DETERMINATION OF PLANCK'S CONSTANT AND WORK FUNCTION OF METALS USING PHOTOELECTRIC EFFECT USER MANUAL

Aim: i) To determine Planck's constant '*h*' from the stopping Potential measured at different frequencies (wavelengths) of light.
ii) To determine the work function "Φ" of a metal.

APPARATUS:
The experiment set up consists of:

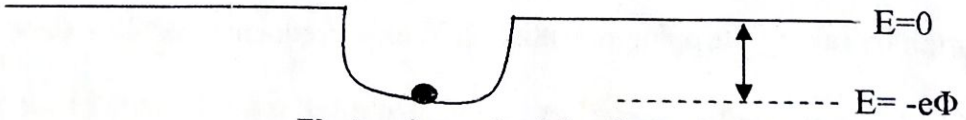
1. Main unit
2. Vacuum Photo tube
3. Light source
4. Color filters

Theory:
Most metals under the influence of radiation emit electrons. This phenomenon was termed as photoelectric emission. The detailed study of it has shown

- The emission process strongly depends on the frequency of radiation
- For each metal there exists a critical frequency such that the light of lower frequency is unable to make the electrons free from the metal, while the light of higher frequency always does.
- 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 the radiation.

The experimental facts given are among the strongest evidence that the electromagnetic field is quantified and field consists of quanta of energy E= *h*v, where v is the frequency of radiation and *h* is Plank's constant. These quanta are called photons.
Further it is assumed that electrons are bond inside the metal surface with an energy eΦ, where Φ is called work function. if the frequency of the light is *h*v > eΦ then it is possible to eject the photoelectron.
The slope of the graph of stopping potential as a function of Frequency yields h and the intercept of extrapolated point at frequency= 0 can give work function Φ.

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



Electron in a potential well at a depth "Φ"

Experimental Set up:
The experimental set-up consists of a light source with four different color filters, a vacuum phototube, a built-in power supply and a Main unit. The base of the phototube is built into a dark room and front side of it a arrangement is given to mount filters.

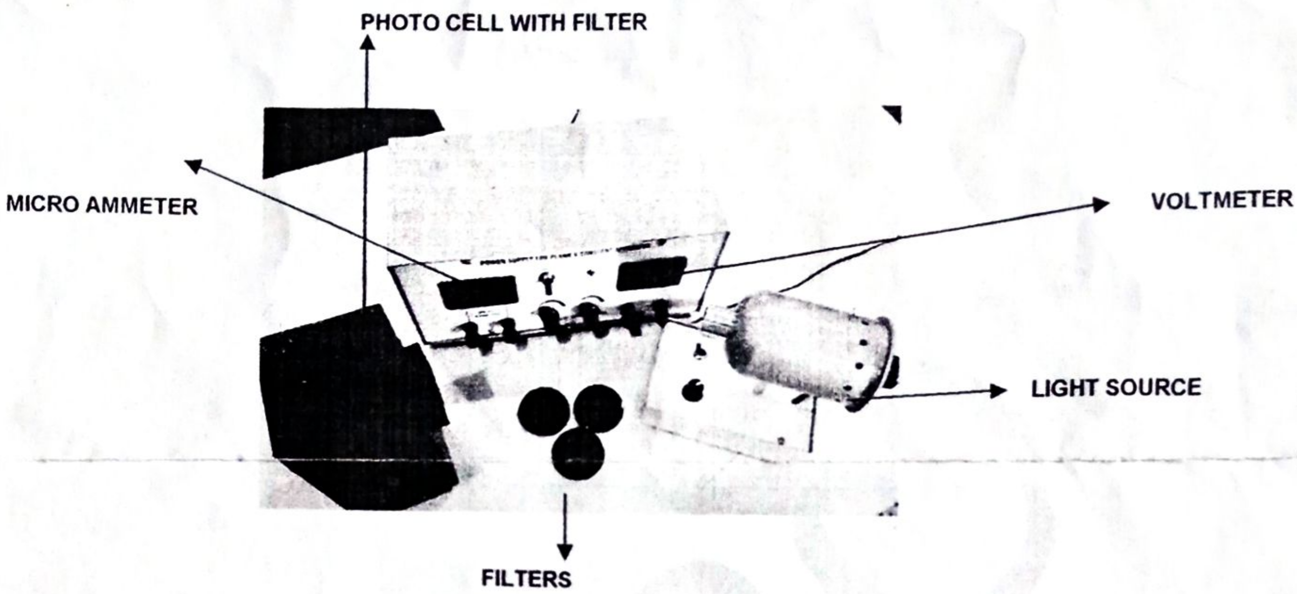


FIG (2)

