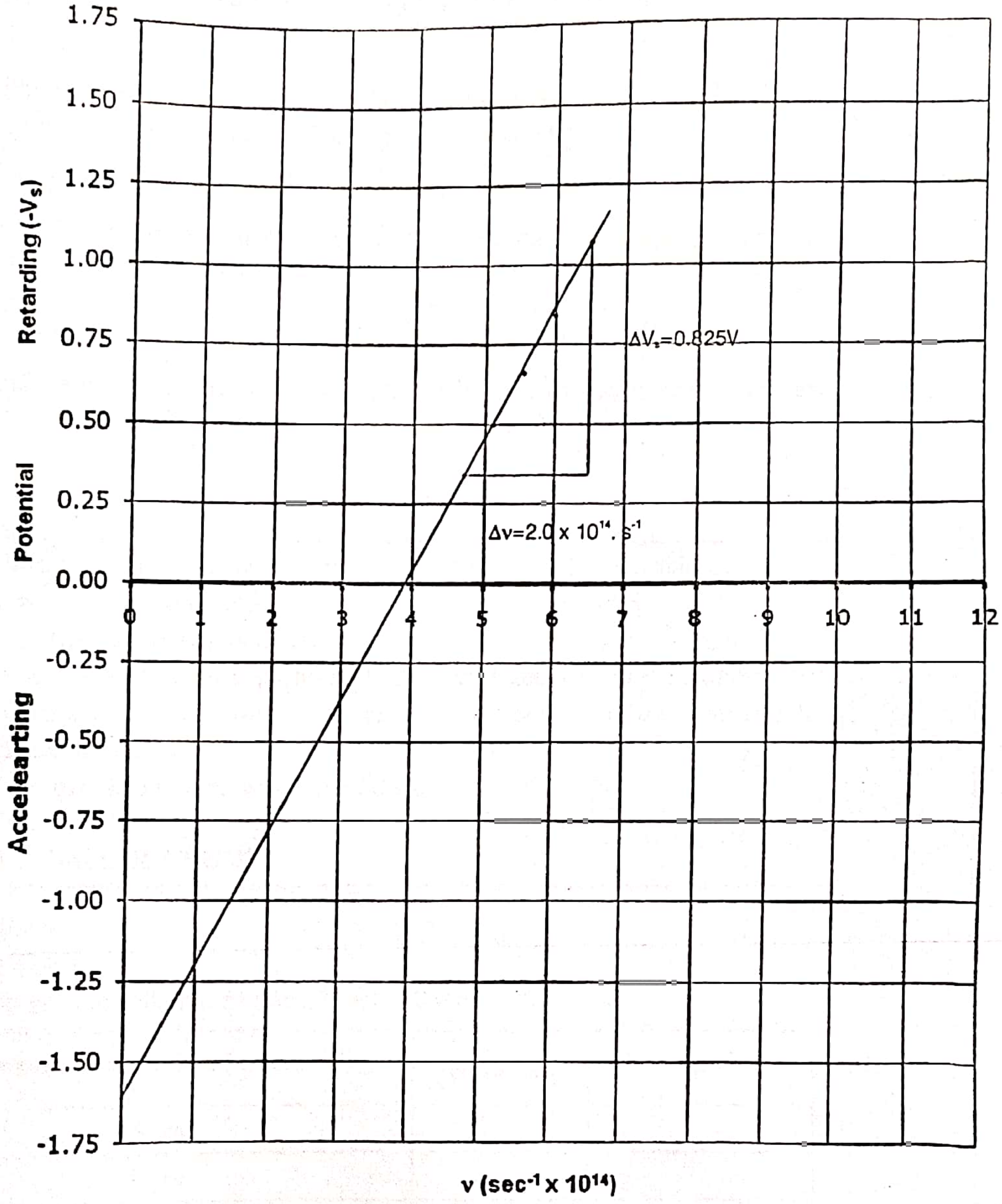
$\phi = 1.625$ V

Compared with accepted value of $h = 6.62 \times 10^{-34}$ Joules. sec. the results are well within accepted error range.

PRECAUTIONS

1. This instrument should be operated in a dry, cool indoor space.
2. Phototube particularly should not be exposed to direct light, particularly at the time of installation of phototube; the room should be only dimly lit.
3. The instrument should be kept in dust proof and moisture proof environment, if there is dust on the phototube, color filter, lens etc. clean it by using absorbent cotton with a few drops of alcohol.
4. The color filter should be stored in dry and dust proof environment.
5. After finishing the experiment remember to switch off power and cover the drawtube (4) with the lens cover (15) provided. Phototube is light sensitive device and its sensitivity decreases with exposure to light, due to ageing.

PLANCK'S CONSTANT MEASUREING APPARATUS



(1) The connection would be same as before except a positive voltage would be applied to the anode with respect to cathode.

(2) Place a filter in front of the photoelectric cell.

(3) Keeping the voltage constant and position of photocell fixed, increase the distance of lamp from photo-cell in small steps. In each case note the position of the lamp r on the optical bench and the current I.

(4) The experiment may be repeated with other filters.

OBSERVATIONS & CALCULATIONS:

Filter red λ 6400 nm

Anode Voltage: 0.25 V

Reading of Photo-electric cell on the optical bench = 0 cm

S. No.	Distance between lamp and photo-cell (r)	$\frac{1}{r^2} \times 10^3\ cm^{-2}$	I μA
1.	18 cm		
2.	20 cm		
3.	22 cm		
4.	24 cm		
5.	26 cm		
6.	28 cm		
7.	30 cm		

Graph between $\frac{1}{r^2}$ taken along the X-axis and I along the Y-axis is a straight line proving the inverse square law of radiation.

PRECAUTIONS

1. This instrument should be operated in a dry, cool indoor space.
2. Phototube particularly should not be exposed to direct light, particularly at the time of installation of phototube; the room should be only dimly lit.
3. The instrument should be kept in dust proof and moisture proof environment, if there is dust on the phototube, color filter, lens etc. clean it by using absorbent cotton with a few drops of alcohol.
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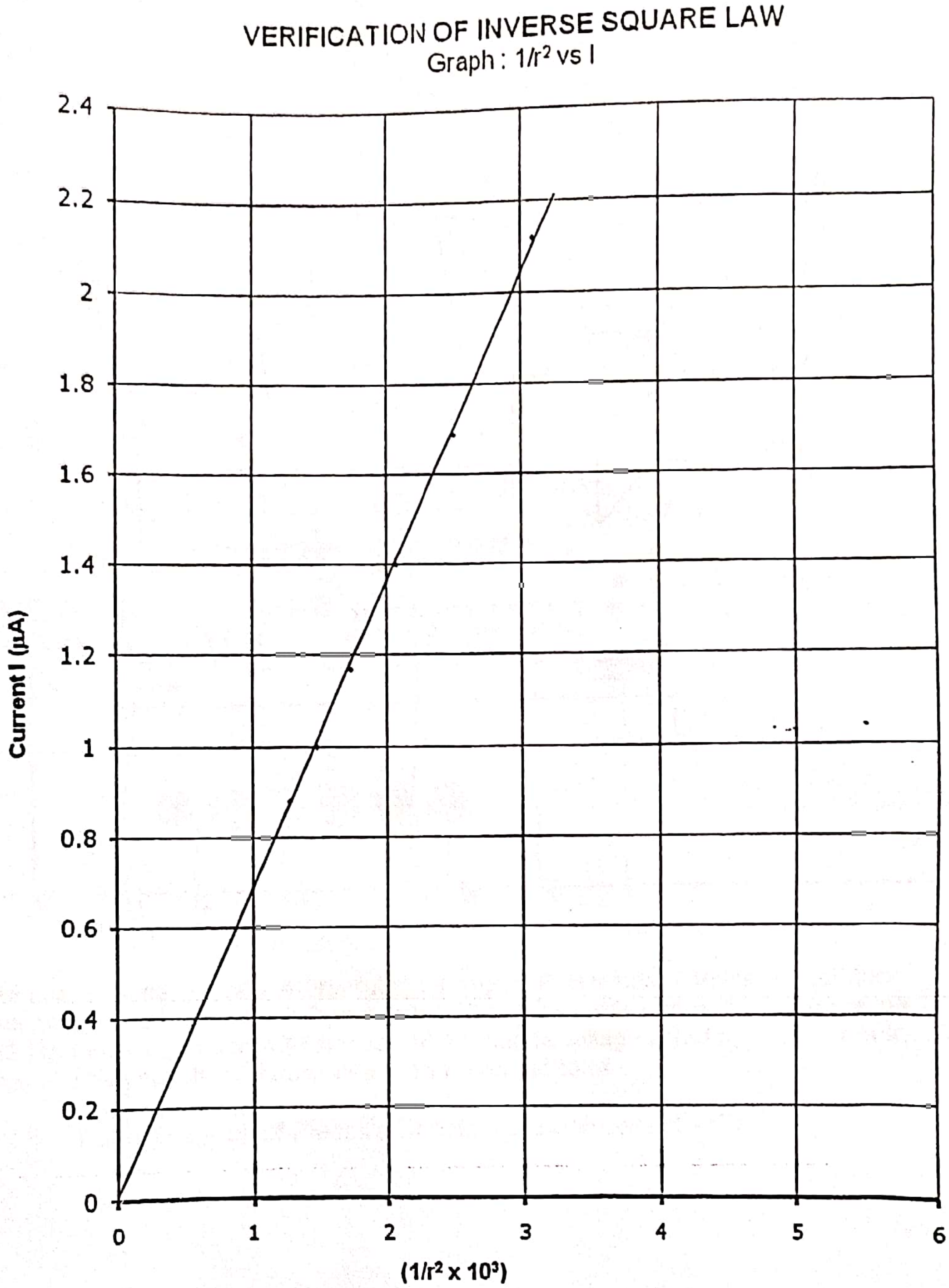

