PHYSICS LAB MANUAL

For Engineering Students

(CIT Branches)

Academic Year 2017-18

(Semester-I)

Subject Code - PHYS-1102

Name...

Branch..................................Roll No.....................................

Institute...

Department of Physics

College of Engineering Studies

University of Petroleum and Energy Studies,

Dehradun

INSTRUCTIONS FOR LABORATORY

- The objective of the laboratory is learning. The experiments are designed to illustrate phenomena in different areas of Physics and to expose you to measuring instruments. Conduct the experiments with interest and an attitude of learning.

- You need to come well prepared to the laboratory with write up and observing lab videos to perform the experiment.

- Work quietly and carefully (the whole purpose of experimentation is to make reliable measurements) and equally share the work with your group mates.

- Be honest in recording and representing your data. Never make up readings or doctor them to get a better fit for a graph. If a particular reading appears wrong repeat the measurement carefully. In any event all the data recorded in the tables have to be faithfully displayed on the graph.

- All presentations of data, tables and graphs calculations should be neatly and carefully done.

- Bring necessary graph papers for each of the experiment. Learn to optimize on usage of graph papers.

- Graphs should be neatly drawn with pencil. Always label graphs and the axes and display units.

- If you finish early, spend the remaining time to complete the calculations and drawing graphs. Come equipped with calculator, scales, pencils etc.

- Usage of electronic gadgets is strictly prohibited in the laboratory.

LIST OF EXPERIMENTS

Academic Year 2017-18

List of Experiments (with Cycles division)

Semester I (CIT)

S. No	Cycle	Experiment
1	I	Planck's constant using LEDs
2		Solar Cell
3		Hall Effect
4		Sonometer
5		Virtual Lab-1 - Photo Electric Effect
6	II	e/m method
7		Optical Fibre
8		Variation of Magnetic Field along the axis of a circular coil
9		Faraday's Laws
10		Virtual Lab-2 - Laser beam Divergence of a spot
11	Extra	Young's Modulus

S. No	Virtual Lab	Title of the Experiment	Link
1	Modern physics lab	Photo Electric Effect	http://vlab.amrita.edu/?sub=1&brch=195&sim=840&cnt=1
2	Lasers & Fibre Optics Lab	Laser beam divergence of a spot	http://vlab.amrita.edu/?sub=1&brch=189&sim=342&cnt=1

EXPERIMENT – 1
PLANCK'S CONSTANT

AIM
STUDY OF PLANCK'S CONSTANT BY USING LEDs.

APPARATUS
0-5V DC at 2mA, D.C Voltmeter, D.C Ammeter, Different color LEDs.

FORMULA & THEORY
Max Planck first proposed the idea that light was emitted in discrete packets or quanta in order to avoid the infamous ultra-violet catastrophe. With one problem resolved other question soon follows. Primarily, how big was a given packet? It was subsequently determined that the energy of given photon is given by the equation:

$$E = h\upsilon$$

where E is the energy of the photon υ is its frequency, and h is the Planck's constant.
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 case of the photoelectric effect, an electron is emitted from metal if the energy of the photon is greater than the work function of the metal. If the energy of the said photon is greater than the work function of the given material then the electron emitted possesses a voltage, which equals the difference in these energies. In case of an LED, 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'. This effect is not normally observed in metals and other typical substances because the photons emitted are outside the range of visible light, usually somewhere in infrared. In addition, the materials in question are rarely transparent to the photons which they emit. Fortunately many years of research have been put forth to develop LEDs that work well and are relatively cheap, making the materials relatively simple to acquire.

Planck's Constant:
Planck's constant is the fundamental constant in modern physics. It relates the energy of a photon to its frequency. To determine this constant we use Light Emitting Diodes (LED). Diodes emitting different colors of light are available in today's market. Each color is achieved by having a slightly different semiconductor material. This experiment has being carried out in many manners with a variety of LEDs. We choose to do the experiment using a number of LEDs, with different colors including Blue, Green, Red and Orange.
The experiment is based on the fact that the energy of the photon relates to its frequency as:
$E = h\upsilon$, Where, E is the energy of photon, h is the Planck's constant and υ is the frequency of the emitted photon. When the diode first emits light the voltage across the diode, V_0 is just enough to give energy to electrons to jump between two energy levels.
Therefore
$E = h\,\upsilon = hc/\lambda$ and $E = eV_0$
$h\,\upsilon = eV_0$
$hc/\lambda = eV_0$
$h = eV_0\,\lambda/c$
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
If the threshold voltage V_0, is measured for several diodes of different colour (and different maximum wavelength λ), a graph of V_0 Vs $(1/\lambda)$ should be linear. The slope (= hc/e) of linear curve can be used to compute the experimental value of Plank’s constant ‘h’.

Dirac Constant:

The Dirac Constant or the "reduced Planck Constant", $\hbar = h/2\pi$. The Planck’s Constant is stated in SI units of measurement, joules per hertz, or joules per (cycle per second), while the Dirac Constant is the same value stated in joules per (radian per second). In essence, the Dirac Constant is a conversion factor between phase (in radians) and action (in joule-seconds) as seen in the Schrodinger equation. The Planck Constant is similarly a conversion factor between phase (in cycles) and action. All other uses of Planck's constant and Dirac's Constant follow from that relationship.

Significance of the size of Planck's Constant

Expressed in the SI units of joule seconds (J·s), the Planck Constant is one of the smallest constants used in physics. The significance of this is that it reflects the extremely small scales at which quantum mechanical effects are observed, and hence why we are not familiar with quantum physics in our everyday lives in the way that we are with classical physics. Indeed, classical physics can essentially be defined as the limit of quantum mechanics as the Planck Constant tends to zero. In natural units, the Dirac Constant is taken as 1 (i.e., the Planck Constant is 2π), as is convenient for describing physics at the atomic scale dominated by quantum effects.

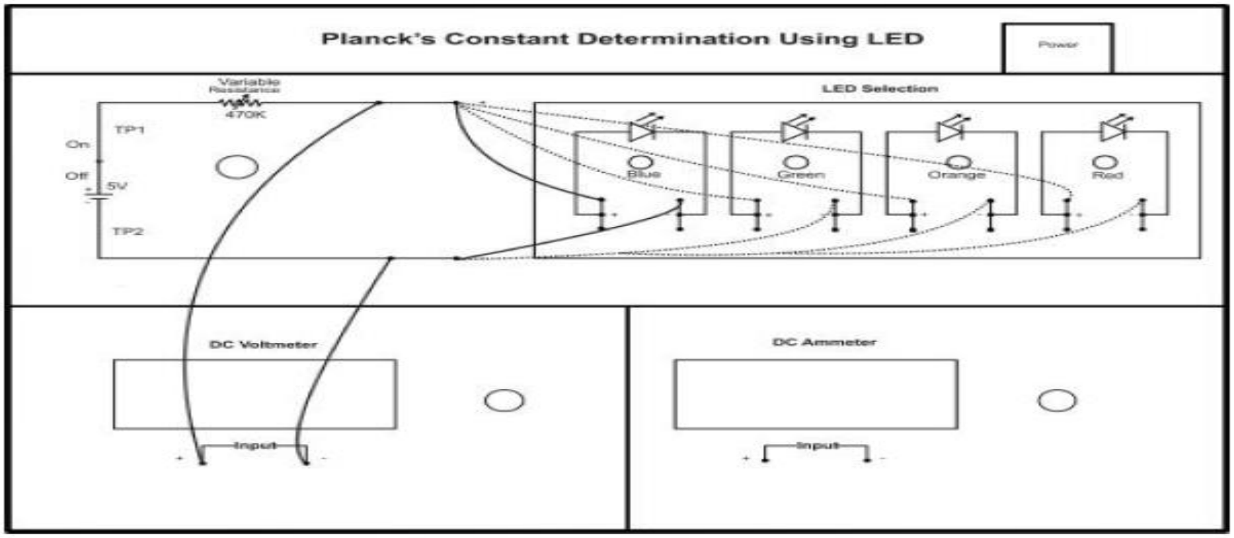
LED’s Wavelengths

Blue:470 nm Green:560 nm Yellow:580 nm Orange:630 nm Red:700 nm

1. DETERMINATION OF PLANCK'S CONSTANT USING LIGHT EMITTING DIODE (LED).

PROCEDURE:

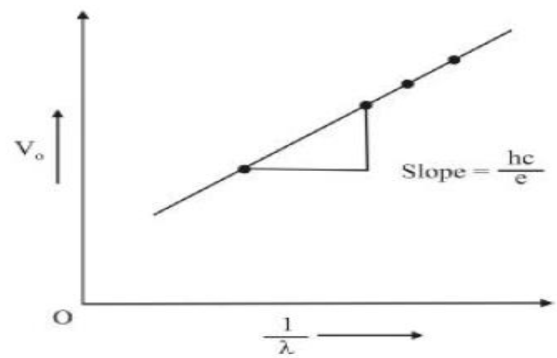
1. Connect + ve terminal of DC power supply to + ve terminal of any one LED and +ve terminal of DC voltmeter.
2. Now connect - ve terminal of DC power supply to -ve terminal of LED and - ve terminal of DC voltmeter.
3. Set the range of DC voltmeter at 20 mV. Connect the mains cord and switch ‘On’ the power supply.
4. Now vary the DC voltage slowly by variable resistance pot and see the LED connected in circuit.
5. When the LED is just starts to emit light note the value of applied voltage by DC voltmeter.



6. Now switch ‘Off’ the DC power supply and break the LED connection.
7. Again make same connection for another color of LED and repeat the experiment for different colors of LEDs.
8. 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.

$$h = eV_0 \lambda/c$$

Take mean value of h calculated for different LEDs.



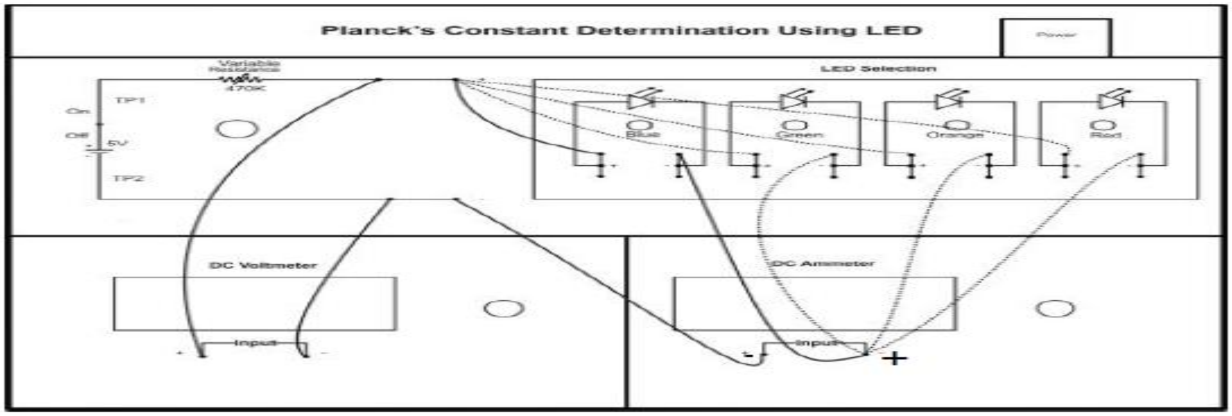
DETERMINATION OF PLANCK'S CONSTANT BY PLOTTING A CURVE BETWEEN THRESHOLD VOLTAGE AND WAVELENGTH OF LEDS.