PROCEDURE:
PLANK'S CONSTANT:

1. Make the connections as shown in fig1 and switch on the main unit.
2. Keep voltage control knob to its minimum position, set digital micro ammeter reading to zero with the help of zero adjust knob.
3. Arrange the light source and photo tube in such a way that light falls on the photo tube. The distance between photo tube and light source is adjusted such that there is a deflection of about 50μA-80μA in digital micro ammeter.
4. Now place a color filter in the path of the light (Slot is given to place filter).
5. After placing the filter there will be some reading in micro ammeter this is called photo current at zero anode potential.
6. Now slowly increase the voltage till current in micro ammeter becomes zero, this voltage is called as stopping potential V_0. Wait for some time and note down this reading in the space provided.
7. Repeat the experiment with different color filters and note down their stopping potential values.
8. Plot the graph by taking Stopping potential on Y-axis, frequency on X-axis and calculate the slope.
9. calculate plank's constant by using the formulae h= slope × e

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

$$T_{max} = \frac{1}{2} m v^2 = h\nu - e\Phi \quad \text{——— (1)}$$

Now consider the case of electrons being emitted by a photocathode in a vacuum tube, as illustrated Fig.2. In this case, all emitted electrons are slowed down as they approach the anode, and some of their kinetic energy is converted into potential energy. There are three possibilities that could happen.

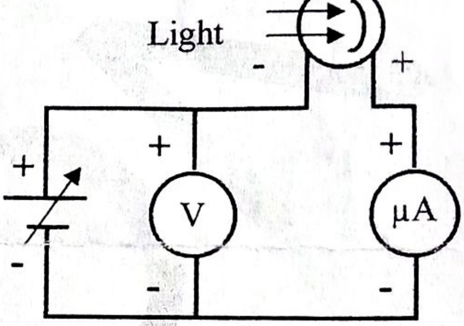


Fig.1

i) First, if the potential is small then the potential energy at the anode is less than the kinetic energy of the electrons and there is a current through the tube.
ii) The second is if the potential is large enough the potential energy at the anode is larger than the kinetic energy and the electrons are driven back to the cathode. In this case, there is no current.
iii) The third case is if the voltage just stops the electrons (with maximum kinetic energy Tmax) from reaching the anode. The voltage required to do this is called the "stopping potential" (V_0).

Thus Eq. 1 can be rewritten as,

$$eV_0 = h\nu - e\Phi$$

$$V_0 = \frac{h}{e}\nu - \Phi$$

It is worth noting here that, since the anode and cathode surfaces are different, an additional contact potential "A" comes into the picture which simply gets added to the work function "Φ". Above Eq. can be written as

$$V_0 = \left(\frac{h}{e}\right)(\nu) - (\Phi + A)$$

$$\Phi = \left(\frac{h}{e}\right)(\nu) - V_0 - A \quad \text{——— (2)}$$

Where Φ- work function
h- Planck's constant (Standard value of **h** is known to be 6.626×10^{-34} J-s.)
e- charge of electron = 1.602×10^{-19} coulombs
ν- Frequency of Particular color filter
V_0- Stopping potential for Particular color filter
A- contact potential

NOTE: Contact Potential A for this photo tube is = 0.5

WORK FUNCTION:

1. Calculate work function Φ for all the filters by substituting the values of plank's constant, frequency, stopping potential and charge of electron in equation (2). Note down readings in the space provided.

OBSERVATIONS AND TABULATIONS :

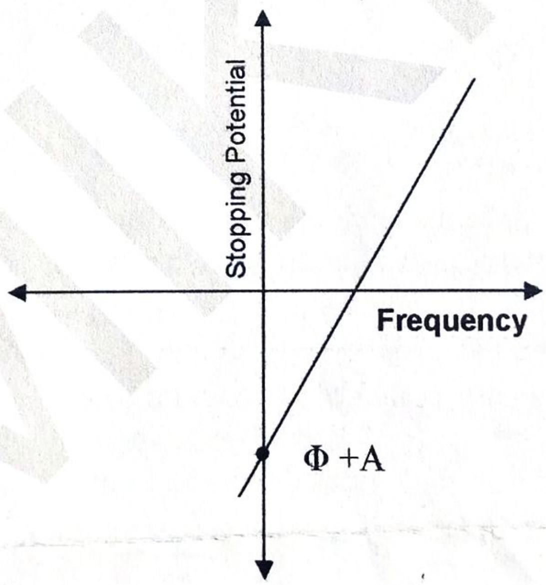
Specifications of filters: ***Unit No. 1808102***