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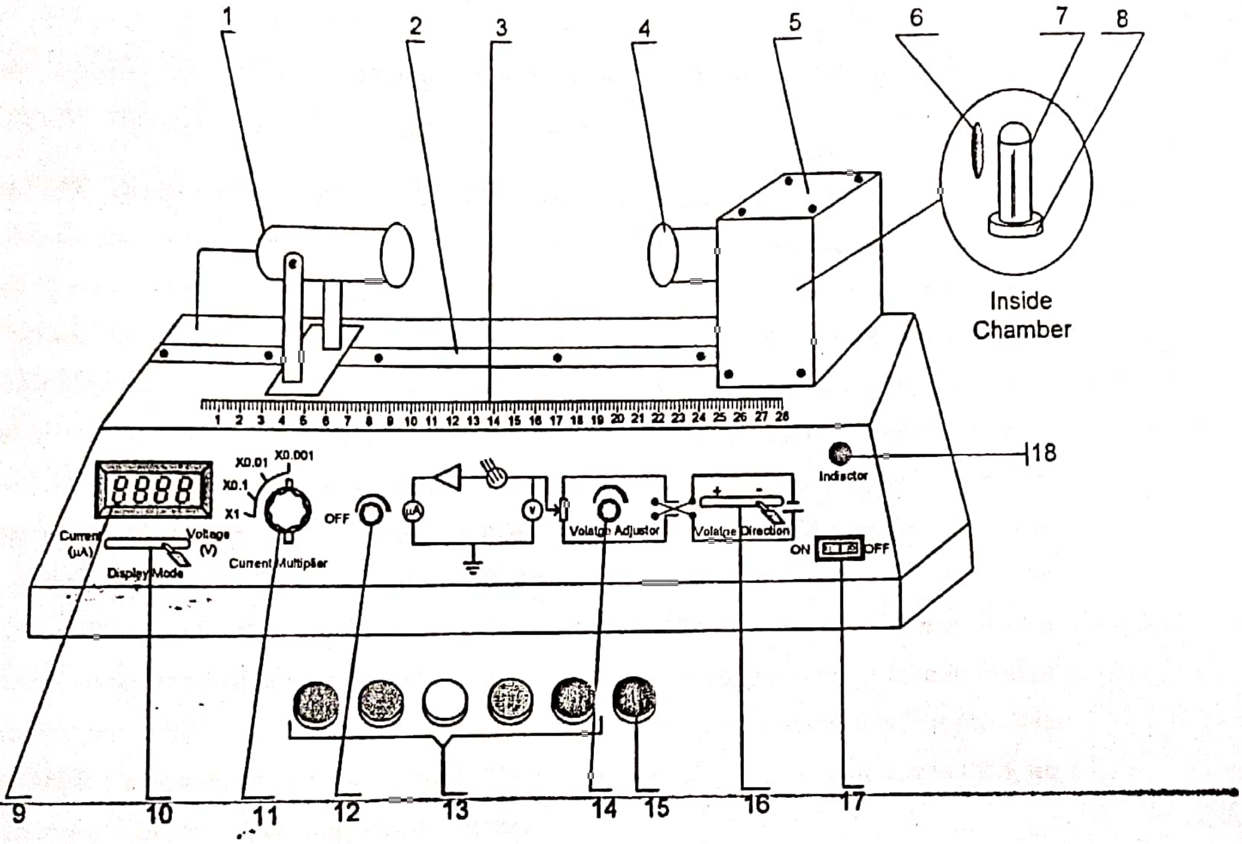


1-Light source, 2-Guide, 3-Scale, 4-Drawtube, 5-Cover, 6-Focus lens, 7-Vacuum Phototube, 8-Base for holding the Phototube, 9-Digital Meter, 10-Display mode switch, 11-Current range selctor,12-Light intensity switch, 13-Filter set, 14-Accelerate voltage adjustor, 15-Lens cover, 16-Voltage direction switch, 17-Power switch, 18-Power indicator.

Panel Diagram of Planck's Constant Experiment, PC-101

EXPERIMENT NO. -3

AIM: To determine the energy band gap (E_g) of a semiconductor (Germanium (Ge) crystal) by Four – Probe method.

APPARATUS: Four-Probe arrangement, P-type Ge crystal (10×8×0.5 mm, (l×w×t)), a current source, voltmeter, an oven to heat the sample, thermometer.

THEORY: The four-probe method is the most common method to measure the resistivity of the semiconductor material. The four-probe arrangement consists of four collinear equally spaced metal tips with finite radius. The probes have springs attached on the other end to make good contact with the semiconductor sample. Since, no soldering is required for the contacts, any error in resistivity measurements due to contamination of the surface, rectification and change of properties is avoided. Four sharp probes are placed on a semiconductor sample. A high impedance current source is used to supply current through the outer probes (1,4) and a voltmeter measures the voltage developed across the inner two probes (2, 3) to determine the sample resistivity and hence, the energy band gap of the semiconductor sample. Figure 1 shows the schematic diagram of four-probe arrangement. The whole arrangement is mounted on a suitable stand and leads are provided for current and voltage measurements. An oven is used to change the temperature of the sample. At the top of the four probe arrangement stand, a hole is provided for inserting a thermometer to measure the temperature of the sample. The sample is in the form of thin wafer with non-conducting bottom surface.

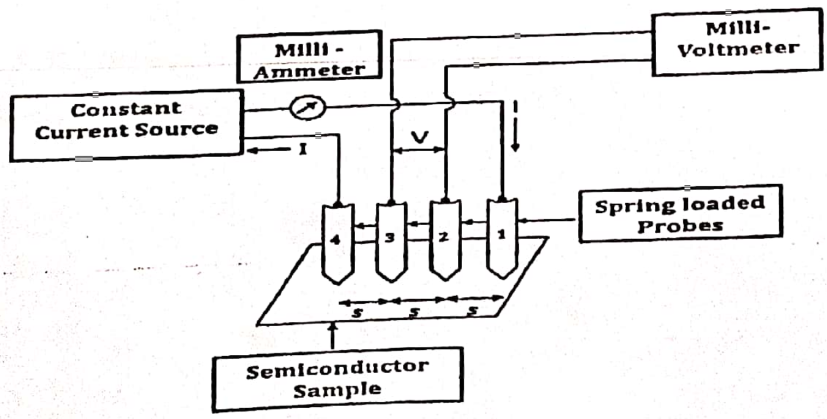


Figure 1: Schematic diagram of Four-Probe arrangement

FORMULA USED:

Resistivity (ρ) is given by

$$\rho = \frac{\rho_o}{F(w/s)}$$

where

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

ρ_o : Resistivity of the sample

ρ : Resistivity of the sample with correction applied

$F(w/s)$: Correction divisor and is a function of the ratio of the thickness of the sample (w) to the probe-spacing (s)

V: Voltage across the two inner probes

I: Current through the two outer probes

s: Probe Spacing

w: Thickness of the sample

The variation of resistivity with temperature is given by the formula

$$\rho = \rho_o e^{E_g/2kT}$$

where E_g is the energy band gap and k is the Boltzman's constant.