Plot a graph between Threshold voltage (V_o) and reciprocal of wavelength ($1/\lambda$) for different LEDs. The plot is as shown below. Find the slope (S) from the graph, which is equal to (hc/e).
Put the values of S, c and e and solve for Planck's constant (h).

OBSERVATION TABLE 1

S.No	**LED colour**	**Voltage V(volts)**	**Wavelength λ (nm)**	**Frequency(Hz) $f = c / \lambda$**	**Energy (J) E = qV**	**h = $eV\lambda /c$ (J-s)**
1						
2						
3						
4						
5						

2. **DRAW THE V-I CHARACTERISTIC FOR LIGHT EMITTING DIODE (LED’S) AND DETERMINE THE VALUE OF PLANCK’S CONSTANT.**



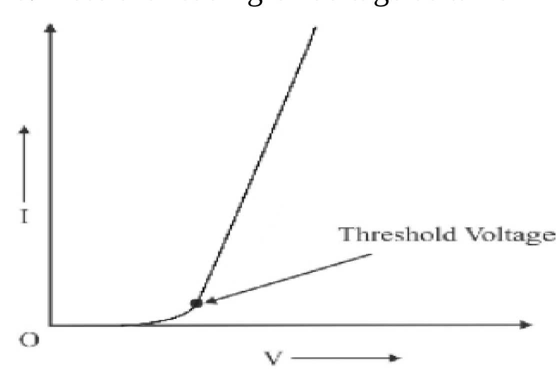
PROCEDURE:

1. Now take another patch cord and connect + ve of power supply to + ve of any one LED.
2. Connect - ve of power supply to - ve of ammeter and connect +ve of ammeter to - ve of selected LED.
3. Connect + ve terminal of power supply to + ve terminal of DC voltmeter and –ve terminal to -ve terminal of DC voltmeter.
4. Set the voltmeter at the range of 20 V and ammeter at the 200 mV.
5. Connect the mains cord and switch 'On' the power supply and increase the DC voltage at the fix interval of 0.1 volt or 100 mV.
6. Note the corresponding current by DC ammeter and tabulate the readings.

OBSERVATION TABLE 2

S.No	**LED (violet)**		**LED (green)**		**LED (red)**	
	V (…)	**I (…)**	**V (…)**	**I (…)**	**V (…)**	**I (…)**
1						
2						
3						
4						
5						

Plot a graph between current on X-axis and voltage on Y-axis. Note the reading of voltage at which the current flow suddenly through the LED, at this point the graph suddenly change their direction. This voltage is the knee voltage or threshold-voltage. Put this value in given formula and calculate the Planck's constant. Do this exercise for different LEDs and find the average experimental value of Plank's constant.



VIVA-VOCE

- What is a Light emitting diode?
- What is the relation between energy and wavelength?

- What is Knee voltage?
- What is wavelength corresponding to red, yellow, blue, green colours?
- What is infrared radiation? What is the range of wavelength?
- What is value of Planck's constant? What is the energy of quanta?

APPLICATIONS

- Photomultipliers
- Image sensors
- The gold-leaf electroscope
- Photoelectron spectroscopy
- Spacecraft
- Moon dust
- Night vision devices

PRECAUTIONS

1. Record the initial value for voltage very precisely.
2. Avoid loose connections in the circuit.

EXPERIMENT – 2
SOLAR CELL CHARACTERISTICS

AIM

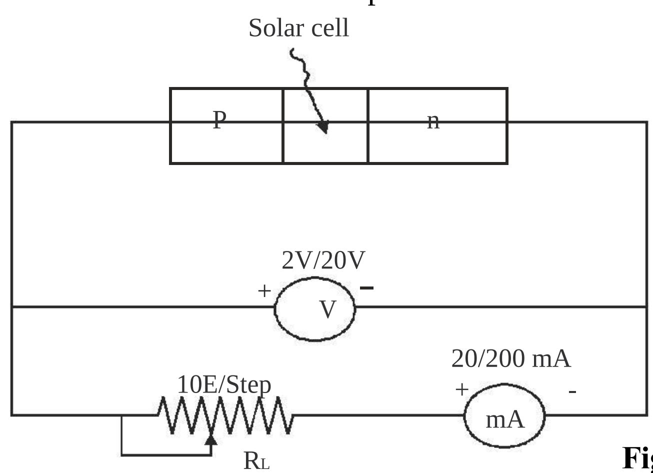
STUDY OF BOTH THE CURRENT - VOLTAGE CHARACTERISTIC AND THE POWER CURVE TO FIND THE MAXIMUM POWER POINT (MPP) AND EFFICIENCY OF A SOLAR CELL.

APPARATUS

Solar Panel Consist of 6 solar Cells, Table lamp, Digital/Analog D.C ammeter and voltmeter.

THEORY

A solar cell or photovoltaic cell is a device that converts light energy into electrical energy. Sometimes the term solar cell is reserved for devices intended specifically to capture energy from sunlight, while the term photovoltaic cell is used when the light source is unspecified. Fundamentally, the device needs to fulfill only two functions: photo generation of charge carriers (electrons and holes) in a light-absorbing material, and separation of the charge carriers to a conductive contact that will transmit the electricity. This conversion is called the *photovoltaic effect*, and the field of research related to solar cells is known as photovoltaic.



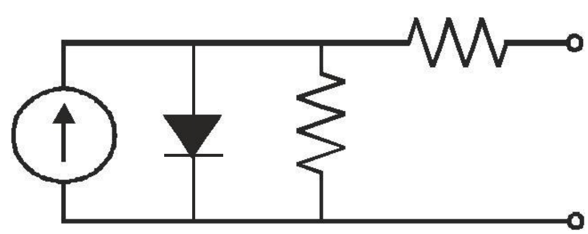
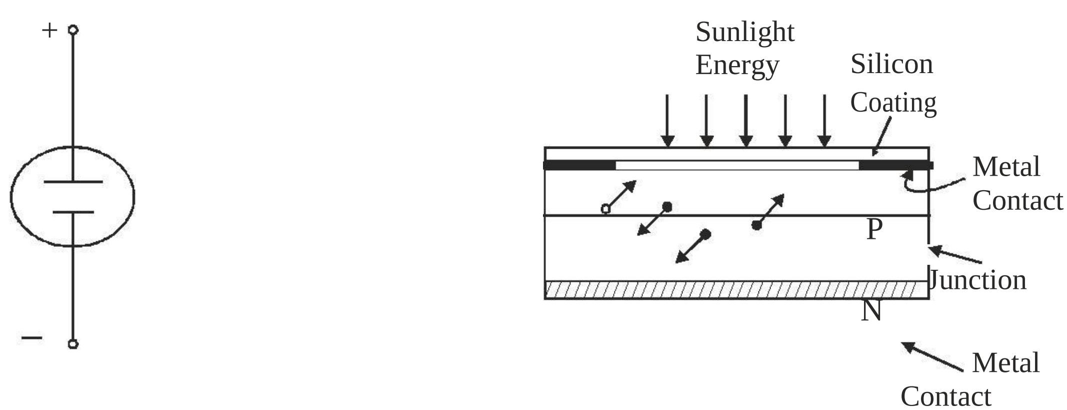


Figure 11.1



(A) Circuit Symbol (B) Cross-section

Figure 11.2: *Solar cell*

SIMPLE EXPLANATION

1. Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.
2. Electrons (negatively charged) are knocked loose from their atoms, allowing them to flow through the material to produce electricity. The complementary positive charges that are also created (like bubbles) are called holes and flow in the direction opposite of the electrons in a silicon solar panel.
3. An array of solar panels converts solar energy into a usable amount of direct current (DC) electricity.

PHOTO GENERATION OF CHARGE CARRIER

When a photon hits a piece of silicon, one of three things can happen:

1. The photon can pass straight through the silicon this (generally) happens for lower energy photons,
2. The photon can reflect off the surface,
3. The photon can be absorbed by the silicon which either generates heat or generates electron-hole pairs, if the photon energy is higher than the silicon band gap value.

CHARGE CARRIER SEPARATION

There are two main modes for charge carrier separation in a solar cell:

1. **Drift** of carriers, driven by an electrostatic field established across the device
2. **Diffusion** of carriers from zones of high carrier concentration to zones of low carrier concentration (following a gradient of electrochemical potential).

In the widely used *p-n junction* designed solar cells, the dominant mode of charge carrier separation is by *drift*. However, in *non-p-n junction* designed solar cells (typical of the third generation of solar cell research such as dye and polymer thin-film solar cells), a general electrostatic field has been confirmed to be absent, and the dominant mode of separation is via charge carrier *diffusion*.

PROCEDURE

1. Take the Solar Energy Trainer NV6005 along with Solar Panel.

2. Place the solar panel in the stand and adjust the panel at an angle of about 45º with the ground. Direct the sunlight
straight at the solar panel (angle of 90º).

Note: *If sunlight is not properly available then any source of light like lamp can be used.*

3. With the DB15 connector connect the Solar Energy Trainer NV6005 with Solar Panel. Then wait for 1 minute to avoid errors due to temperature fluctuations.

4. Set the potentiometer to maximum resistance i.e. at fully clockwise position and measure and record its resistance into the Observation Table.

5. Connect the solar cell as shown in the following circuit diagram as shown in figure 11.3.

- **a.** Connect positive terminal of solar cell to P1 terminal of the potentiometer.
- **b.** Connect other end of potentiometer i.e. P2 to positive terminal of ammeter.
- **c.** Connect negative terminal of ammeter to negative terminal of solar cell.
- **d.** Now connect the positive terminal of voltmeter to P1 and negative terminal of voltmeter to P2.

6. Record the values of corresponding voltage and current into the observation Table.

7. Now gradually move the potentiometer in anti- clockwise direction so that the resistance of the potentiometer decreases. Now measure the resistances at successively smaller values and record the corresponding values of voltages and current into the Observation Table below.

Note: *Always to measure the resistance of potentiometer at any position, first remove the patch cords from P_1andP_2 and measure resistance by multi meter. Reconnect these connections again for further measurements.*

OBSERVATION TABLE

S.No.	Resistance, R	Voltage, V (Volt)	Current, I (mA)	Power Calculated P = V.I (watt)
1				
2				
3				
4				
5				
6				
7				
8				

8. Plot the V-I characteristics from the measurements recorded in the table, to show how the photoelectric current depends on the photoelectric voltage and to find maximum power point.

Fillfactor Calculation

Fill factor is the ratio of maxmium useful power to ideal power:
Maximum useful power is area of largest rectangle that can be formed under V-I curve. V_m and I_m are values of voltage and current for these conditions.

Maximum useful power $= V_m \times I_m$

And Ideal power $= V_{OC} \times I_{SC}$

where I_{SC} = maximum value of saturation current

V_{OC} = emfgenrated by photovoltaic cell in open circuit.

$$\text{Fill factor} = \frac{V_m \times I_m}{V_{OC} \times I_{SC}}$$

From V-I characteristics you can easily find the maximum power point (MPP). MPP occurs where the product of voltage and current is greatest.