Color	Blue	Green	Orange
Frequency (Hz)	6.06×10^{14}	5.40×10^{14}	5.08×10^{14}

Filter	Frequency (Hz)	Stopping Potential (V)	Work function (Φ)
Orange	5.08×10^{14}		
Green	5.40×10^{14}		
Blue	6.06×10^{14}		

PLANK'S CONSTANT h VALUE = ____________________.

GRAPH:



NOTE: DO NOT INTER CHANGE THE COLOR FILTERS OF ONE EXPERIMENTAL SETUP WITH OTHER. FOLLOW THE SERIAL NUMBER OF RESPECTIVE UNITS. INTERCHANGING WILL LEAD TO ERRONEOUS RESULTS.

HALL EFFECT EXPERIMENT USER MANUAL

AIM: To determine Hall Coefficient, Nature of charge carriers, Carrier Density & Carrier Mobility (Lorentz Force) of a semiconductor crystal.

APPARATUS: I.C regulated power supply, Electromagnets, Constant current power supply, Hall Sensor & Semiconductor Crystal.

Theory: When a transverse magnetic field (B) is applied to a semiconductor carrying current (I), an voltage is induced in the direction perpendicular to both current (I) & magnetic field (B). This phenomenon is known as Hall Effect. If the sign of Hall Coefficient is positive the semiconductor is of P-type& if the sign of Hall Coefficient is negative the semiconductor is of n-type.

Experiment 1: Hall current Vs Hall Voltage at constant Magnetic field.

Procedure:

1. Connect the IC regulated power supply terminals to Electromagnetic coils in their respective sockets.
2. Connect Hall probe to Gauss meter. Switch "ON" the Gauss meter, set the Gauss meter reading to "0.00" by adjusting the knob.
3. Now place the Hall probe in the magnetic field exactly at the center of the electromagnet cores. Set the gauss meter reading to 0.5KG magnetic field. This is achieved by applying suitable current to electromagnets & by simultaneously positioning the electromagnet cores by turning the knobs.
4. Connect the crystal mounted PCB to constant current power supply to their respective sockets.
5. Remove Hall probe from the magnetic field and place crystal in the same position without disturbing the position of magnetic cores.
6. Switch "ON" the constant current power supply & apply current in steps of 0.1mA, rotate the crystal till it becomes perpendicular to magnetic field. Hall voltage will be maximum in this adjustment, note the corresponding Hall voltage at constant magnetic field.
7. Plot the graph between current (I) and hall voltage (V_H) which is a straight line & find the slope.
8. Repeat the above steps from 3 to 7 for different values of magnetic fields say 0.75KG, 1KG, 1.25KG, 1.5KG, 1.75KG & 2KG.

NOTE:

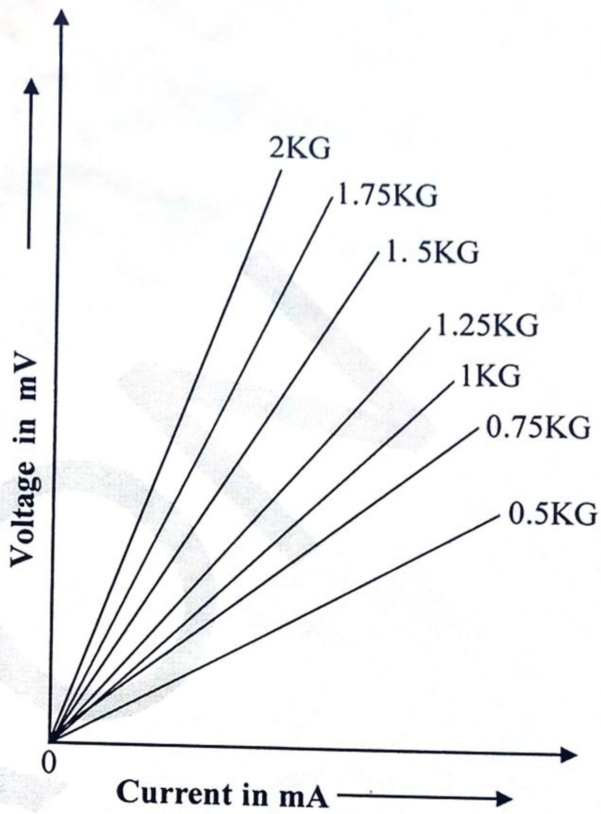
1. There may be some voltage even outside the magnetic field. This is due to the imperfect alignment of the four contacts of the crystal and is generally known as the "Zero Field Potential". In all the cases this error should be subtracted from the Hall voltage reading.