Taking log on both side of above equation

$$ln\, \rho = \ln \rho_0 + \frac{E_g}{2kT}$$

or

$$log_{10} \rho = log_{10} \rho_0 + \frac{E_g}{2 \times 2.303 \times kT}$$

Thus, a graph between $\frac{1}{T}$ and $log_{10} \rho$ would be a straight line. From the slope of this line, the energy band gap, E_g of the semiconductor can be determined as follows

$$\text{Slope} = \frac{E_g}{2 \times 2.303 \times k}$$

$$\frac{log_{10} \rho}{1/T} = \frac{E_g}{2 \times 2.303 \times k}$$

$$E_g = 2 \times 2.303 \times k \times \frac{log_{10} \rho}{1/T}$$

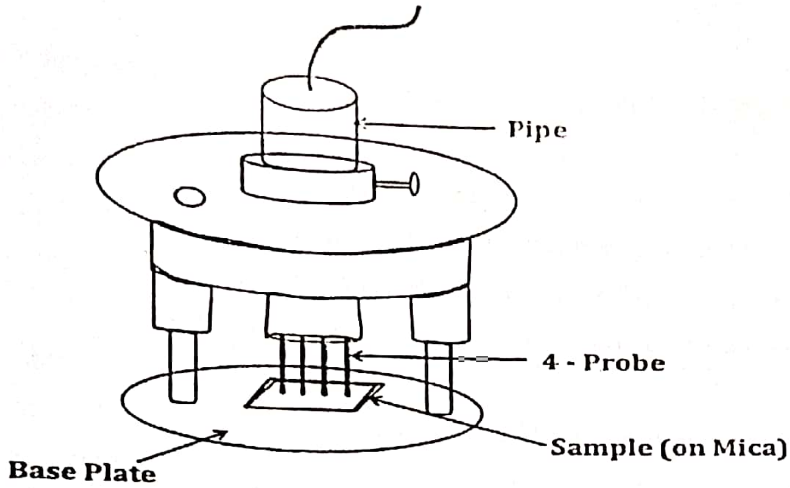


Figure 2: Four-probe arrangement for mounting the sample.

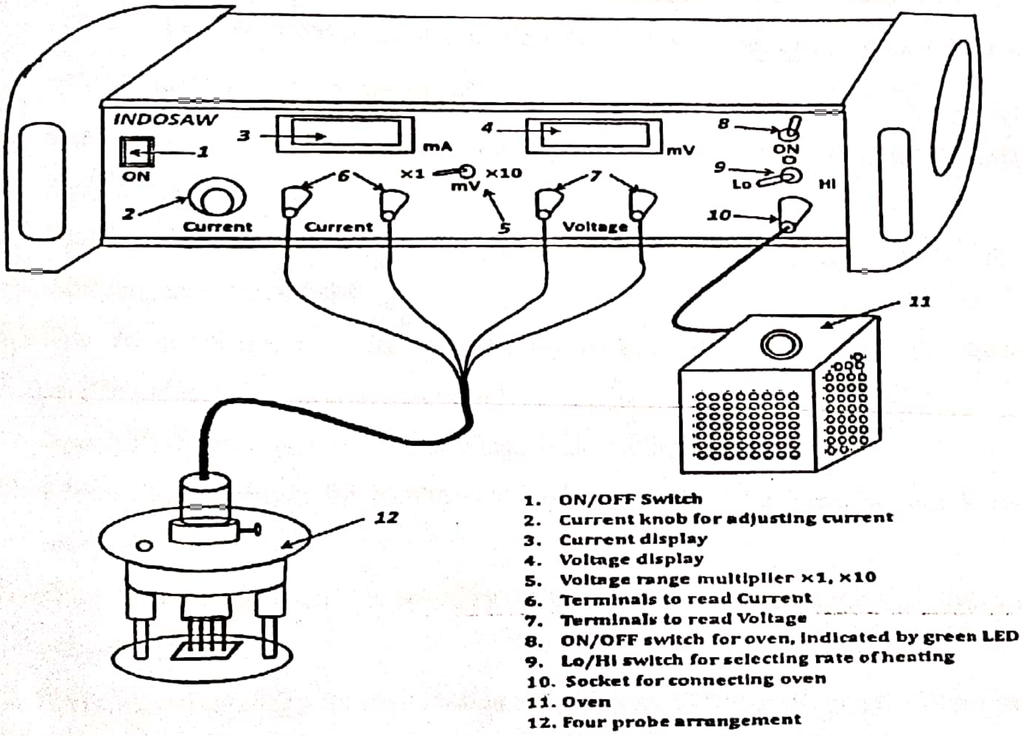


Figure 3: Various parts of four-probe apparatus.

PROCEDURE:

1. If there is any need of replacing or mounting the P-type Ge sample then proceed as per the following procedure:
   (i) Unscrew the pipe of the four probe arrangement and place the sample on the base plate such that the 4-point probe lie in the middle of the sample as shown in figure 2.
   (ii) Gently apply some pressure and tighten the pipe in this position so that all the 4-probes are in good contact with the sample. (Warning : Application of excess pressure may break the sample)
2. Connect the RED and BLACK plug leads of the 4-probe arrangement to 4 mm sockets (7) marked as "Voltage".
3. Connect the YELLOW plug leads to 4 mm sockets (6) marked as "Current".
4. Switch "ON" the apparatus using switch (1). Note that voltage should be positive. If it is not so then interchange the current leads.
5. Set the current to a desired value (say 8 mA) using current adjusting knob (2) as shown in figure 3. Also, select the range of multiple as ×1 or ×10 of the voltage display. (It is always better to start with lower range i.e. ×1)
6. Using the switch (9) as shown in figure 3, select the rate of heating of oven as low (Lo) or high (Hi) as per requirement.
7. Switch "ON" the oven using switch (8) as shown in figure 3. Green LED will glow, indicating that oven is "ON".
8. Note down voltage, V in the voltmeter (4) for different temperatures while heating the sample and record the readings in table 1.
9. Switch off the oven and record the voltage while cooling the sample.
10. Repeat the experiment for another value of current. Find the mean voltage V for each temperature.
11. From the values of w and s supplied by the manufacturer, find the correction divisor $F(w/s)$ using the table A.
12. Calculate resistivity (ρ) for each reading and plot a graph between $log_{10}\rho$ along y-axis and $\frac{1}{T}$ along x-axis.

OBSERVATIONS :

1. Least count of thermometer = --------- °C
2. Distance between probes (s) = 0.24 cm.
3. Thickness of the sample (w) = 0.05 cm
4. $\frac{w}{s}$ = ----------
5. Correction divisor, $F(w/s)$ = ----------
6. $\frac{2\pi s}{F(w/s)} = D$ = -------- cm

Observation Tables:

SET- I: Table 1 Current I = -------- mA

S. No.	Temperature T (°C)	Temperature T (K)	Voltage V (mV)		Mean V (mV)
			While Heating	While cooling	

Set- II: Make a similar table for Current I = -------- mA

CALCULATIONS:

1. Find the resistivity, corresponding to different temperatures using expression

$$\rho = \frac{\rho_o}{F(w/s)}$$

where $F(w/s)$ can be found from the table A.

(NOTE: For different values of V, there will be different values of ρ_o)

2. Make an observation table as shown below.

Table 2:

S. No.	Temp. T (K)	Resistivity $\rho = \frac{V}{I} \times D$ (Ω m)	$\frac{1}{T}$ (K^{-1})	$log_{10}\rho$

3. Plot a graph $log_{10}\rho$ versus T^{-1} and find the slope of the curve as shown in the typical graph figure 4.
4. Calculation of energy band gap (E_g) is as follows

$$Slope = \frac{E_g}{2 \times 2.303 \times k}$$

$$E_g = 2 \times 2.303 \times k \times Slope \text{ eV}$$
$$E_g = 0.396 \times 10^{-3} \times \text{Slope eV}$$

Now, $k = 1.38 \times 10^{-23}$ J/K $= 8.6 \times 10^{-5}$ eV/K

The percentage error in the experimental result is calculated by the following formula

$$Percentage\ Error = \frac{Standard\ value - Calculated\ value}{Standard\ value} \times 100$$

GRAPH :

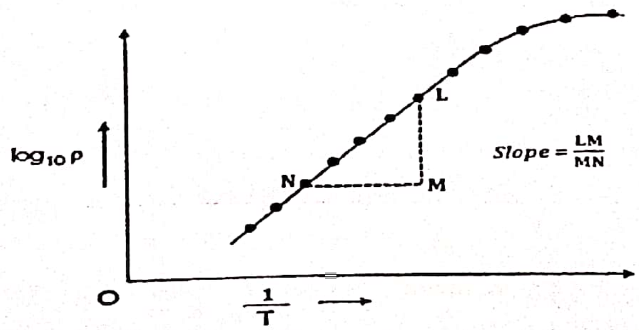


Figure 4: Plot between $log_{10}\rho$ and T^{-1}.