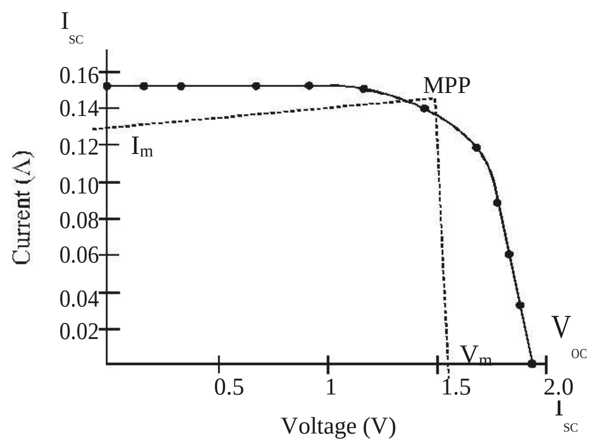


Figure11.4: *Current voltage characteristicof the solar cell*

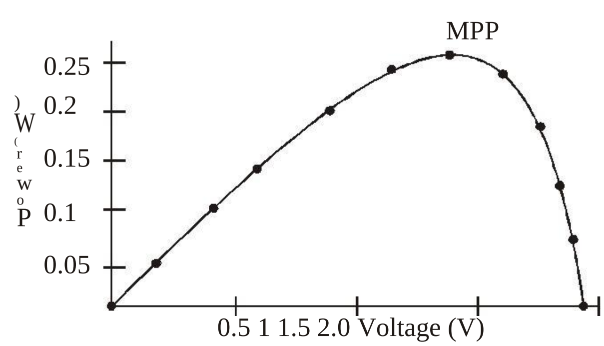


Figure 11.6: *Power curve of the solar cell as a function of voltage*

9. Plot the curve of power as a function of voltage from the measurements recorded in the table.

Expected Power - Voltage curve is as shown in figure 11.6.

The maximum power point (MPP) is the maximum value of power in the above curve.
The resistance, RMPP, at which the output power is at a maximum, can be calculated using the following formula:

$$R_{MPP} = \frac{V_{MPP}}{I_{MPP}}$$

TO CALCULATE THE EFFICIENCY (η) OF SOLAR CELL

The efficiency of the solar cell is the ratio of produced electrical power (Pout) and the incident radiant power (Pin).
Efficiency of solar cell, $\eta = \frac{P_{Out}}{P_{In}}$

Where P_{out} is the output electrical power (maximum power point).
Pin is calculated by multiplying approximated irradiance ("irradiance" means radiant power of the light incident per unit area) by the effective area of the solar cell on the panel.
This method used the fact that the practical value of the current (maximum photoelectric current measured) is proportional to the photons (radiation) striking the solar cell. This current is therefore proportional to the incident radiant power of the light.
The open circuit voltage depends on the semiconductor material of which solar cell is made. It is not proportional to the incident radiant power and therefore cannot be used for this measurement.

Efficiency of solar cell, $\eta = \frac{P_{Out}}{P_{In}}$
Where P_{out} (Output Electrical Power) = Maximum Power Point (MPP)
P_{in} (Incident radiant power) = Approximated IrradiancexArea of solar cell = $F \times I_P \times A$ Here A = Area of a solar cell (Length x Breadth) m^2
I_p= Practical value of current (maximum photoelectric current measured) indicated on the ammeter,

F is a constant and is given by

$$F = \frac{Maximum\ Solar\ Irradiance(\ specified\ by\ Manufacturer)\text{or (the power of the source used)}}{Maximum\ Value\ of\ Current}$$

The maximum irradiance in summer is approx. 1000 W/m^2 (or the power of the source used).. The maximum value of the current specified by the manufacturer is achieved at this value i.e. 150mA in the given solar cells. (The parameters of the solar cell/panel are related to the standard test conditions of $1000W/m^2$ and cell temperature of 25^o C.)

$$F = \frac{1000\text{ W/m2}}{150\text{mA}}$$

$$F = 6.67\ \frac{W}{m^2.mA}$$

Multiplying the practical value of current (Ip) indicated on the ammeter by the factor gives an approximation of the radiant power per unit area (irradiance) striking the solar cell.

$$F = 6.67\ \frac{W}{m^2.mA}$$

The efficiencies of solar cells lie between 12 to 15 %. If efficiency is slightly less than determined value then it is due to measuring errors and inaccuracies in determining the incident radiant power. Furthermore, the efficiency of solar panel is less than that of their separate constituent cells. This is caused by losses that arise in matching solar cells that do notall have exactly the same properties. If the solar cells are connected in series to generate desired voltage, the maximum power point may not be same for all cells. Solar cell losses arise as not all photons striking the solar cell can be converted into charge carriers. Part of the light is reflected as soon as it hits the surface and the metal contacts cast shadows. Since the photon energy does not correspond to the energy gap, less than half of the incident energy is used. Recombination of charge carriers (atomic rebinding of electrons) and electrical losses caused by internal resistances (ohmic losses in the semiconductor) of the solar cell and its contacts also arise.

RESULT

The efficiency of the given Solar Cell is …..%

PRECAUTIONS

1. Do not make inter connections on the board with mains switched ON.
2. All the connections should be tight.
3. Switch off after taking the readings.

VIVA-VOCE

1. What is solar cell?
2. Why solar cell is also called photovoltaic cell?
3. What are the uses of solar cell?
4. What do you mean photoelectric effect?
5. On what factors does the photocurrent depend?
6. Define the efficiency of Solar Cell?
7. How does temperature effect efficiency of solar cell/photo voltaic cell.
8. What happens to the current when Photo voltaic cells are connected in series and in parallel.
9. What is the order of current in photo voltaic cell?
10. Define a fill factor of a photo voltaic cell.

APPLICATIONS

- Telecommunication systems: Radio transceivers on mountain tops or telephone boxes in the country can often be solar powered.
- Remote monitoring and control: scientific research stations, seismic recording, weather stations, etc. use very little power which, in combination with a dependable battery, is provided reliably by a small PV module.
- Ocean navigation aids: many lighthouses are powered by solar cells.
- Water Pumping/Rural Electrification/Domestic supply
  Health Care/Lighting, Electronic industry and Electric Power Generation in Space.

EXPERIMENT – 3
HALL EFFECT

AIM

TO STUDY THE HALL EFFECT AND HENCE DETERMINE THE HALL COEFFICIENT (R_H) AND CARRIER DENSITY (n) OF A GIVEN SEMICONDUCTOR.

APPARATUS

Hall Probe (Ge Crystal) (thickness 0.4-0.5 mm); Hall Probe (InAs crystal), Hall Effect set-up(Digital mill voltmeter (0-200 mV) and constant current power supply, Electromagnet (Field intensity 11,000 ± 5% gauss), Constant current power supply.

FORMULA

The Hall Coefficient and Carrier Density are given by

(i) Hall Coefficient (R_H) = $\left(\frac{Z}{H_Z}\right)\left(\frac{V_H}{I}\right)$ Volt cm A^{-1}Gauss^{-1} = ……..x10^8 cm^3/coulomb

(where 'I' in Amperes, 'V' in volts, 'Z' in cm and H_z in Gauss)

(ii) Carrier density n = $\left(\frac{1}{R_H q}\right)$ cm^{-3} (where q = electronic charge = 1.6 x 10^{-19} C)

where, 'z' (in cm) is the thickness of the crystal along Z-axis, H_z is the magnetic field (in Gauss) applied along Z axis. Current 'I' (in mA) is flowing along X-axis. Hall voltage V_H is developed across the faces normal to Y-axis.

THEORY

An E.M.F. is set up transversely across a current carrying conductor when a perpendicular magnetic field is applied. This is known as the Hall Effect.

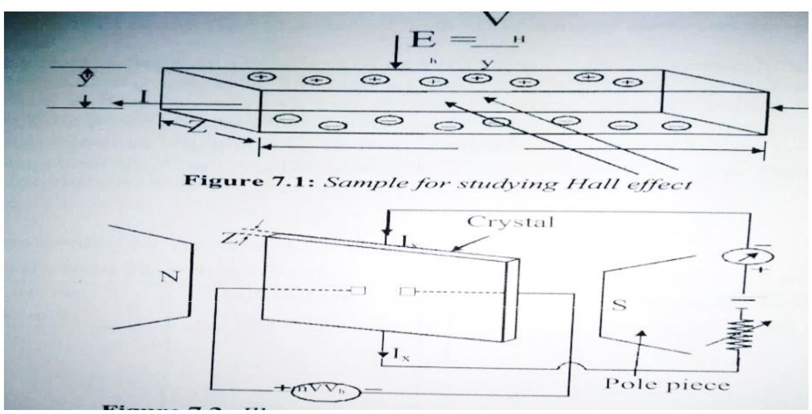


Figure 1: *Illustration of measurement of Hall Voltage*

PROCEDURE

1. Connect the widthwise contacts of the Hall Probe (with Ge crystal) to the voltage terminal and lengthwise contacts to current terminals of the Hall effect set-up. (dimensions may vary with setup).
2. Now switch 'ON' the Hall Effect set up and adjust the current to a few (mA).
3. Check the 'Zero field Potential' by changing Knob to the voltage side. This voltage is error voltage and should be subtracted from the Hall voltage reading. (i.e., when Hall probe is outside the magnetic field).
4. Now place the Hall probe in the magnetic field. This Hall probe must be fitted in the wooden stand before placing in magnetic field so that Hall probe becomes perpendicular to the magnetic field.
5. Switch on the electromagnet power supply by connecting the pole piece to the power supply.
6. Now place the Hall probe (InAs) attached with Gauss-meter between the pole pieces to measure the magnetic field.
7. Measure the Hall voltage as a function of current keeping the magnetic field constant (Table – 1).
8. Measure the Hall voltage as a function of magnetic field keeping a suitable value of current as constant (This is done by placing two probes between the pole pieces and decrease the spacing between the pole piece and measure the magnetic field and Hall voltage). (Table – 2).
9. Plot the graph between V_H and I (when H_Z = constant); V_H and H_Z (when I = constant).
10. Calculate the slope V_H/I and V_H/H_Z from the two graphs and calculate Hall coefficient in two ways and determine the mean value.

OBSERVATIONS

Thickness of the semiconductor crystal Z = 0.5 mm = 0.05 cm

Table – 1: Magnetic field Hz = 500/1000 Gauss

S. No	Current (I) (mA)	Hall Voltage (V_H) (mV)

Table – 2: Current I = 5/10 mA

S. No	Magnetic field Hz (in Gauss)	Hall Voltage (V_H) (mV)

Graph-1

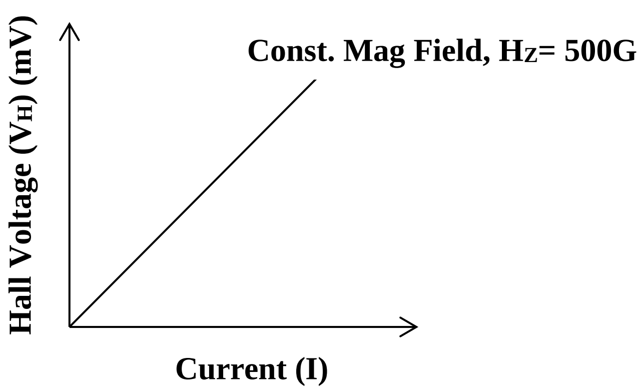


Figure 2. *Plot of V_H versus I*

Graph-2

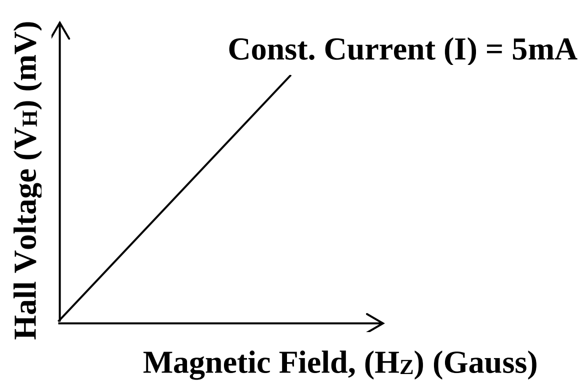


Figure 3. *Plot of V_H versus H_Z*

CALCULATIONS

Determine the slopes from two graphs to find out R_{H_1} and R_{H_2} respectively. Finally, the Hall coefficient is given by

$$R_H = (R_{H_1} + R_{H_2})/_2$$

$$Carrier\ Density\ ,\boldsymbol{n} = \left(\frac{1}{R_H q}\right) \quad = \left[\frac{1}{(\ldots\ldots\ldots cm^3/coulomb)(1.6\times10^{-19}\ coulomb)}\right]$$

RESULT

The value of Hall Coefficient (R_H) for the given semiconductor was found to be ——cm^3/coul.