2. Gap between the magnetic cores should remain fixed for one set of readings.

TABULAR COLUMN:

SI NO	HALL CURRENT I,mA	HALL VOLTAGE V,mV
1	0.1	
2	0.2	
3	0.3	
4	0.4	
5	0.5	
6	0.6	
7	0.7	
8	0.8	
9	0.9	
10	1	
11	1.1	
12	1.2	
13	1.3	
14	1.4	
15	1.5	
16	1.6	
17	1.7	
18	1.8	
19	1.9	
20	2	
21	2.1	
22	2.2	
23	2.3	
24	2.4	
25	2.5	

IDEAL GRAPH:



Experiment 2: Magnetic Field Vs Hall Voltage at constant current across the Semiconductor.

Procedure:

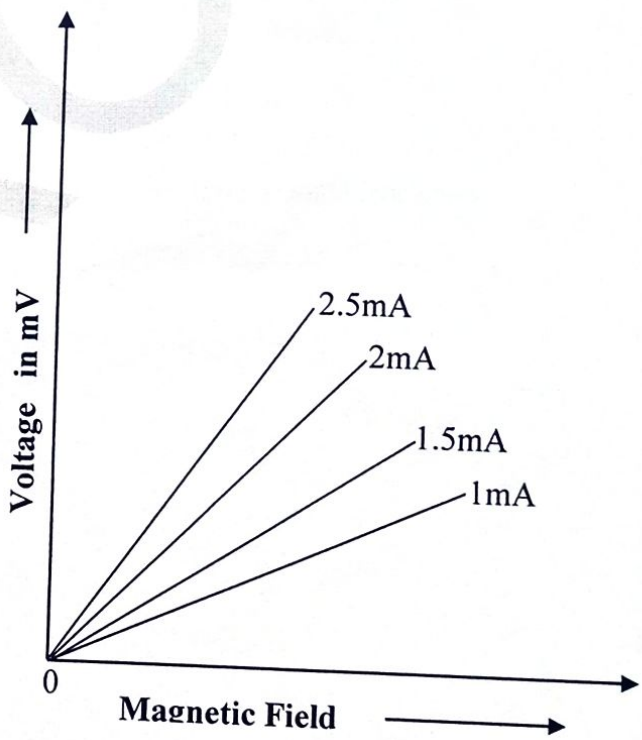
1. To demagnatise the coils, place the sensor mounted PCB exactly at the center of the core. Apply reverse current through the coils till the Gauss meter reads '0.00'
2. Switch "OFF" all the sources, set the IC regulated power supply (to the magnetic coils) knob to minimum.
3. Increase the gap between magnetic cores to maximum by turning the core knobs.
4. Place crystal & sensor mounted PCB together in the magnetic field exactly at the center of the magnetic cores gap.

5. Connect the crystal mounted PCB to constant current power supply to their respective sockets.
6. Connect Hall probe to Gauss meter. Switch "ON" the Gauss meter, set the Gauss meter reading to "0.00" by adjusting the knob.
7. Switch "ON" IC regulated power supply to the magnetic coils & constant current power supply.
8. Set the current across the crystal to 1mA, vary magnetic field (starting from 0.00 KG) in steps of 0.25KG.This can be achieved by applying current to electromagnetic coils & simultaneously changing the position of electromagnetic cores.
9. Note the corresponding Hall voltage at constant current through semiconductor sample.
10. Plot the graph between magnetic field (B) and hall voltage (V_H), which is a straight line & find the slope of the line.
11. Repeat the above steps from 2 to 6 for different values of current applied to semiconductor crystal say 1mA, 1.5mA, 2mA & 2.5mA.