RESULT:

The band gap (E_g) for the given semiconductor at room temperature = ---------- eV.

Standard Value = ---------- eV

% Error = ----------

PRECAUTIONS AND SOURCES OF ERROR:

1. Current should be constant while performing the experiment.
2. Reading should be taken not only while heating the sample, but also, while cooling it. Better results are expected while cooling since more stable conditions prevails.
3. The top of the sample should be cleaned very carefully with the finest quality sand paper to remove any coating formed on it.
4. The pressure on the probes should be just appropriate to make a contact. As too much pressure can break the crystal.
5. The tip of the thermometer should be well inside the hole and temperature should be read carefully.
6. The surface on which the probes rest should be flat with no surface leakage.
7. The four probes should lie in a straight line.

Table A: Values of $F(w/s)$ for different combination of w/s for non-conducting bottom surface.

w/s	0.100	0.141	0.200	0.333	0.500	1.000	1.414	2.00	3.33	5.00	10.00
$F(w/s)$	13.863	9.704	6.931	4.159	2.780	1.504	1.223	1.094	1.0228	1.0070	1.0004

EXPERIMENT No. -5

AIM: To Determine Joule's Mechanical equivalent of heat by using an electric calorimeter.

APPARATUS: Electric Calorimeter, set of masses, ice for cooling water, 10 Amp current source, 110^{0}C thermometer, stop watch, distilled water.

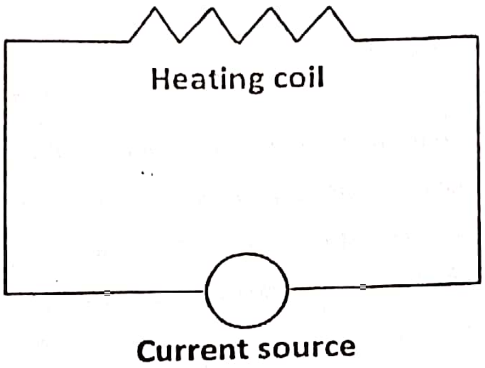


Fig.1: Circuit Diagram

THEORY:

A measured potential difference and current are maintained for a given time in an electric calorimeter. The heat evolved is measured by the usual calorimetric methods. The value of electrical equivalent of heat, joule's constant J, is determined from the ratio of the electric energy expended to the heat produced.

Potential difference is defined as work per unit charge,

$$V=W/Q \quad \text{------------------------------------} \ (1)$$

Where W is the work done in moving the charge Q through the circuit. The most frequently used units are V in Volts, W in Joules and Q in Coulombs.

If equation (1) is written in the form W=VQ, and the substitution Q = It and V=IR are made, the basic equation for electrical energy may be written in the form

$$W = VQ = VIt = I^2Rt \quad \text{--------------------------------} \ (2)$$

This equation indicates that 1 joule of work must be done in maintaining current of 1 amp in a resistor of 1 ohm resistance for 1 second.

In a circuit containing only resistance, a direct proportionality, between the expenditure of electric energy W and the heat H developed. This fundamental law is represented by the conservation of energy

$$W = JH \qquad \text{------------------------------------ (3)}$$

Where, J is the proportionality factor called the mechanical (or the electrical) equivalent of heat.

In equation (3), J has the value of approximately 4.18 joules/cal.

A useful form of the equation for the heat developed in a resistor is obtained by combining equation (2) and (3)

$$H = \frac{W}{J} = \frac{VIt}{4.18} = \frac{I^2Rt}{4.18}\text{ Calories} \qquad \text{------------------------------ (4)}$$

The variation of the heating effect of an electric current with various factors as represented by the equation $H = I^2Rt/J$ is usually referred to as Joule's Law. From this equation it is evident that the heat developed in a resistor varies directly with (i) the current I (when R and t are kept constant), (ii) the resistance R (when I and t are constant) and (iii) then time t (when I and R are constant)

PROCEDURE:-

Part-I:- Variation of heating effect with time

1. Connect the apparatus as in figure-1.
2. Arrange the apparatus so that the observer can conveniently watch the ammeter on the panel of the current source.
3. Never switch ON the current source unless the heating coil is immersed in water, as otherwise the resistance element might be burned out.
4. One can make a short test run, using tap water in the calorimeter and a current of about 2 Amp Practice the technique of carefully stirring the water and nothing rise of temperature. This is optional.
5. (a) Empty the calorimeter and refill it with 250 gm of distilled water (to which a little ice has been added to reduce the temperature to about 10^0C).

   (b) Stir the water thoroughly until the temperature approached the equilibrium value.

   (c) At an accurately noted time, switch ON the current source, quickly set current at the desired value (2 Amp).

   (d) Continue stirring the water and record the temperature every minute until about ten observations have been made. Record the current and the voltage.

Part-II:- Heating effect as a function of current

1. Take observations of temperature rise of same mass of water as in Step-5 of part-I, beginning with cold water each time. Note the temperature rise in 5 min. and record the final temperature after water had risen to its highest temperature.
2. Repeat observations for a total of five different currents. Data recorded in Step-5 of Part-I can be used for one observation.
3. Do not heat the water above 40°C, as otherwise the effects as much below room temperature as the final temperature is above that of the room. If necessary the water should be cooled with ice to produce this condition. Record each voltage.

OBSERVATIONS:

Mass of the calorimeter $M_c = 85.3$ gm

Mass of the calorimeter + water = 335.5 gm

Mass of water $M_w = 250$ gm

Resistance of the coil R = 3.0 ohm

Specific heat of water $S_w = 1$ Cal/gm/^{0}C

Specific heat of cupper $S_c = 0.093$ Cal/gm/^{0}C

TABLE-I:

S. No.	Time interval (sec)	Initial Temp. $T_1(^0C)$	Final Temp. $T_2(^0C)$	Temp. Difference $\Delta T(^0C)$

TABLE-II:

Time interval = 5 minutes

S. No.	Current I (A)	I^2 (A^2)	Initial Temp. T_1 (°C)	Final Temp. T_2 (°C)	Temp. Difference ΔT (°C)
1					
2					
3					
4					
5					

CALCULATION:

1. Use the data of step-5 of Part-I to plot a curve showing the variation of the heating effect with time, all other factors being constant. In this case the rise in temperature is direct measure of the heat developed. Discuss the significance of the shape and intercepts of curve.
2. Use the straight line curve of ΔT against I^2 which was plotted in Part-II as the basis for the computation of the average value of J from the observed data.
3. The working equation may be written as

$$J = \frac{W}{H} = \frac{I^2 Rt}{(M_W S_W + M_C S_C)(T_2 - T_1)} \quad \text{---(5)}$$

Where the symbols have the usual significance of those used in calorimeter. The reciprocal of the slope of the curve gives $I^2/(T_2 - T_1)$.

Use proper value for the water equivalent of the heating coil, stirrer and electrodes. Determine the percentage difference between the average values of J obtain by the use of the curve and curve and eq. (5) and the standard value of 4.18 joules/cal.

RESULT:

The value of mechanical equivalent of heat (J) is found to be .... Joule/cal.

Standard value of J = 4.18 Joule/Cal

$$\text{Percentage error} = \frac{\text{Standard value} - \text{Experimental value}}{\text{Standard value}} \times 100\ \%$$

PRECAUTIONS AND SOURCES OF ERROR:

1. Stirring should be uniform and slow.
2. Check that current does not vary during the observation.
3. While taking masses of the calorimeter and water care should be taken to ensure the initial balancing of the balance.
4. The coil should not touch the calorimeter.
5. Temperature should be measured carefully.

EXPERIMENT NO. – 6

AIM: To draw the I-V characteristics for light emitting diode (LED) and determine the value of Planck's constant.

APPARATUS: Power Supply, Patch cords and Training board.

THEORY:

The energy of a photon is given by the equation:

$$E = h\upsilon \qquad \text{........ (1)}$$

Where E is the energy of photon υ is its frequency, and h is a constant.

In the photoelectric effect, an electron is emitted from a metal surface when a light is incident on the metal surface. The emission of electrons is deeply connected to the frequency of the light incident upon the surface. If the energy of the incident photon is greater than the work function of a given material then the electron emitted possesses energy E_k, which is given by:

$$E_k = h\upsilon - W \qquad \text{-------- (2)}$$

Where, E_k is the kinetic energy of the emitted electron, W represents the work function of the material.