The carrier density (n) = ——/cm^3.

PRECAUTIONS

1. The Hall probe is placed between the pole pieces (in magnetic field) such that maximum Hall voltage is generated.
2. Current through the Hall probe should be strictly within the limit as mentioned by the manufacturer.
3. Hall voltage developed must be measured very accurately.
4. Magnetic field is varied gradually in steps to avoid damage to the electromagnetic coils.

VIVA-VOCE

1. What is the Hall Effect?
2. On what factor, the sign of the Hall potential difference develops?
3. Why is the potential difference developed when a transverse magnetic field is applied to a current carrying conductor?
4. How will you determine the direction of the force exerted on the charge carriers?
5. What is the Hall coefficient? What are its units?

APPLICATIONS

Automotive Industry: Level/tilt measurement sensor, Throttle angle sensor automotive sensors, Crankshaftposition or speed sensor, Anti-skid sensor, Door interlock and ignition sensor Transmission mounted speed sensor, RPM sensors, Distributor mounted ignition sensor etc.

Electronic industry: Sequencing sensors, Magnetic card reader, Proximity sensors, Office machine sensors, Adjustable current sensors, Linear feedback sensor, Multiple position sensor, Microprocessor controlled sensors, Brushless DC motor sensors etc.

Aerospace Industry: Temperature or pressure sensor, Remote conveyor sensing, Remote

EXPERIMENT – 4
SONOMETER

AIM
TO DETERMINE THE FREQUENCY OF A.C. MAINS BY USING A SONOMETER.

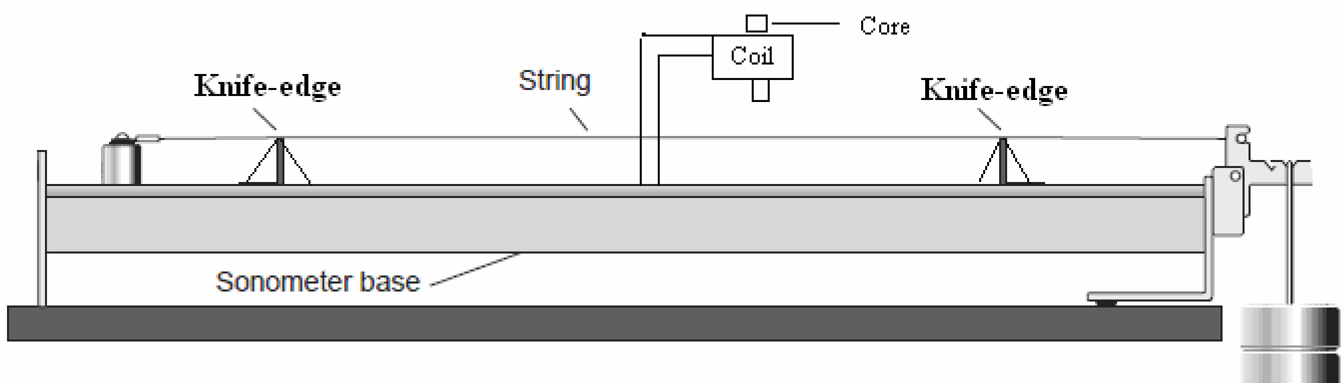
APPARATUS
Sonometer with magnetic wire, step down transformer of 6-8 volts, set of weights with hanger, electromagnet.

FORMULA
The frequency (f) of A.C mains is given by

$n = 2f = \frac{1}{2L}\sqrt{\frac{T}{m}}$ Hz (when experiment is performed with a magnetic wire)

i.e $f = \frac{n}{2} = \frac{1}{4L}\sqrt{\frac{T}{m}}$ Hz

Where,
n = natural frequency of sonometer wire in Hz.
L is the resonating length of wire between the two bridges in cm.
T is the tension applied to the wire = Mg (where M is the mass suspended to wire in gms and g is the acceleration due to gravity in cm/ sec^2) (dynes)
m is the mass per unit length of the wire in gm/ cm, given by $m = \pi r^2 d\ gm/cm$
where 'r' is the radius of the wire in cm.
and 'd' is the density of the material of the wire in gm/cm^3.



Sonometer

THEORY

Sonometer is a useful apparatus for investigating the vibration of a string or wire under tension. The equipment allows the change in length of the string in accordance with the variation in the tension. Sonometer is an apparatus by which we can determine the frequency of A.C. mains in a very easy method. In this, we have a very fine arrangement for precise determination.
Sonometer is a device which consists of a thin metallic (steel) wire stretched over two bridges that are usually mounted on a soundboard and which is used to measure the vibration frequency, tension, density, or

diameter of the wire, or to verify relations between these quantities also known as monochord. This set up is provided with 6V AC supply, which is applied to electromagnet.
To find the frequency of A.C. mains using an electromagnet and a sonometer, the A.C. is passed through the primary coil of a step-down transformer (220-230 volts to 4-6 volts). The two ends of the secondary coil of the step-down transformer are connected to the two ends of the windings of the electro- magnet which consists of a coil of insulated copper wire wound over a soft iron core provided with an insulated handle.
As the A.C. from the secondary coil of the step- down transformer passes through the electro-magnet it gets magnetized twice in each cycle, first with one of its faces as a north pole and then with the same face as the south pole. The electromagnet is kept close to and vertically above the sonometer steel wire. The position of the knife edges is so adjusted above that the sonometer steel wire vibrates in resonance with the A.C. supply (In India A.C. Supply is 50Hz). The wire is attracted and pulled twice in each cycle of the A.C. mains supply; once when the end of the electromagnet just above the wire is a north pole and again after half a cycle when this end is a south pole. In other words, the natural frequency (n) of the sonometer wire is double the frequency (f) of the A.C. Mains.

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

$$\text{or} \quad f = \frac{n}{2} = \frac{1}{4L}\sqrt{\frac{T}{m}}$$

PROCEDURE

1 Assembly the setup as shown in figure below.
2 Firstly tie the wire at one fixed end and other end passes over pulley and carries a hanger of weights.
3 Mount the L clamp of wires with the screws of sonometer base at a distance of 2- 3 mm above the wire.
4 The core of electromagnet should lie at the centre of coil.
5 Now connect main cord between mains and sonometer.
6 Take two patch cords and connect 6V AC supply from sonometer to the coil with polarity.
7 Now hang the weight of 500 gm to the hanger connected with one end of the steel wire.
8 Switch ON the A.C supply.
9 Now adjust the two knife edges near and far to each other so that you get the vibrations in the wire.
10 Now slowly adjust the knife edges for maximum vibrations.
11 Note the resonating length (l) between the two knife edges by a meter scale.
12 Also note load (M) in gm.
13 Now increase the mass in steps of 500 gm and adjust the knife edges for maximum vibrations.
14 Again note (l) of wire between the two knife edges.
15 Repeat the same procedure by increasing the weight of 500 gm and note down the length (l) for maximum vibrations.
16 Note all the values in the observation table given below.
17 Frequency of A.C mains (f) = $\frac{n}{2}$………Hz
18 Also calculate percentage error as standard frequency of A.C mains is 50Hz.

$$Percentage\ Error(in\ \%) = \frac{Standard\ Value - Calculated\ value}{Standarad\ value} \times 100$$

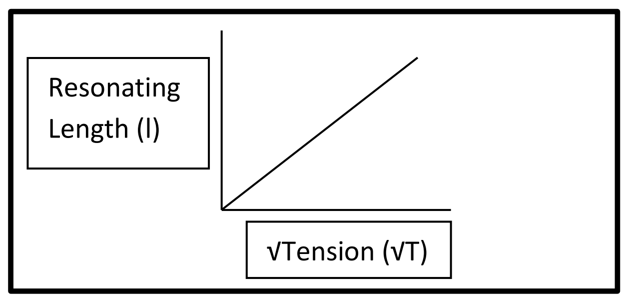
OBSERVATION TABLE

Length of the wire = …cm
Mass of the wire =……gm
Mass per unit length of the wire =…..gm/cm

S.No	Mass(M) gm	Tension in Newton T = M g =M x 980 Dynes	Resonating length between two knife edges (l) cm			$\frac{\sqrt{T}}{l}$ Dynes/cm	$n = \frac{1}{2L}\sqrt{\frac{T}{m}}$ Hz
			Mass increasing	Mass decreasing	Mean length cm		
1							
2							
3							
4							

Mean frequency ‘n’ = ………..Hz

A graph is to be drawn between $\sqrt{T}$ on x-axis and resonating length (l) on Y-axis. It should be a straight line passing through origin.



From graph, $\frac{\sqrt{T}}{l}$ = ………….. dynes/ cm.

N=…………….Hz

f = $\frac{n}{2}$ = ……….. Hz

This should be approximately equal to the average value of ‘n’.

VIVA-VOCE

Q. 1. What type of vibrations is produced in the sonometer wire and the surrounding air?
Q. 2. How are stationary waves produced in the wire?
Q. 3. What do you understand by resonance?
Q. 4. Is there any difference between frequency and pitch?
Q. 5. What are the positions of nodes and antinodes on sonometer wire?
Q.6. What is the frequency of D.C?
Q.7. What do you mean by Resonating Length of the wire in the experiment?
Q.8. On which principle does the ac sonometer work ?

PRECAUTIONS

1. The electromagnet should not touch the wire, it should be just above the wire.
2. Take care to see that a magnetic wire is fixed on the sonometer.
3. Determine the radius of the wire when no mass is attached to the mass hanger.
4. The length between the two bridges has to be taken accurately when the formed loop is stable.

EXPERIMENT – 5
SPECIFIC CHARGE (e/m) OF AN ELECTRON

AIM

TO DETERMINE THE VALUE OF SPECIFIC CHARGE (E/M) OF AN ELECTRON BY THOMSON METHOD

APPARATUS

1. Cathode ray tube (CRT) , mounted on wooden stand
2. Power supply, fitted with a Digital Voltmeter (DVM) to measure the deflecting voltage
3. Bar Magnets (Permanent) one pair
4. Compass box one set
5. Wooden stand having two arms, fitted with scales to measure the distance of the poles of the magnets. The stand can accommodate Cathode Ray Tube in its middle
6. Another wooden stand is also provided to place the compass box in the centre. This wooden stand also be mounted in the middle of the armed stand

FORMULA

The specific Charge of an electron is given by

$$e/m = (V\lambda \,/\, IL\, H^2 d) \times 10^7 \text{ e.m.u./gm.}$$

Where $H = H_e \tan\theta$ (where H_e is the horizontal components of earth magnetic field of the place where experiment is performed, usually we take its value = 0.345 Oersted)

here various parameters are defined as follows.