TABULAR COLUMN:

SI NO	Magnetic Field,KG	Hall voltage,mV
1	0.00	
2	0.25	
3	0.50	
4	0.75	
5	1	
6	1.25	
7	1.50	
8	1.75	
9	2	

IDEAL GRAPH:



Description of Experimental Setup:

Fig (1) shows the experimental set up consisting of IC Regulated Power Supply of 2Amps for Magnetic Coils, Constant Current Source of 2mA for Crystal, Gauss Meter, Semiconductor Crystal mounted on PCB, Hall Sensor mounted on PCB
Coil arrangement with magnetic coils mounted on the wooden base, handles provided the coils moves the cores of the magnetic coils to change the magnetic field as desired. Brass bars provided on either side of the coils is used to hold the crystal & sensor PCB.

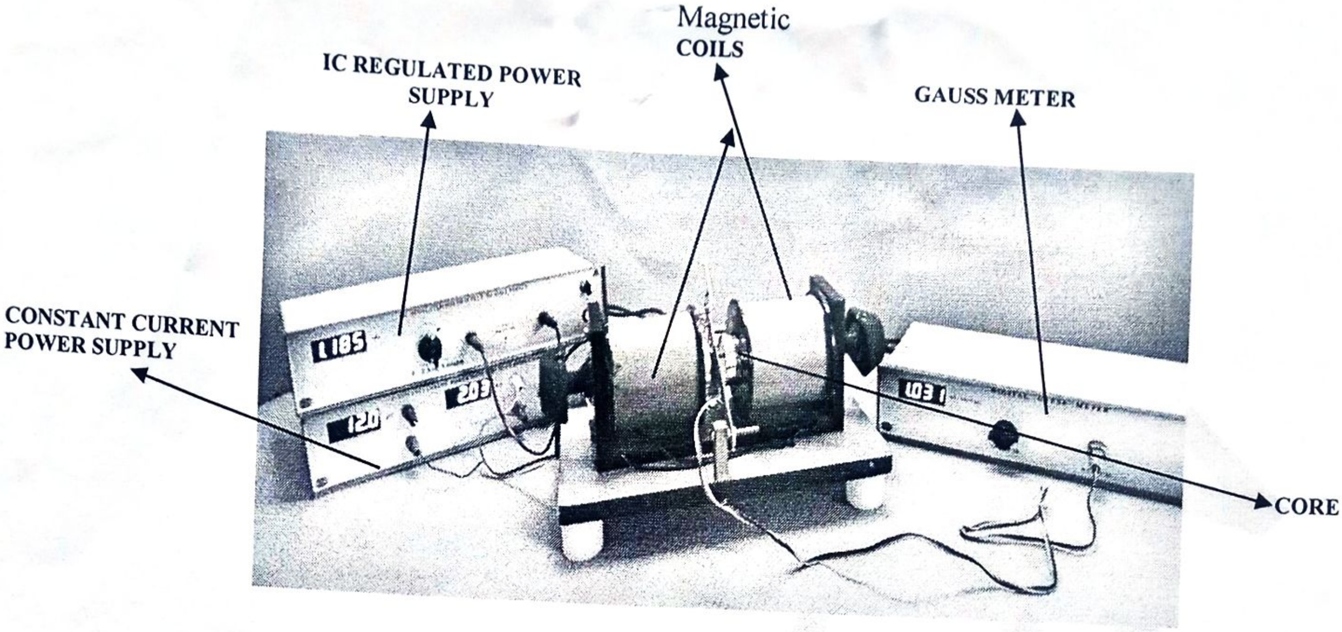
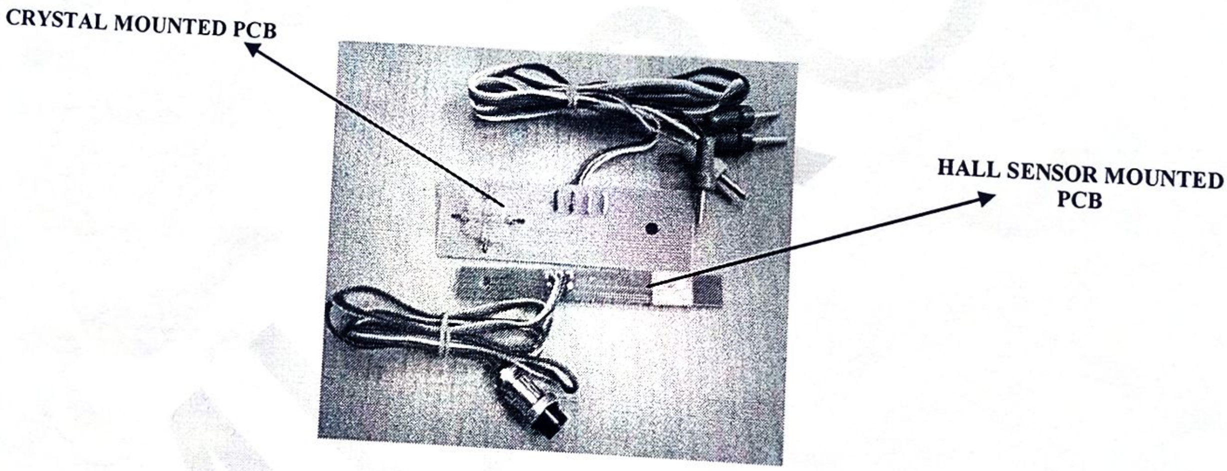