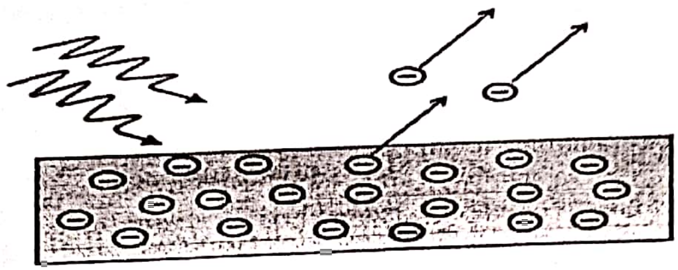


Figure 1: Emission of Photoelectrons

Laws of Photoelectric emission:

1. For a given metal and frequency of incident radiation, the rate at which photoelectrons are ejected is directly proportional to the intensity of the incident light.
2. For a given metal, there exists a certain minimum frequency of incident radiation below which no photoelectrons can be emitted. This is called the threshold frequency.
3. Above the threshold frequency, the maximum kinetic energy of the emitted photo electron is independent of the incident light but depends on the frequency of the incident light.

4. The time lag between the incidence of radiation and the emission of a photo electron is very small less than 10^{-9} seconds.

In this experiment, the current-voltage relationship of a set of light emitting diodes (LEDs) are used to measure Planck's constant. An LED is a semiconductor device that emits electromagnetic radiation at optical and infrared frequencies. The device is a p-n junction diode made from p-type and n-type semiconductors, usually GaAs, GaP or SiC. They emit light only when an external applied voltage is used to forward bias the diode above a minimum threshold value. The gain in electrical potential energy delivered by this voltage is sufficient to force electrons to flow out of the n-type material, across the junction barrier, and into the p-type region. These excited electrons recombine with holes in that region and photons are emitted having energy approximately equal to the band gap energy.

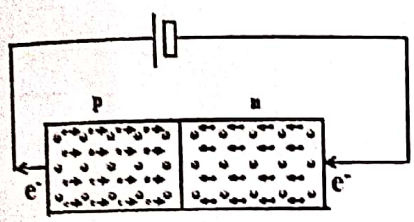


Fig. 2 p-n junction of LED

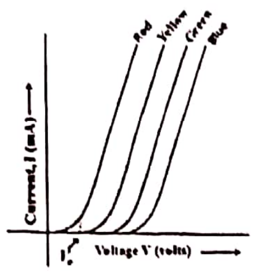


Fig. 3 I-V characteristics for different LED colour

If V_o is the minimum voltage required for the emission of light, then The light energy emitted during forward biasing is given as ,

$$E = \frac{hc}{\lambda} \qquad \text{--------- (3)}$$

where

c -velocity of light.
h -Planck's constant.
λ-wavelength of light used.

If V_o is the forward voltage applied across the LED when it begins to emit light (the knee voltage), the energy given to electrons crossing the junction is,

$$E = eV_o \qquad \text{------------- (4)}$$

Equating (3) and (4), we get

$$eV_o = \frac{hc}{\lambda} \qquad \text{------------------- (5)}$$

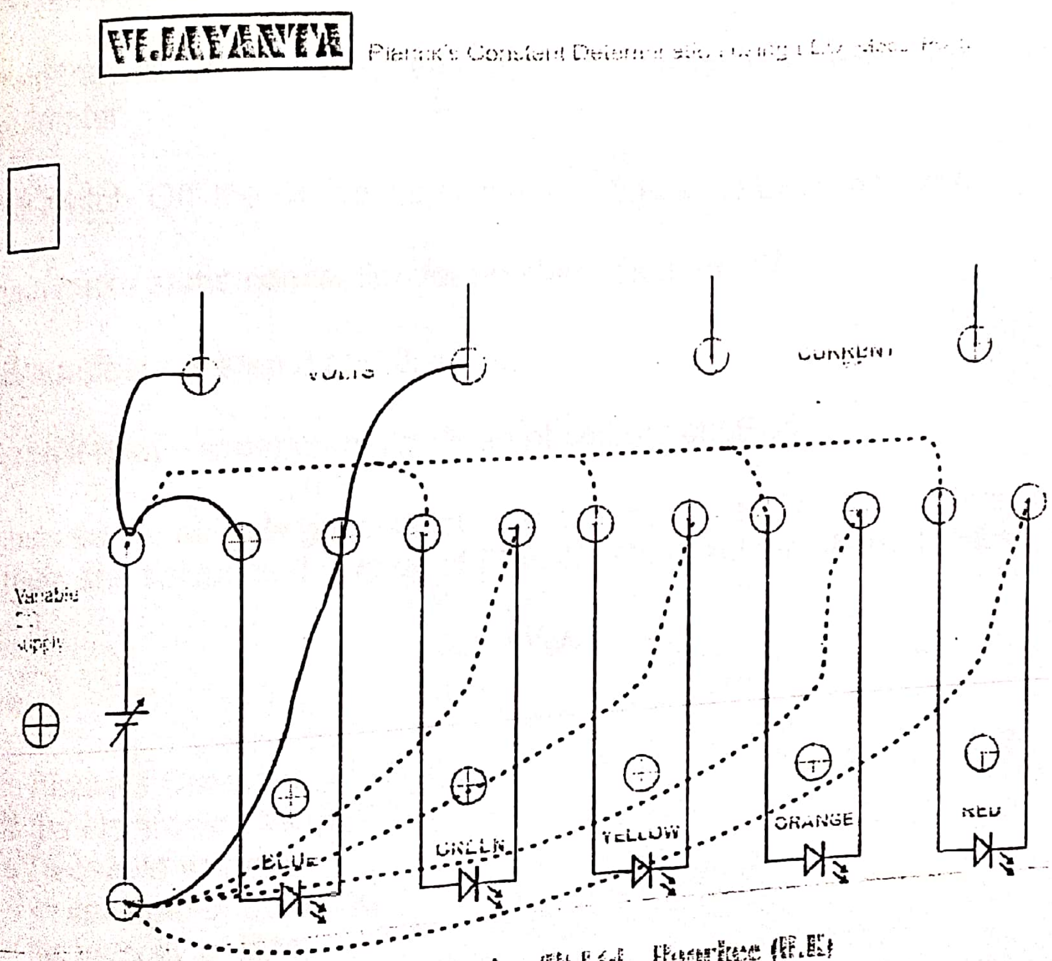
It is recommended that all the Experiments should be done in Dark Room.

Objective:

Determination of Planck's constant using Light Emitting Diode (LED).

Procedure:

1. Take the Planck's Constant Determination Setup. Make the connections as shown in figure below.



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2. Connect + ve terminal of DC power supply to + ve terminal of DC voltmeter and +ve terminal of any one LED.

3. Now connect - ve terminal of DC power supply to - ve terminal of DC voltmeter and - ve terminal of LED.

4. Set the range of DC voltmeter at 20 V.
5. Connect the mains cord and switch 'On' the power supply.

6. Now vary the DC voltage slowly by variable resistance pot and see the LED connected in circuit.

7. When the LED is just start to emit light note the value of applied voltage by DC voltmeter.

8. Now switch 'Off' the DC power supply and break the LED connection.

9. Again make same connection for another colour of LED.

10. Now repeat the step 8 and 9.

11. Repeat above experiment for different colours of LEDs.

12. Now use the formula given below and put the value of all parameters used in formula and calculate the value of Planck's Constant for different LEDs.

$$h = eV_0\lambda/c$$

Where,

h is Planck's Constant,
e is the electronic charge,
V_0 is Threshold voltage,
λ is wavelength of LED and
C is the velocity of light

Take mean value of h calculated for different LEDs.

It is recommended that all the experiments should be done in Dark Room

Electronic Charge e = 1.601 x 10-19 coulomb

Velocity of Light c = 3 x108 m/s

Formula used : h = eV0λ/c

TABLE 1

LED	Threshold Voltage Vo (in V)	Wavelength (mm)	H (in Js)
Blue		470	
Green		525	
Yellow		580	
Orange		630	
Red		700	
		Common	

Standard Value of h = 6.63×10^{-34} J s

Calculated Value of h =

Percentage error = Calculated value – Standard value / Standard value × 100

Percentage error = – 6.63 /6.63 x 100

Error % = %

2.Take the V-I Characteristics Determination Setup. Make the connections as shown in figure below.