I = length of horizontal pair of plate

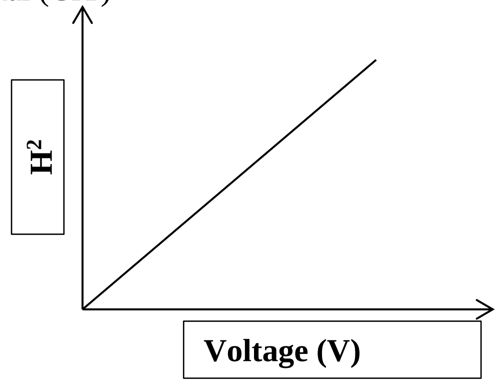
L = distance of the screen from the edges of the plates

V = voltage applied to the plates

λ= total deflection of the spot on the screen

H = intensity of the applied field

d = separation between the plates



THEORY

Cathode Ray Tube consists of 3 basic components:

1. **ELECTRON GUN**: FF is a filament which when heated emits electrons. G(control grid) carries a negative charge, so sends out a beam of electrons which are accelerated by the anodes.
2. **DEFLECTING SYSTEM**: This system deflects the beam of electrons either electrically or magnetically.
3. **FLUORESCENT SCREEN**: When beam impinges on it visible spot is produced.

The value of e/m is independent on the nature of gas and material of the cathode of the discharge tube which indicates that electrons are fundamental constituents of all materials. The present accepted value of e/m is 1.7×10^7e.m.u./gm.

PROCEDURE

1. Mount Cathode Ray Tube (CRT) in armed wooden stand such that the CRT faces towards North & South direction while arms of the stand toward East and West Direction (set the direction with the help of compass box).
2. Connect the CRT Plug to the power supply socket mounted on the front panel.
3. Switch on the instrument using ON/OFF toggle switch provided on the front panel.
4. Set the deflection voltage to 0 volt and x shift control potentiometer to middle position. Adjust the intensity & focus of the spot (clear as small as a point) on screen of CRT. Throw the deflection selector switch towards forward position.
5. Read the initial reading of spot on the scale attached to the screen of the CRT, say it is 0.2cm. Now give a deflection to the spot in the upward direction by applying deflecting voltage (say 5 volts) such that the final deflection reading is 1.2cm. So the total deflection on the screen of the spot is (1.2-0.2) = 1.0 cm. Note down this applied voltage (V) & deflection of the spot (λ) in observation table.
6. Now place bar magnets on both sides of the wooden stand arms such that their opposite poles face each other and their common axis is perpendicular to the axis of cathode ray tube. The magnets should be kept in such a manner that these may be made to slide along the scales.
7. Adjust distances and polarity of the magnets so that the spot traces back to its initial position (which was 0.2cms).
8. Remove Cathode Ray Tube from stand and place a magnet meter compass box mounted in a stand in centre of the armed wooden stand. Adjust the pointer of the compass box to read 0-0 without disturbing the direction of armed wooden stand.
9. Note down the deflection angle (θ) through compass box & note down it in the observation table. Calculate the value of magnetic field (H) by using formula,

$$H = H_e \tan\theta$$

   (where H_e is the horizontal components of earth magnetic field of the place where experiment is performed usually we take its value = 0.345 Oersted)

10. Calculate the value of e/m by using formula **e/m = $(V\lambda / IL\, H^2 d) \times 10^7$ e.m.u./gm.**

11. Repeat steps 5 to 10 for other values of spot deflection with different voltages (5V, 10 V, 15V)
12. Calculate mean value of e/m for different set of readings.
13. Draw a graph between voltage on X-axis and H^2 on Y-axis, the plot is to be a straight line passing through origin. Caculate the value of e/m from graph

NOTE: For better accuracy apply deflection voltage only up to 20 volts.

OBSERVATIONS

Constant of the CRT used (8SJ31J)

Length of horizontal pair of plates (I) = 18mm = 1.8cm

Distance of the screen from edges of plates (L) = 100mm = 10cm

Separation between the plates (d) = 5mm = 0.5cm

NOTE: when the deflection voltage is 0, the position of spot on CRT is 0.2cm. So in forward movement we will subtract the 0.2cm reading from the final reading of the spot on CRT, when deflection voltage is applied.

Reference Spot deflection, $\boldsymbol{\lambda_0}$ = ---------- cm.

S.No	**Applied Voltage (V) (in volts)**	**Spot Deflection (λ_v) (in cm)**	**Actual spot Deflection (λ)=λ_v- λ_0 (in cm)**	**Compass box Deflection (θ) (in degrees)**	**Magnetic field H = $H_e\tan\theta$ where H_e = 0.345**	**(H^2)**	**(e/m) (in e.m.u/gm)**
1	5						
2	10						
3	15						

Average value for the specific charge, **(e/m) = ----------------e.m.u./gm.**

CALCULATIONS:

Formula used to calculate value of e/m

e/m = ($V\lambda$ / $ILdH^2$)X 10^7e.m.u./gm. **……………eq (1)**

Where ILd = 1.8 x 10.0 x 0.5 = 9 cm^3

e/m for 1^{st} set of reading = put all values in equation (1)

similarly calculate for other set of readings.

e/m for 2^{nd} set of reading = put all values in equation (1)

e/m for 3^{rd} set of reading = put all values in equation (1)

e/m for 4th set of reading = put all values in equation (1)

Mean value of e/m (calculated) = [() + () + () + ()] x 10^7e.m.u./gm

Calculated value of e/m = --------- x 10^7e.m.u./gm

Calculated value of e/m from graph = --------- x 10^7e.m.u./gm

Standard value of e/m = 1.5 x 10^7e.m.u./gm

Error = (---------) x 10^7e.m.u./gm

RESULT

The value of specific charge e/m of an electron by Thomson Method comes out to be

…….emu/gm

PRECAUTIONS

1. Take care while locating the filament at a position normal to the line joining the two slits.
2. The cathode ray tube must be set in the north south direction.
3. The axis of the bar magnets and the axis of the cathode ray tube must be exactly at right angles and in horizontal plane.
4. The cathode ray tube must be handled carefully.
5. The deflecting voltage must be reversed to produce the deflections of the spot of light in the opposite direction and the magnetic field must also be reversed to bring it back to initial position.

EXPERIMENT -6
OPTICAL FIBRE

AIM: To determine the (1) Numerical Aperture (NA), (2) Power Losses due to Macro bending and adaptor of givem optical fibre.

APPARATUS: LED, NA Jig, D.M.M, scaled screen, adaptor, one and three meter length of optical fiber, mandrel.

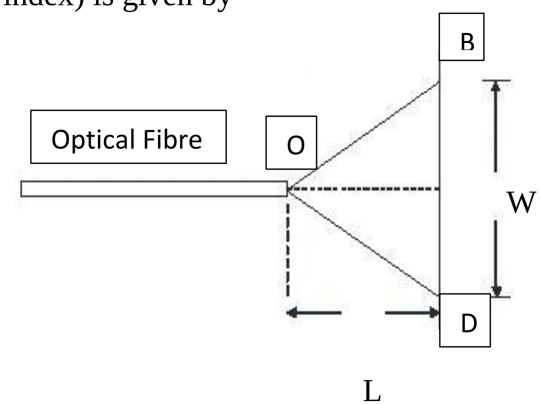
PRINCIPLE & FORMULA

1. The Numerical Aperture (N.A) of an optical fiber (step index) is given by

$$NA = \left[n_{core}^2 - n_{cladding}^2\right]^{1/2}$$

$$= \sin i_{max}$$

$$\text{or} \quad i_{max} = \sin^{-1}(NA)$$



n_{core} = refractive index of core,
n_{clad} = refractive index of cladding
i_{max} = acceptance angle

Figure 8.1

As shown in figure 8.1, light from the end of the optical fiber ‘A’ falls on the screen BD. Let the diameter of light falling on the screen BD=W, Let the distance between end of the fiber and the screen AO=L. knowing W and L, the N.A can be calculated and substituting this N.A value in Eq (2), the acceptance angle ‘θ’ can be calculated.

2. Losses of power in a fibre optic cable are mainly due to the absorption or scattering of light with an Optical fibre. Macro bending and joints between the cables (adaptor). This loss of power ‘P’ from input (P_o) to output (P_L) at a distance ‘L’ can be written as

$$P_L = P_0 e^{-\alpha L}$$

where ‘α’ is the attenuation coefficient in decibels (dB) per unit length, measured in dB/KM.

PROCEDURE

1. Insert one end of either one or three meter length optical fiber cable the LED and NA jig.. Switch on LED, then red light will appear at the end of the fiber on the N.A Jig. Turn SET P0/IF knob the intensity will increase. Arrange the scaled screen at a distance L, and then view the red spot on the screen. Measure the diameter of the spot (w). Note the measured values L and W in the table. Repeat the experiment with different distances and note the readings.

Tabular Form 1

S. No	L (mm)	W (mm)	$NA = \frac{W}{[4L^2 + W^2]^{1/2}}$	i_{max}

2. Insert one end of the three meter length plastic optical fibre cable to the FOLED and connect another end to the power meter module. Connect D.M.M test leads to Pout, red lead to red socket and black lead to black socket respectively. Set D.M.M to 2000 mV range. Switch on LED, adjust the Set Po/IF knob to set output power of the FOLED to the value -22.0 dBm(milli decibels) i.e., DMM reading will be - 220mV, note this as P_O, wind the fibre on the mandrel and note the reading as P_Ow_1, similarly for two and three turns. Note the readings as P_Ow_2 and P_Ow_3 respectively**.**
3. Connect one meter OF cable as given above and set D. M. M. for a constant value(~120mV) and note the reading as P_1. Similarly take P_2 by replacing one meter cable with three meter cable without disturbing set Po/If knob. Now j0in the 1m and 3m cables with the adapter as shown in the figure and note DMM reading as P_3.

Tabular Form 2

x O/P power (dbm)		Loss due to turns (dbm)
Po0	-	
Pow1	-	(Po0 – Pow1)
Pow2	-	(Po0 – Pow2)
Pow3	-	(Po0 – Pow3)

OBSERVATIONS

P_1 =

P_2 =

P_3 =

CALCULATIONS

Take P_1, P_2 and P3 as shown in Fig., without disturbing the SET Po / I_f knob.

Loss in one meter cable (X) = $(P_2 - P_1)/2$

Loss due to adopter = $P_3 - P_1 - 3X$ =

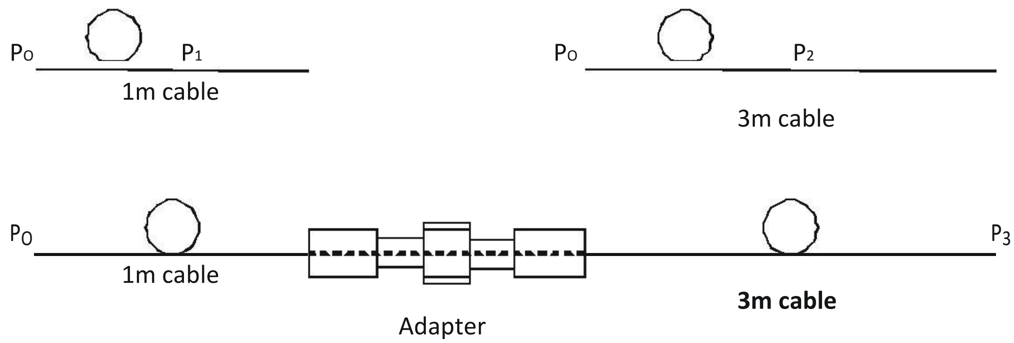


Figure 8.2

RESULT

1. N.A of given Optical fiber is ————————
2. Power loss due to one turn——————— dBm, two turns ——————dBm and three turns ———dBm
3. Power loss due to one meter cable——————— dBm and due to adaptor ——— dBm

PRECAUTIONS

1. Gently insert the optical fiber cable is to LED by turning clockwise direction of its clinch nut. (until you feel the fiber touches the micro lens)
2. Do not push applying over force which may damage micro lens
3. Gently tight the clinch nut that holds the inserted fiber firmly.
4. Before taking reading check out fiber is free of all twists and strains.
5. Two cables must meet at the center of the adopter while taking P_3 reading.