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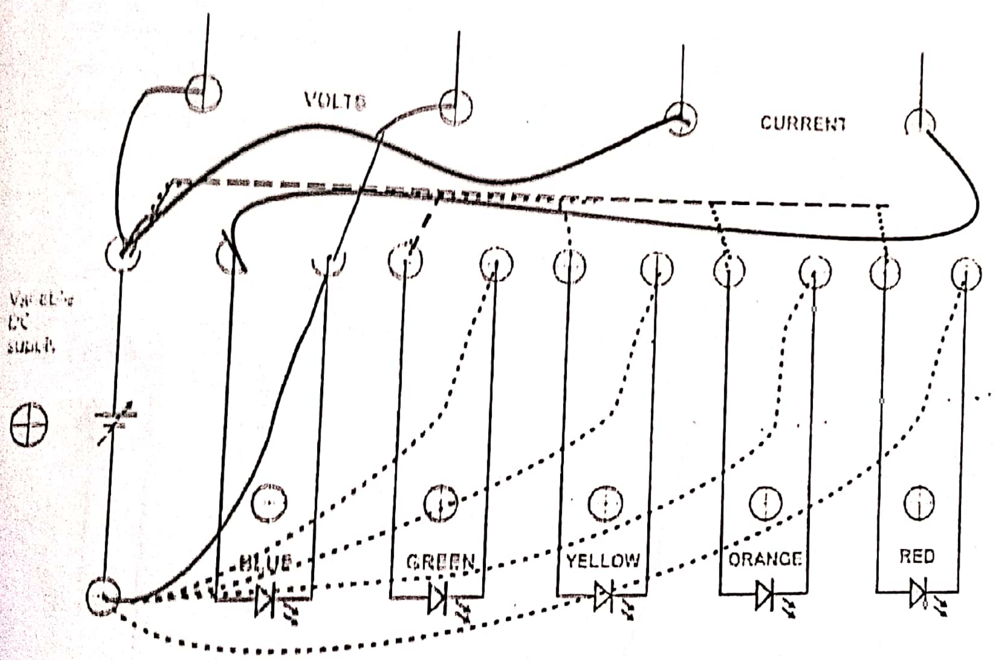


TABLE-2

LED V-I Characteristics

LED :- BLUE

SL NO	Threshold Voltage V_o (in V)	CURRENT IN I_o(in I)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		

Department of Applied Physics

EXPERIMENT NO.- 8

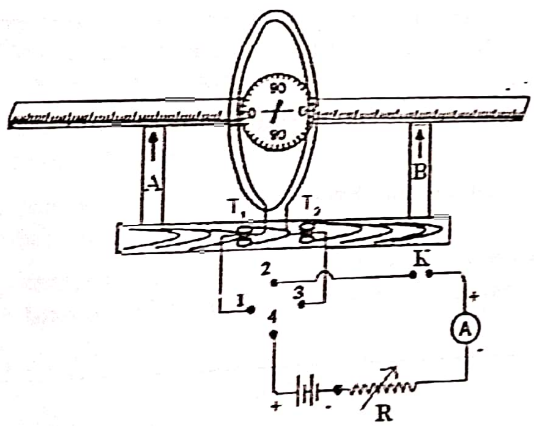
Objective: Determination of the magnetic field with the variation of distance along the axis of current carrying coil

Items Required

1. Tangent Galvanometer
2. Current carrying coil measurement unit
3. Magnetometer
4. Patch cords
5. Mains cord

Procedure

1. Place the Tangent Galvanometer on the table such that the arms of magnetometer lie roughly in east and west direction.
2. Place the magnetometer at the centre of the coil in such a manner that magnetic needle lies at the center of the vertical coil in same direction.
3. Place the eye a little above the coil and rotate the Tangent Galvanometer in the horizontal plane till the coil, the needle and its image in the mirror of magnetometer, all lie in the same vertical plane.
4. In this manner the coil will be set roughly in the magnetic meridian.
5. Now rotate the Magnetometer so that the pointer read the position of 0-0.



6. Now take the current carrying coil measurement unit and place it near the instrument.
7. Connect C and 5 terminals of coil to the 6 and 7 terminal of reversing key.
8. Connect DC power supply between the points 2 and 3 with same polarity.

9. Connect DC Ammeter between the points 10 and 11 with same polarity.
10. Now short the terminals 4 and 5, 8 and 9, 12 and 13, 1 and 14 respectively.
11. Connect the mains cord and switch on the power supply.
12. Select reversing key in one direction and switch on the DC power supply.
13. Observe the deflection of the needle of magnetometer.
14. Now slide the magnetometer along the axis of the coil and find the position where the maximum deflection is obtained. In this position the center of the needle co-insides the center of the vertical coil.
15. Now change the direction of current by reversing key and note down the deflection again. If the both deflections are nearly equal that means the coil is in magnetic meridian.
16. If the mean deflection of both cases is not nearly equal, then slightly turns tangent galvanometer till the deflection for the direct and reverse current become nearly equal.
17. Note the position of the deflection θ1 and θ2 in observation table by both ends of pointer keeping the current constant. Now reverse the current and again note the deflection of pointer for both ends and say it θ3 and θ4.
18. Above readings are for origin (0-0) position.
19. Now note the value of the current shown by ammeter.
20. Shift the magnetometer by 1 cm in Left hand side of the coil and note down the deflection θ1 and θ2 in observation table by both ends of pointer keeping the current constant.
21. Now reverse the current and again note the deflection of pointer for both ends and say it θ3 and θ4.
22. Take the number of observations by shifting the magnetometer by 1 cm at a time for both forward and reverse current.
23. Similarly repeat the steps 20, 21 and 22 by shifting the magnetometer in the Right hand side of the coil keeping the constant current.

Nvis 6034 Current Carrying Coil Setup

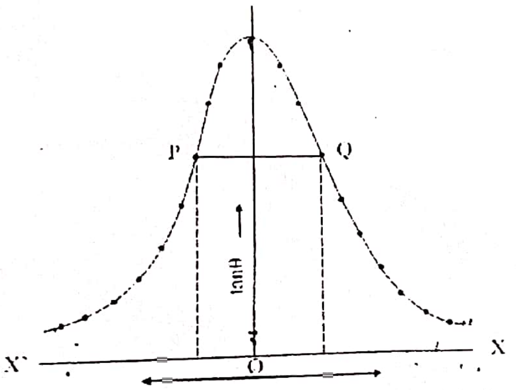
Observations Table

No. of turns (n) = ...

Current I = ... A

S. No.	Distance x	Left Side: Direct Current θ_1	θ_2	Reversed Current θ_3	θ_4	Mean θ	$\tan\theta$	Right Side: Direct Current θ_1	θ_2	Reversed Current θ_3	θ_4	Mean θ	$\tan\theta$
1.													
2.													
3.													
4.													
5.													
6.													
7.													
8.													

24. Now plot a graph taking positing (x) along the X- axis and $\tan\theta$ along the Y- axis, it will be similar to graph shown in figure, below



Note: For plotting the graph take left hand side reading as "-ve" and right hand side reading as "+ve".

25. **Find out the two inflexion point on the curve, the distance between these two point will be the radius of the coil.**

i.e. a = PQ

26 **Similarly perform all the steps for another no. of turns of coil.**

27. **Similarly perform all the steps for another no. of turns of coil**

Observation Table

No. of turns (n) =.......... ,

Current I =........... A,

Radius (a) =..............m

S.No.	Distance x	Magnetic Field $\frac{\mu_0}{4\pi} \times \frac{2\pi n I a^2}{(a^2 + x^2)^{3/2}}$
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		

Department of Applied Physics

EXPERIMENT NO.- 9

Objective: Determination of ballistic constant by steady deflection method

Items Required

1. Ballistic galvanometers
2. Ballistic galvanometer power supply
3. Lamp and scale arrangement

Procedure

1. First set the ballistic galvanometer for experimental procedure as described above.
2. Take ballistic galvanometer power supply and connect it with mains cord.
3. Connect terminal 1 and 2 to supply (polarity wise).
4. Keep S2 towards P1 (1E) and S3 towards T1.
5. Connect terminal 3 & 4 to ballistic galvanometer.
6. Set resistance Q and R to any value.
7. Turn on power switch.
8. Keep S1 toggle in ON mode (you will see the deflection).
9. Note and record the deflection of spot on scale. (First throw)
10. Select S1 towards OFF mode.
11. Wait till reflecting spot rests on Zero.
12. When reflecting spot stops oscillating than select S3 toward T2.
13. Select S1 towards 'On' mode (You will see the deflection in opposite direction).
14. Note and record the deflection of spot on scale. (First throw)
15. Keep S1 towards off mode.

Nvis 6107 Ballistic Galvanometer Setup

16. Now change the value of R and note the value.
17. Again select S1 towards on mode and see the deflection.
18. Note and record the deflection.
19. Select S3 toward T2 and note reverse deflection.
20. Repeat this procedure for different value of R and note down the corresponding deflection. Tabulate all the retrieved data in below table.

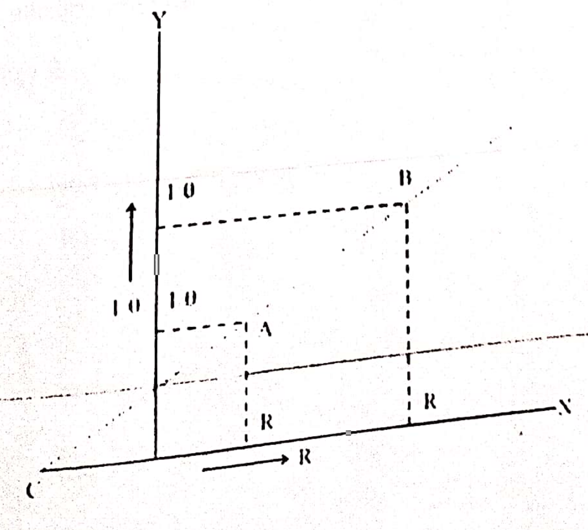
Observation Table

S.No.	Resistance			Deflection		Mean	$1/\theta$
	P	Q	R	Direct	Reversed		
1.			5000				
2.			6000				
3.			7000				
4.			8000				
5.			9000				
6.			10000				

For P = 1 E

2 Plot a graph between resistance R along X axis and reciprocal of deflection

($1/\theta$). The graph will be straight line as shown in Figure.



Nvis 6107 Ballistic Galvanometer Setup

21 Corresponding to two values of R2 and R1 find the value of (1/θ2 – 1/θ1) and calculate the value of η from equation

η1 = EP/ (P+Q) (R2 – R1) * (1/θ2 – 1/θ1)

Where, E = ... (Voltage of supply)

P + Q = ... ohm

R2 - R1 = ...Ohm

So, ballistic constant

$$k_1 = \frac{T}{2\pi} \eta_1$$

Where, T is time period of ballistic galvanometer

22. For Time period of galvanometer take reference of xvii

23. Again repeat this procedure for P = 2E and calculate ballistic constant

$$k_2 = \frac{T}{2\pi} \eta_2$$

Where

η2 = EP / (P+Q) (R2 – R1) * (1/θ1 – 1/θ2)

24. Find the average of k_1 and k2, which will give average value of ballistic constant

Hence ballistic constant

$k = k_1 + k_2 / 2$.

Nvis 6107 Ballistic Galvanometer Setup

PART-II

Object: To find the logarithmic decrement for a ballistic galvanometer

Procedure

1. Set the ballistic galvanometer for experiment.
2. Obtain sharp image of spot of light at the center of scale
3. Connect mains cord with ballistic galvanometer power supply.
4. Turn on power switch.
5. Connect terminal 9 and 10 with supply
6. Keep toggle S4 and S7 towards off condition
7. Select S4 towards on mode
8. Connect voltmeter across 7 and 8 terminals.
9. Use Vr1 to set voltage and note down the reading of voltmeter
10. Select any one capacitor C1 or C2 using S6 toggle
11. Let it chose for 1 MFD towards C2
12. Select S5 towards charging mode
13. After a bit time simultaneously chose S5 toward discharging and S7 towards on condition.
14. Observe the deflection on scale
15. Note the first and the eleventh throw of the spot light on the scale
16. Select S7 towards off mode.
17. Tabulate all the retrieved data in below table

S.no	Potential difference across capacitor (V)	Deflection of spot			Logarithmic decrement L=2.303/10 log10 q1/q2
		Initial	First throw q1	11th throw q2	

$L = 2.303/10 \log_{10} q_1/q_2$

Logarithmic decrement of ballistic galvanometer =..........

EXPERIMENT NO-10

AIM: To determine the ratio of charge to mass (e/m) for an electron.

APPARATUS: e/m tube, Power supply with voltmeter and ammeter, Variable measuring scale.

BRIEF INTRODUCTION OF THE SET UP :

The arrangement for measuring e/m, the charge to mass ratio of the electron is a simple set up and is based on Thomson's method. The e/m tube is bulb like tube and contains a filament, a cathode, a grid, a pair of deflection plates and an anode. The filament heats the cathode which emit electrons. The electrons are accelerated through a known potential applied between cathode and anode. The grid and the anode have a hole through which the electrons can pass. The tube is filled with helium at a very low pressure. Some of the electrons emitted by the cathode collide with the helium atoms which get excited and radiate visible light. The electron beam thus leaves a visible track and all manipulations on it can be seen. The tube is placed between a pair of fixed Helmholtz coils which produce a uniform and known magnetic field. The socket of the tube can be rotated so that the electron beam is at right angles to the magnetic field. The beam is deflected in a circular path of radius r depending on the accelerating potential V, the magnetic field B and the charge to mass ratio e/m. This circular path is visible and the diameter d can be measured and e/m obtained from the relation

$$e/m = 8V/B^2d^2$$

The deflecting plates are interesting for visual observation of how the electron beam gets deflected when a potential difference is applied between the deflecting plates.

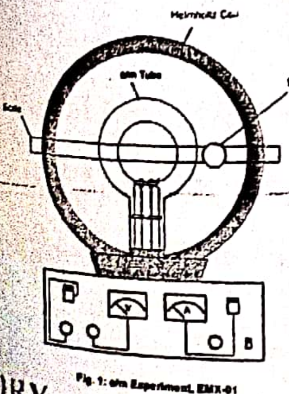


Fig. 1: e/m Experiment, EMX-01

THEORY: RELATION CONNECTING e/m TO ACCELERATING POTENTIAL V, ... OF THE CIRCULAR PATH

EXPERIMENT NO-10

AIM: To determine the ratio of charge to mass (e/m) for an electron.

APPARATUS: e/m tube, Power supply with voltmeter and ammeter, Variable measuring scale.

BRIEF INTRODUCTION OF THE SET UP :

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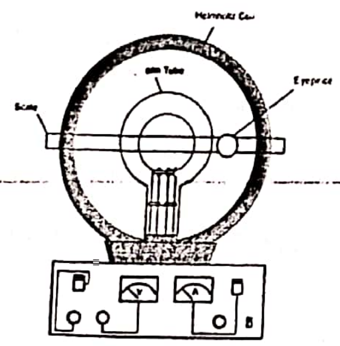


Fig. 1: e/m Experiment, EMX-01

THEORY : RELATION CONNECTING e/m TO ACCELERATING POTENTIAL V, MAGNETIC FIELD B AND RADIUS R OF THE CIRCULAR PATH

Scanned by CamScanner

When the electrons are accelerated through the potential V, they gain kinetic energy equal to their charge times the accelerating potential. Therefore, $eV = mv^2/2$. The final (non relativistic) velocity of the electrons is therefore

$$v = \left(\frac{2eV}{m}\right)^{1/2} \quad (1)$$

When these electrons pass through a region having magnetic field B, they are acted upon by Lorentz force, given by $e\vec{v}\times\vec{B}$. If the electrons are initially moving along the x-axis and magnetic field is along z-axis, the electrons describe a circular path in the xy- plane with the centripetal force balancing the Lorentz force,

$$evB = mv^2/r$$

$$\text{or} \quad v = eBr/m \quad (2)$$

Eliminating v between Eqs. (1) and (2), we get

$$e/m = 8V/B^2d^2 \quad (3)$$

Where d is the diameter of the circular path. This result assumes uniform magnetic field. This in the apparatus is produced by a pair of Helmholtz coils. If n is the number of turns in a coil and a is the radius, then the magnetic field B, midway between the coils is given by

$$B = 2\times\frac{\mu_0 In}{2\left(\frac{5}{4}\right)^{3/2}a} = 2\times\left(\frac{2\pi In}{\left(\frac{5}{4}\right)^{3/2}a}\times10^{-7}\right)tesla$$

When a current of I *amp* is flowing in the coils. μ_0 is permeability of free space and is given by $\mu_0 = 4\pi\times10^{-7}$ N/A^2. The field is uniform in the region where electrons are moving.