VIVA-VOCE

1. What do you mean by numerical aperture?
2. On what factors the numerical aperture depends?
3. What do you mean by acceptance angle?
4. On what factors the acceptance angle of the fiber depends?
5. A fiber with high numerical aperture (NA) is preferable or not? Why?
6. What is irradiance?
7. What do you mean by bandwidth?

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APPLICATIONS

Telecommunications

Local Area Networks(LAN) and Wide Area Networks(WAN)

Factory Automation, premises. Wiring, Fiber-Optic biomedical sensors, Endoscopic Imaging, Aerospace and Military Applications, Fiber Optic Sensors.

EXPERIMENT – 7
VARIATION OF MAGNETIC FIELD WITH DISTANCE ALONG THE AXIS OF A CIRCULAR COIL

AIM

TO STUDY THE VARIATION OF MAGNETIC FIELD WITH DISTANCE ALONG THE AXIS OF A CURRENT CARRYING CIRCULAR COIL AND HENCE ESTIMATE THE RADIUS OF THE COIL.

APPARATUS

Tangent galvanometer of the Stewart and Gee type, Battery eliminator, Rheostat, Commutator, Plug key and connecting wires.

FORMULA

The magnetic field on the axis of a circular coil is given by:

$$\mathbf{B} = \frac{2\pi \mathbf{nIa}^2}{\mathbf{10(a^2 + x^2)^{3/2}}}$$

Where **n** = number of turns in the coil

a = radius of the coil in cm

I = current in the coil in amperes

x = distance of the point from the centre of the coil in cm

THEORY

If we pass a current of I ampere in the coil keeping it vertical in magnetic N-S direction and place the needle at a distance x from the centre on any side of the arm, the magnetic field B acting on the needle due to the current in the coil is given by

$$B_1 = \frac{2\pi nIa^2}{10(a^2 + x^2)^{3/2}}$$

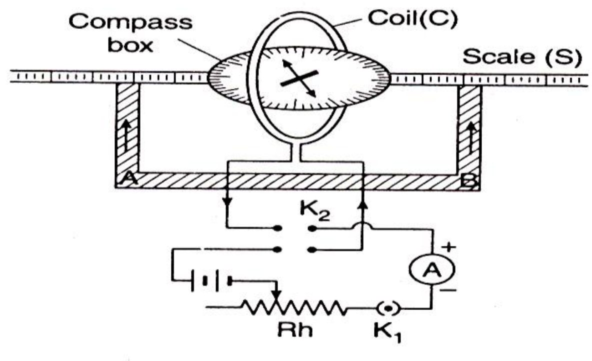
This acts East-West in horizontal plane. The horizontal component of earth magnetic field B_H acts on the needle in N-S direction horizontally. Thus two mutually perpendicular coplanar magnetic fields act on the needle deflecting it. According to tangent law:

$$B_2 = B_H \tan\theta$$

or,
$$\frac{2\pi nIa^2}{10(a^2+x^2)^{3/2}} = B_H \tan\theta$$

Hence, the variation of θ with x is studied which gives the variation of magnetic field along the axis of the circular coil.

PROCEDURE



1. The apparatus called Stewart and Gee tangent galvanometer is used to study the variation of magnetic field along the axis of current carrying circular coil and is shown in the figure.
2. Rotate the whole apparatus in the horizontal plane such that the coil lies in the magnetic meridian roughly. In this case the coil, needle and its image all lie in the same vertical plane. Rotate the compass box till the pointer ends read 0-0 on the circular scale.
3. To set the coil exactly in the magnetic meridian, send the electric current in one direction with the help of commutator and note down the deflection of the needle. Now reverse the direction of the current and again note down the deflection. If the deflections are equal then the coil is in magnetic meridian.

OBSERVATION TABLE

Current , I = ……Amp

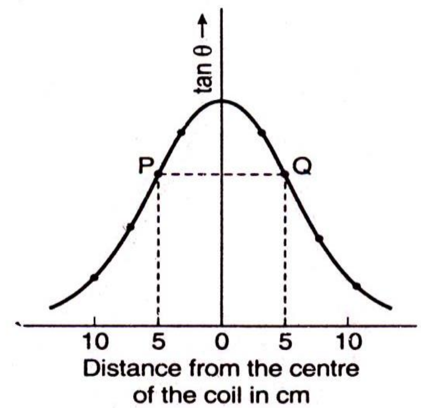
S. No.	**Distance (x) (cm)**	**Deflection on Eastern Arm**						**Deflection on Western Arm**						**Mean tan θ**	**B_2 = B_H tan θ**
		Current in one direction (Direct)		**Current in other direction (Reverse)**		**Mean θ**	**tan θ**	**Current in one direction (Direct)**		**Current in other direction (Reverse)**		**Mean θ**	**tan θ**		
		θ_1	**θ_2**	**θ_3**	**θ_4**			**θ_1**	**θ_2**	**θ_3**	**θ_4**				
1.	0														
2.	2														
3	4														
4	6														
5	8														
6	10														
7	12														

4. With the help of rheostat, adjust the current such that the deflection in the compass box should be 65 to 70° when it is placed at the center of the coil.
5. Displace the compass box on the bench through 2 cm. each time along the axis of the coil and for each position note down the mean deflection.
6. Repeat the measurements exactly in the same manner on the other side of the c.

Graph

Plot a graph taking distance along X-axis and tan θ

along Y-axis. Mark the points of inflection P and Q and hence the radius of the coil.



Result

(i) The graph shows the variation of Magnetic field along the axis of a Current carrying circular coil.

(ii) The radius of the coil (R_m) = ……cm

S. No	Distance (x) cm	B_1	B_2

Standard result

The radius of the coil as estimated by measuring its circumference **(R_s) =** 10 **cm**

Percentage error

(R_m -R_s) x 100/ (R_s) = ...%

where **R_m** and **R_s** the measured and the standard values of the radius.

PRECAUTIONS

1. The coil should be adjusted carefully in the magnetic meridian.
2. All the magnetic materials and current carrying conductors should be at a considerable distance from the apparatus.
3. The current passed in the coil should be of such a value so as to produce a deflection of nearly 65°.
4. Before reading the two ends of the pointer parallax between the pointer and its image in the plane mirror should be removed so as to record the correct value of the deflection.
5. The curve should be drawn smoothly.

VIVA-VOCE

Q. 1 : What do you mean by a uniform magnetic field?

Q. 2 : What is magnetic effect of a current?

Q. 3 : What is the Tangent law?

Q. 4 : What is magnetic meridian?

Q. 5 : How the coil is set in the magnetic meridian? How can you test this setting?

Q. 6 : What is the direction of the magnetic field produced by the coil?

Q. 7 : Why is it necessary to set the coil ion the magnetic meridian?

Q. 8 : Why both the ends of the pointer in the compass box be read.

Q. 9 : Why the readings must be repeated after reversing the current?

Q. 10 : How does the field vary along the axis of the coil?

Q. 11 : What is the magnitude of the field at the centre of the coil?

Q. 12 : Is the field uniform at the centre?

Q. 13 : Will the presence of any current carrying conductor close by, will effect the results?

Q. 14 : How do you find out the radius of the coil from x Vs $\tan\theta$ from graph?

APPLICATIONS

Motors, transformers, microphones, compasses, telephone bell ringers, television focusing controls, advertising displays, magnetically levitated high-speed vehicles, memory stores, magnetic separators etc.

EXPERIMENT – 8
STUDY OF ELECTROMAGNETIC INDUCTION- FARADAY'S LAWS

AIM

1. TO STUDY THE INDUCED EMF AS A FUNCTION OF VELOCITY OF THE MAGNET PASSING THROUGH THE COIL.

2. TO STUDY THE CHARGE DELIVERED DUE TO ELECTROMAGNETIC INDUCTION.

APPARATUS

The experimental setup consists of a permanent magnet mounted on an arc of a semicircle (D shaped) of radius 40cm, measurement board consisting of voltmeter, milliammeter, resistance, condenser and diode The arc part of rigid frame of aluminum and is suspended at the center of the arc so that the whole can oscillate freely in its plane. (Fig. 1.)

THEORY

Weight(A,A) have been provided on the diagonal arm, so that by altering positions the time period of oscillation can be varied from about 1.5 to 3 sec. Two coils of about 10,000 turns of copper wire loop the arc so that the magnet can pass freely through the coil. The two coils are independent and can be connected either in series or parallel. The amplitude of the swing can be read from the graduated circle by the pointer, when the magnet moves through and out of the coil the flux of the magnetic field through the coil changes, inducing the emf.

On the panel of the measurement board one voltmeter with four range 0-2.5V, 5V, 10V, 20V and one ammeter with two ranges 1mA, 2.5mA are provided. Board also has four different value condensers five resistances and two diodes and one SPST for performing experiments.

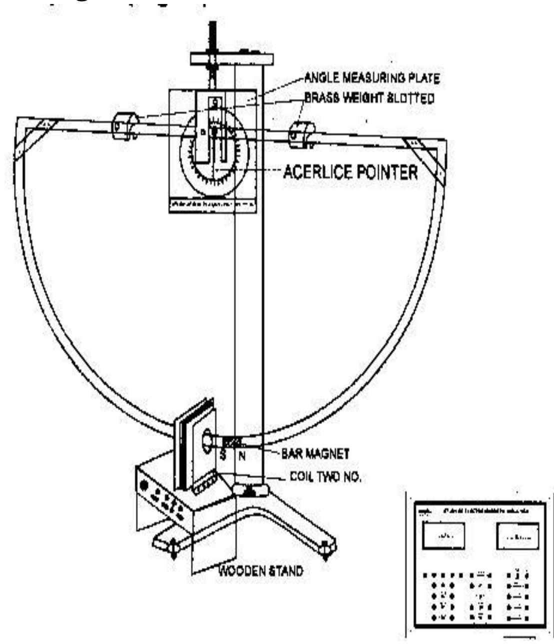


Fig. 1. Experimental setup of Faraday's law

Features

1. Mechanical part consisting of a permanent magnet mounted on an arc of semicircle of radius 40cm. The arc is part of a rigid frame of aluminum and is suspended at the centre of arc so that the whole frame can oscillate freely in its plane. Weights have been provided on the diagonal arm, so that by altering their position, the time period of oscillation can be varied from about 1.5 to 3 sec. Two coils of about 10,000 turns of copper wire loop the arc, so that the magnet can pass freely through the coil. The two coils are independent

and can be connected in series or parallel.2. Measurement board consisting of voltmeter, milliammeter, resistance, condenser and diode.

BASIC PRINCIPLE

The basic principle of generation of alternating emf is electromagnetic induction discovered by Michael Faraday. The phenomenon is the production of an induced emf, V_{emf} (in volts) in a closed circuit is equal to time rate of change of magnetic flux linkage by the circuit. Faraday's law of induction tells us that the induced emf, "V_{emf}" is given by

$$V_{\text{emf}} = -\frac{d\lambda}{dt} = -N\frac{d\emptyset}{dt} \text{.............................} (1)$$

Where $\lambda = N\emptyset = flux\ linkage$ and $ø$ represents flux through each turn and N is the number of turns.The negative sign shows that the induced voltage acts in such a way that it opposes the flux producing it. This is known as Lenz's law.