Substituting the value of B in Eq. (3), we get

$$\frac{e}{m} = \left(\frac{125a^2}{128\pi^2n^2}\times10^{14}\right)\frac{V}{I^2d^2} \quad (4)$$

The coils in this apparatus have 160 turns each and their radii is 0.14m. Using these values, we get

$$\frac{e}{m}=\left(7.576\times10^{6}\right)\times\frac{V(volt)}{I^2(amp^2)d^2(m^2)}\ \text{coul/kg} \quad (5)$$

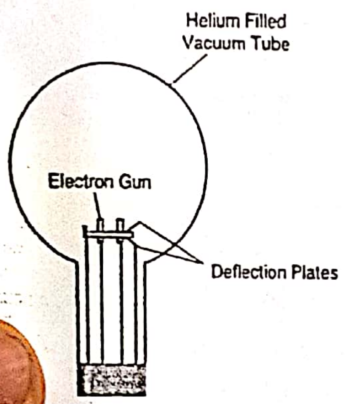


Fig 2: e/m Tube

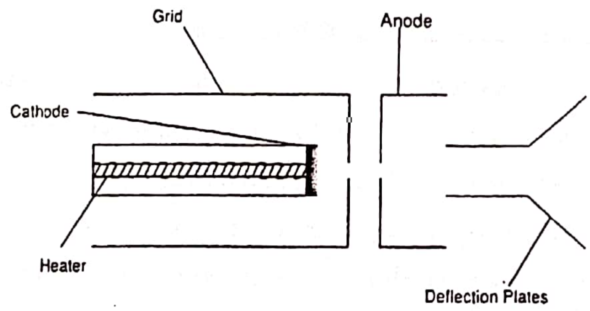
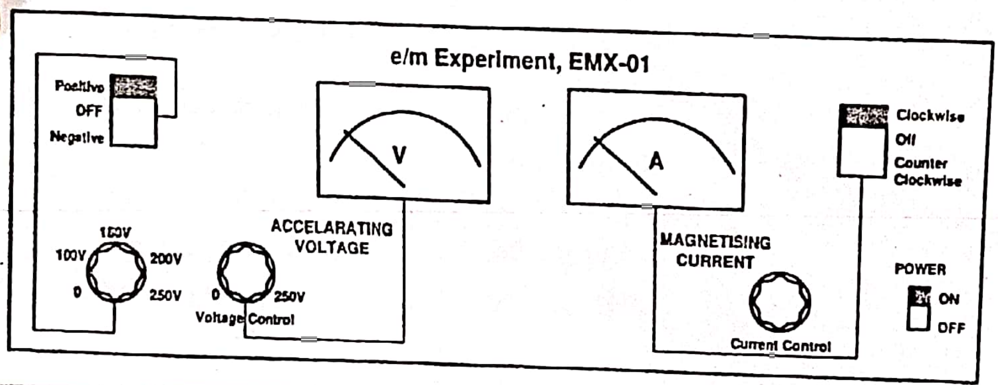


Fig. 3: Electron Gun



Control Panel

DESCRIPTION OF THE EXPERIMENTAL SET-UP :

The central part of the set-up is the e/m-tube. This is energized by

(i) Filament current supply,

(ii) Deflection plates voltage supply,

(iii) Continuously variable accelerating voltage supply to the anode.

The tube is mounted on a rotatable socket and is placed between a pair of Helmholtz coils. The tube can be rotated about a vertical axis, varying the orientation of the electron beam with respect to the Helmholtz coils. This allows deflection of the beam to be demonstrated for various orientations of the beam direction, circular, helical or undeflected paths can be seen. The direction of the current can be changed. The magnetizing current I and the accelerating voltage V are respectively measured by an ammeter and a voltmeter mounted on the front of the panel. The diameter of the electron beam path is measured by a detachable scale mounted in front of the bulb of the tube. This scale has a slider with a hollow tube (fitted with cross wires at its both ends) to fix the line of sight while making the measurements of the beam path diameter. Base of the unit contains the power supply that provides all the required potentials and the current to the Helmholtz coils. The entire apparatus is contained in a wooden case for convenient storage.

SPECIFICATIONS:

Helmholtz coils of radii	14 cm
Number of turns	160 on each coil
Accelerating Voltage	0 – 250V
Deflection plates voltage	50V – 250V
Operating Voltage	220V AC/ 50Hz

PROCEDURE :

1. Before the power is switched 'ON', make sure all the control knobs are at their minimum position.

2. Turn the power switch to 'ON'. The indicator lamp will glow.
3. Wait a little for the cathode to heat up.
4. Turn the accelerator voltage adjust knob clockwise to increase the voltage. Rectilinear electron beam emerging from the cathode will be visible. Adjust the accelerator voltage at about 200 volt.
5. It should be clear that the electrons themselves in the beam are not visible. It is the glow of the helium gas in the tube which is observed on the collision of electrons with the atoms of the gas. We actually see the glow of gas atoms which have been excited by collisions with the electrons.
6. Rotate the *e/m* tube so that the electron beam is parallel to the plane of the Helmholtz coils.
7. Earth's magnetic field interferes with the measurements. However this magnetic field is weak compared to the field generated by the Helmholtz coils and we could ignore its effect as first approximation.
8. Slowly turn the current adjust knob clockwise to increase the current for Helmholtz coils. The electron beam will get curved. Increasing the current will increase the curvature of the electron beam.
9. In case the electron beam does not make a complete circle and the circular path is skewed, rotate the socket of the tube until the path is a closed circle. This happens when the tube pointer is set at about 90^0.
10. Measure the diameter of the electron beam. This measurement has been facilitated by fixing a hollow tube on the slider of the scale. This tube fixes the line of sight during measurements.
11. Note the ammeter reading for the current to the Helmholtz coils and the voltmeter reading for accelerating voltage.
12. Decrease the accelerating voltage by a small amount (20 volt, say) and measure the diameter of the electron beam.
13. Carry on the observations. The voltmeter reading should not be increased beyond 250 volt. A value lower than 80 volt is also not advisable. Similarly the current to the Helmholtz coils should not be more than 2 amp.

Department of Applied Physics

Delhi Technological University

B. Tech. (2nd Semester) Common to All Branches

List of Experiments

1. To determine the Hall co-efficient and hence find the density of charge carriers in a semiconductor at room temperature by Hall effect measurement.
2. To determine the Plank's constant by photoelectric effect.
3. To determine the energy band gap of a semiconductor by four probe method.
4. BIOT SAVART'S LAW.
5. Determination of Mechanical Equivalent of Heat.
6. To draw the I-V characteristic for emitting Diode (LED) and determine the value of Plank's constant.
7. To determine the magnetic susceptibility of hydrous manganese chloride ($MnCl_2$, $4H_2O$) by Quinck's tube.
8. To study the variation of magnetic field with distance along the axis of a circular coil carrying current and to find the radius of the coil and horizontal component of earth's magnetic field.
9. Measurement of high resistance by Ballistic galvanometer.
10. To determine the ratio of charge to mass ratio (e/m) for an electron.

OBSERVATIONS :

Measurement of accelerating voltage V, magnetizing current I and diameter d of the electron beam path

Accelerating Voltage (volt)	Current to the Helmholtz coils (amp)	Diameter of the beam path (m)	(Diameter)^2 (m^2)	V/I^2d^2

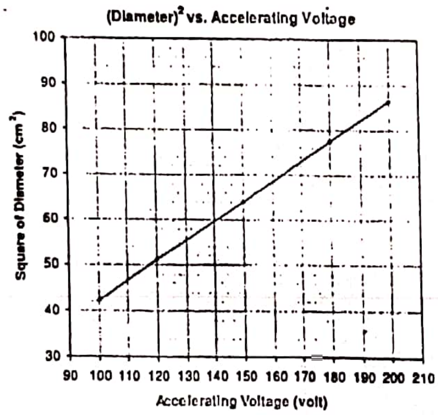
RESULT :

e/m form graph = ...C/kg

Average e/m from calculations = ...C/kg

Standard value of e/m = 1.76×10^{11} C/kg

Error % =



PRECAUTIONS :

1. Range of all meter should be properly chosen.
2. Handle the apparatus carefully and do not leave the beam ON for long periods of time.

3. Observation of the electron beam touching the edge of the electron tube should be done by first increasing the current more than required, when the curvature of the electrons path is well inside the tube. Then start decreasing the current and observe the curvature till it touches the edge.
4. The value of the filament current should remain constant throughout the experiment.

DISCUSSION : The main source of error in this experiment is the velocity of the electrons. There is a hole in the anode to allow the electrons to pass through it. This makes the velocity of the electrons non uniform and slightly less than the theoretical value. Further the collisions of the electrons with the helium gas in the tube decrease their velocity a little bit. The effect of these errors can be minimized by measuring the outer radius of the electron beam path and by not using low values of the accelerating voltage.
Other source of error is the measurement of the diameter of the electron beam.