STUDY OF ELECTROMAGNETIC INDUCTION AND VERIFICATION OF FARADY'S LAW.

This experiment is performed in two parts.

Part 1.To study the induced emf as a function of velocity of the magnet passing through the coil.

Magnet NS pass through the coil C (by using coil 1 OR 2) with varying velocities (Fig.2.) An aluminum frame can swing about a pivot O, its period adjustable by sliding the loads A, A. If D is released from angle $\theta_0$from the equilibrium, the velocity V_{max} with which the magnet passes through the coil is given by

$$V_{max} = \frac{4\pi}{T}\sin\frac{1}{2}\theta_0 \text{.......................}(2)$$

Where P is radius of D-shape arc (=40 cm).

The magnetic flux (fig.3.) through the coil (Φ) changes as the magnet NS passes through it also two pulses with opposite signs are generated in the coil for each swing. The peak E_0 corrosponds to maximum $\frac{d\Phi}{dt}$.

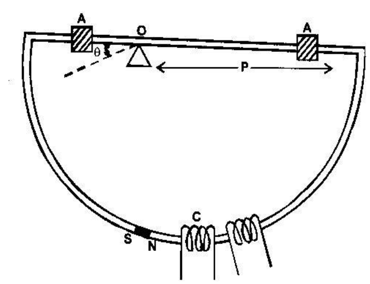


Fig.2. THE MECHANICAL PART WITH MAGNET NS PASS THROUGH COIL 'C' WITH A MEASURABLE VELOCITY

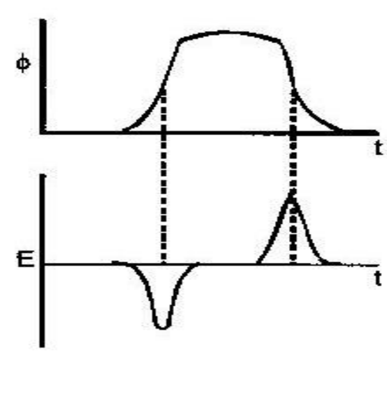


Fig. 3. Time Variation of Magnetic Flux Φ and emf E

PROCEDURE

1. Make the circuit as shown in Fig.4. Keep switch S in OFF position. C ≈ 100µF and R1 ≈ 500Ω . (here R1 represents the internal resistance of the coil and the forward resistance of the diode D.) At each swing the diode permits the capacitor to gain a charge once. The charging time RC being 50 ≈ ms. and the pulse width τ (Fig.3) being a little smaller, the capacitor reaches the E_0 value in a few swings.

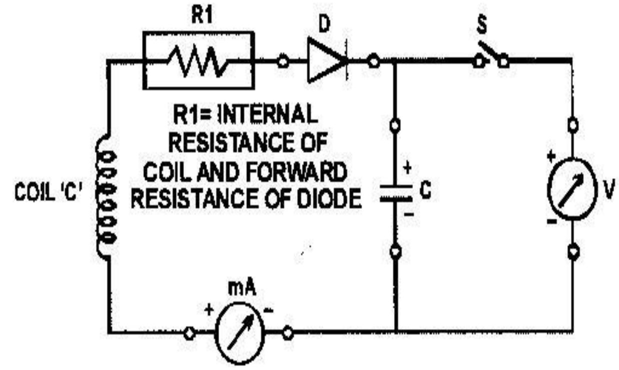
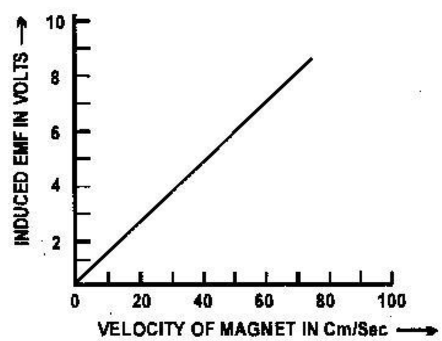


Fig. 4. Circuit Diagram for measuring v_{max}

2. When the milliammeter shows no more kicks, it means the capacitor C has reached the potential E_0 measure this potential by changing switch to ON position and take reading on Voltmeter.
3. Vary V_{max} by choosing different θ_0 values and measure E_0 each time.
4. Plot a graph of E_0 versus V_{max} and observe it is linear.
5. Repeat after shifting the loads A, A (Fig.2.) so that T changes. The E_0 versus V_{max} data in this set-up fall on the same graph line as in step 4.

OBSERVATION TABLE 1

S.No	Release angle θ_0 (deg)	Capacitor Potential E_0 (Volts)	$V_{max} = P\frac{4\pi}{T}\sin\frac{1}{2}\theta_0$ (cm/sec)
1			
2			
3			
4			
5			



`Fig.5. Ideal graph showing the variation of Induced emf with V_{max}

Part 2. To study the charge delivered due to electromagnetic induction

The induced emf E (eq.1) is applied in a circuit of resistance R the charge delivered is given by

$$q = \int_1^2 \frac{E}{R}dt = -\frac{1}{2}\int_1^2 \frac{d\Phi}{dt}dt = -\frac{1}{R}(\Phi_1 - \Phi_2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (4)$$

When the diode in the circuit of Fig.6 the capacitor C integrates one pulse of Fig.3 and does not receive the opposite pulse. The charge collected is (1/R) times the $\int E\,dt$

PROCEDURE:-

1 Make the connections as Fig 6. keep RC large compared with width τ by connecting resistance R (given on the panel) in the circuit (Fig 3) which is approximately given by the magnet length divided byV_{max}. With a given release angle θ_0 measure V across the capacitor for N swings taking n=1, 2, 3… by turns. (Each time hold the D by hand after n swings are completed and measure V)

2 Plot q=CV against number of swings (n). Observe the plot to be a straight line as shown in Fig 7.

3 Repeat with a different R values and observe the new q versus n curves.

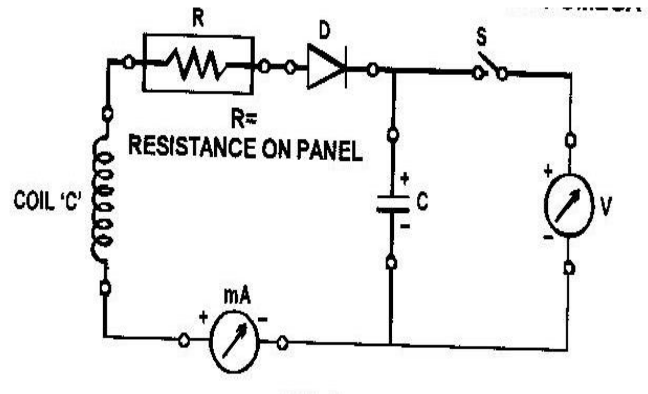


Fig. 6. Circuit Diagram for measuring Charge

OBSERVATION TABLE 2

Capacitance (C) in circuit = …….

Release angle θ_0 (deg) = ………

S.No	R1 (...)			R2 (...)		
	Swing 'n'	V (…) (Volts)	Charge Q=CV	Swing 'n'	V (…) (Volts)	Charge Q=CV
1						
2						
3						
4						
5						
6						
7						

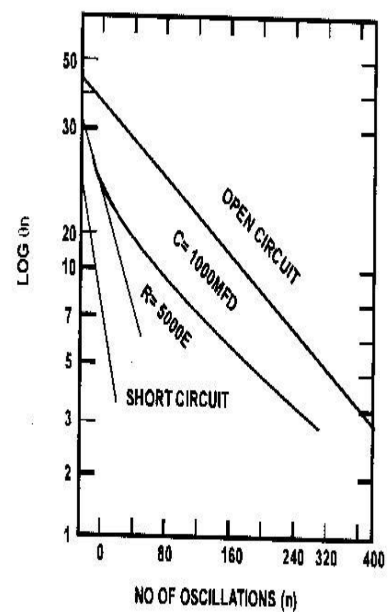


Fig.7. Graph showing the variation of Induced charge with no. of oscillations

RESULT

To be interpreted by the student basing on the observed data.

VIVA VOCE

3. What is electromagnetic induction?
4. State Faraday’s laws of electromagnetic induction.
5. Why Michael Faraday is called the father of electricity though he was not the one who discovered electricity?
6. What is damping?
7. What are eddy currents?
8. State Lenz law.

APPLICATIONS

1. The ground fault interrupter (gfi) is an interesting safety device that protects users of electrical appliances against electric shock. its operation makes use of faraday’s law.
2. Another interesting application of faraday’s law is the production of sound in an electric guitar.
3. Generators and motors.

EXPERIMENT – 9
YOUNG'S MODULUS

AIM

DETERMINATION OF YOUNG'S MODULUS OF ELASTICITY OF THE GIVEN SAMPLE MATERIAL BY BENDING.

APPARATUS

1. Sample Stand
2. Weights of 500 gm
3. Samples (Iron, Aluminum, Brass)
4. DC Adaptor
5. Weight Holder
6. Spherometer Stand with Buzzer

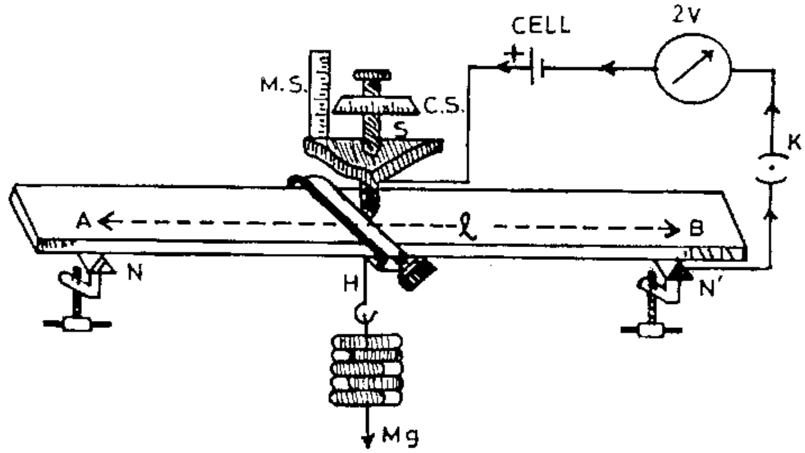


FIG. 1 BENDING OF BEAM APPARATUS

FORMULA

$$Y = \frac{mgl^3}{4bd^3\,e}\,\frac{\text{dynes}}{\text{cm}^2}$$

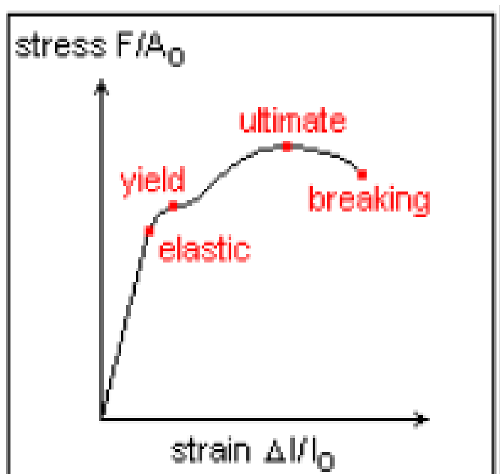
where

Y – Young's modulus of the material of beam.
m - Load (in gm);
l – length of beam (cm);
g – gravitational acceleration. (cm/sec^2)
b – Breadth (cm); d – thickness (cm);
e– depression of the beam produced by load(cm).

THEORY

Elasticity:

An important property of many structural materials is their ability to regain their original shape after a load is removed. These materials are called elastic. Steel, glass and rubber are elastic; putty or modeling clay are not elastic. Each of these materials is elastic to varying degrees; steel and glass are both more elastic than rubber. The degree of elasticity or "stiffness" of a material is called its Modulus of Elasticity (E). Using the modulus of elasticity, possible deformations can be calculated for any material and loading.



Stress-Strain Relation

Elastic body:

A body which regains its original shape when the deformation force is removed is called an elastic body.

Inelastic or Plastic body:

A body which cannot regain its original shape, when the deformation force is removed is called a plastic body.

Elasticity is molecular property of the matter. Elasticity is the property of an object or material which causes it to be restored to its original shape after distortion. It is said to be more elastic if it restores itself more precisely to its original configuration. A rubber band is easy to stretch, and snaps back to near its original length when released, but it is not as elastic as a piece of piano wire. The piano wire is harder to stretch, but would be said to be more elastic than the rubber band because of the precision of its return to its original length.

PROCEDURE

1. Mount the setup by fixing two long round rods with U-type brackets.
2. Tighten the sample (Iron) on Sample stands.
3. Place it horizontally on the smooth surface.
4. Tighten the Weight holder at the center of sample with the help of screw.
5. Place the spherometer stand, beyond the center of sample (Iron).
6. Adjust the spherometer height with the help of screw according to the sample.
Note: Spherometer leg must be in contact by rotating the Circular Scale with the center of the sample.
7. Connect buzzer with adaptor and connect patch cord with banana terminal, provided on the sample for buzzer connection.
8. Switch ‘On’ the supply for adaptor.
9. Buzzer blows because at this stage spherometer leg is in contact with the sample.
10. Consider spherometer Main Scale divisions 1 to 20 mm from top to bottom.
11. Note Pitch Scale (P.S) reading and Circular Scale reading (C.S) i.e., no. of divisions * 0.01mm (least count) reading in Observation Table 1 and find total reading M.S + C.S x lc
Note: This time there is no load on the sample it is said to be initial reading.

Increment of the Loads

12. Now place the 500 gm weight on the Weight holder with the help of T – Pin, at this stage buzzer stops blowing because spherometer leg is not in contact with sample owing to bending of rod.
13. Rotate the Circular Scale of spherometer (clock wise direction) till the buzzer blows (because when it touches the sample, circuit becomes complete and buzzer starts blowing).
14. Again note the readings of M.S. and C.S. * 0.01mm (least count) in Table 1, and then evaluate the total reading.
15. Depression of sample is determined by x_n-x_0. Tabulate the reading in observation Table 1.
16. Place one more 500 gm weight on the Weight holder, total 1 kg weight is hanging, at this time again buzzer stop blowing because spherometer leg is not in contact with sample.
17. Rotate the Circular Scale of spherometer till the buzzer blows (because when it touches the sample, circuit becomes complete and buzzer starts blowing).
18. Again note the readings of M.S. and C.S. * 0.01 (least count) in Table 1, and then evaluate the total reading.
19. Depressions of sample is determined by x_n-x_0. Tabulate the reading in observation Table 1.
20. Place 500 gm weights one by one on the Weight holder i.e., total weight will be1.5kg, 2kg, 2.5kg and 3.0kg. For these different weights position, repeat the steps 16 to 19 and tabulate the readings.
21. Tabulate all the readings in the given Observation Table 1.

Decrement of the Loads

22. At 0 gm load decreasing, spherometer reading is same as 3kg increasing load.

23. Now remove 500 gm weight from the Weight holder (i.e., decreasing of 0.5 kg load from sample) and again note main scale reading (M.S), circular scale reading (C.S) i.e., no of divisions * 0.01mm (least count) and find total reading.

Note: Before removing the weights rotate the spherometer fully anticlockwise.

24. Depression of sample is $X_n \sim X_{11}$. Tabulate the reading in Observation Table 1.

25. Now again remove 500 gm. weight from the Weight holder (i.e., decreasing of1kg load from sample) and again note main scale reading (M.S), circular scale reading (C.S) i.e., no of divisions * 0.01mm (least count) and find total readingi.

26. Remove 500 gm weights one by one from the Weight holder i.e., decrement of load will be 1.5kg, 2kg, 2.5kg and 3kg respectively. For these different weights position, repeat the steps 25 and 26 and tabulate the readings.

28. Tabulate all the readings in the given Observation Table 1 in the load decreasing column.

29. Take the mean of depressions individually d1 = (x1+x10)/2, d2 = (x2+x9)/2 ...and so on.

30. In Observation Table 2, insert all the values of individual Mean of depressions d1, d2, d3.......

OBSERVATION TABLE 1

S. No	Mass(M) in gm	Spherometer Reading When Load Increasing(in mm)				Spherometer Reading When Load Decreasing(in mm)				Depression (e) in cm	M/e gm/cm
		PSR a (mm)	HSC x l.c b (mm)	TR=a+b (in mm)	Depression d = $X_n \sim X_0$ (in cm)	PSR a (mm)	HSC x l.c b (mm)	TR=a+b (in mm)	Depression d =$X_n \sim X_{11}$ (in cm)		
1	0			X_0				X_{11}			
2	500			X_1	d_1			X_{10}	d_1	e_1	500/ e_1
3	1000			X_2	d_2			X_9	d_2	e_2	1000/ e_2
4	1500			X_3	d_3			X_8	d_3	e_3	1500/ e_3
5	2000			X_4	d_4			X_7	d_4	e_4	2000/ e_4
6	2500			X_5	d_5			X_6	d_5	e_5	2500/ e_5

Avg value of (M/e) = ……gm/cm

31. Take the length, breadth, depth of a given material of sample.

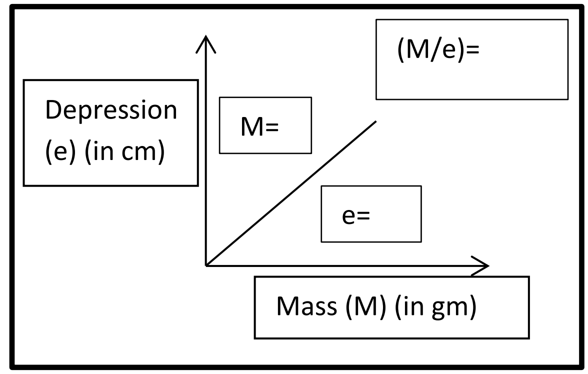
32. Length, Breadth, Depth all are in cm. Change it into meter.

l =................... (in meter) 1 m = 100cm
b =.................. (in meter) 1 m = 1000mm

d =.................. (in meter)

33. Put all the readings in given formula, where Y is elastic constant or Young's Modulus of elasticity.

$$Y = \frac{gl^3}{4bd^3}\left(\frac{M}{e}\right) \text{ dynes/ cm}^2$$



where 'm' is mass (in gm), g = 980 cm/sec^2, length (l)(cm), breadth (b) (cm),, depth (d) (cm),, depression(e) (cm) and Elastic Constant (Y) is in dynes/cm^2.

Draw a graph between Mass (M) on X-axis and Depression (e) on Y-axis, the plot should be a straight line passing through origin as shown. Find reciprocal of the slope from the graph and find the value of Young's Modulus.

RESULT

The value for Y from average value of (M/e) = ……….. dynes/ cm^2

The value for Y from graph value of (M/e) = ……….. dynes/ cm^2

The standard value of Young's Modulus for a given material = ………….. dynes/ cm^2

The error % = --------

PRECAUTIONS

1. The 'Beam' must be symmetrically placed on the knife edges K_1 and K_2.
2. The hanger must always be suspended at the centre of gravity of the beam.
3. To avoid backlash error spherometer should be rotated in one direction.
4. Special care should be taken in observing the thickness 'd' and depression 'e'
5. The elasticity of Aluminum and Brass samples is less so doesn't exceed weight more than 1.5kg on Weight holder.

APPLICATIONS

The elastic property of the material is useful while studying materials for industrial applications such as construction of bridges, railway wagons etc.

VIVA – VOCE

1. What is Hook's law?

Ans: Hooke's law of elasticity was discovered by the English scientist Robert Hooke in 1660, which states that, for relatively small deformations of an object, the displacement or size of the deformation is directly proportional to the deforming force or load. Under these conditions the object returns to its original shape and size upon removal of the load. Elastic behaviour of solids according to Hooke's law can be explained by the fact that small displacements of their constituent molecules, atoms, or ions from normal positions is also proportional to the force that causes the displacement.

Mathematically, Hooke's law states that the applied force F equals a constant k times the displacement or change in length x, or **F = kx**. The value of k depends not only on the kind of elastic material under consideration but also on its dimensions and shape.

2. What is modulus of elasticity?

Ans: An elastic modulus, or modulus of elasticity, is the mathematical description of an object or substance's tendency to be deformed elastically (i.e., non-permanently) when a force is applied to it. The elastic modulus of an object is defined as the slope of its stress–strain curve in the elastic deformation region.

$$\lambda = \frac{stress}{strain}$$

where lambda (λ) is the elastic modulus; stress is the restoring force caused due to the deformation divided by the area to which the force is applied; and strain is the ratio of the change caused by the stress to the original state of the object. If stress is measured in pascals, since strain is a dimensionless quantity, then the units of λ are pascals as well.

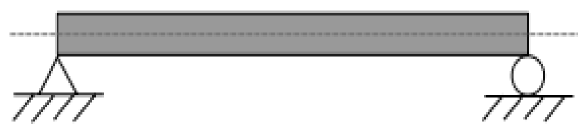
3. What is young's modulus?

Ans: Young's modulus (Y) describes tensile elasticity, or the tendency of an object to deform along an axis when opposing forces are applied along that axis; it is defined as the ratio of the longitudinal stress to the longitudinal strain. It is often referred to simply as the elastic modulus.

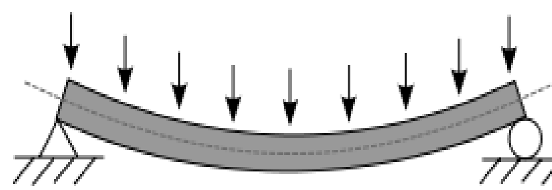
$$\text{Y} = \frac{longitudinal\ \ stress}{longitudinal\ \ strain}$$

4. What is a beam?

Ans: When the length of the rod of uniform cross-section is very large compared to its breadth such that the shearing stress over any section of the rod can be neglected, the rod is called a beam.



Beams are traditionally descriptions of building or civil engineering structural elements, but smaller structures such as truck or automobile frames, machine frames, and other mechanical or structural systems contain beam structures that are designed and analyzed in a similar fashion.



5. What is the change produced in depression when the thickness is doubled?

Ans: If thickness is doubled, then the depression is reduced to 1/8 of its previous value.

6. What is the change produced in depression when the breadth is doubled?

Ans: If breadth is doubled, then the depression is reduced to l/2 of its previous value.

7. What is the change in Young's modulus when the thickness and breadth of the bar is doubled?

Ans: Young's modulus does not change.

8. How are longitudinal strain and stress produced in your experiment?

Ans: Due to depression, the upper or the concave side of the beam becomes smaller than the lower or the convex side of the beam. As a result, longitudinal strain is produced.The change in length will be due to the force acting along the length of the beam. These forces will give rise to longitudinal stress.

Elastic Properties of different Materials

Material	Rigidity * $10^{10} N/m^2$	Young's Modulus * 10^{10} N/m^2	Poison's ratio
Steel	7.9 – 8.9	19.5 – 20.6	0.28
Aluminium	2.67	7.50	0.34
Copper	4.55	12.4 – 12.9	0.34
Iron (Wrought)	7.7 – 8.3	19.9 – 20.0	0.27
Brass	3.5	0.7 – 10.2	0.34 – 0.38