Fig (1)



Specifications of the Specimen supplied with the Set up:

Crystal type = Germanium p-type
Size = 5mm x 5mm
Thickness of the crystal (Z) = 0.7mm
Resistivity (ρ) = 2.1217 ohm m
Conductivity (σ) = 0.4713201col volt^{-1} sec^{-1}m^{-1}

Sample calculation for Hall Coefficient, Carrier Density & Carrier Mobility

Thickness of the Crystal (Z) = 0.7mm= 0.07cm
Resistivity (ρ) = 2.3578625 ohm m
Conductivity (σ) = 0.4241129 col volt^{-1} sec^{-1}m^{-1}

Calculation of Hall Coefficient (RH)

$$\text{Hall Coefficient } (R_H) = \frac{V_H \times Z}{I \times B}$$

Where V_H/I = Slope of 2KG graph
Z = Thickness of the crystal
B = Magnetic Field (2KG in this case)

Substituting the values in the equation :

$$\text{Hall Coefficient } (R_H) = \frac{20.478 \times 7 \times 10^{-2}}{2 \times 10^{3}}$$

$$= 71.673 \times 10^{3}\ cm^{3}\ col^{-1}$$

As per the calculation since the sign of Hall coefficient is positive, the semiconductor is P-type.

Calculation of Carrier Density :

Carrier Density (n) = $1/(R_H \times q)$

R_H= Hall Coefficient
q= Charge of an electron = 1.6×10^{-19} Coulombs

$$= \frac{1}{71.673 \times 10^{3} \times 1.6 \times 10^{-19}}$$

$$= 8.7201 \times 10^{13}\ cm^{3}$$

Calculation of Carrier Mobility:

Carrier Mobility (μ) = $R_H \times \sigma$

R_H= Hall Coefficient
σ =Conductivity

$= 71.673 \times 10^{3} \times .4477163$
$= 32089.185 \times 10^{-2}$ cm $volt^{-1}$ sec^{-1}

7 Resonance in LCR circuits

Purpose of the experiment :

1. To study resonance effect in series and parallel LCR circuit.
2. To determine the resonant frequency.
3. To determine self-inductance.
4. To determine quality factor of the coil in the series and parallel circuits.

Apparatus :

Oscillator (function generator), variable capacitor (set of capacitor), resistance, resistance box, inductor, AC mill voltmeter, connecting wires and plug key.

Introduction and Theory :

The electrical analog of the damped mass-spring oscillator [Resonating mechanical system] is the LCR circuit. In the electrical case it is the charge q(t) on the capacitor (or the current (I= dq/dt)) that satisfies a differential equation analogous to the displacement of the mass in the familiar spring mass system. The inductance L acts as the "inertia" of the system, while the reciprocal of capacitance 1/C=V/Q acts as the "force constant", in this case voltage per unit charge, which is a kind of "electrical pressure". Not surprisingly, the resistance R serves as the source of damping.

The correspondence between mechanical and electrical parameters is shown in the following table.

Mechanical System	Electrical System
Displacement (x)	Charge (q)
Driving Force (F)	Driving Voltage (V)
Mass (m)	Inductance (L)

Mechanical System	Electrical System
Damping Constant (b)	Resistance (R)
Spring Constant (k)	Reciprocal Capacitance (1/C)
Resonant Frequency $\sqrt{\frac{k}{m}}$	Resonant Frequency $1/\sqrt{LC}$
Resonance Width $\gamma = b/m$	Resonance Width $\gamma = R/L$

The forced damped harmonic equation (mechanical system) is given.

$$\frac{d^2x}{dt^2} + \frac{b}{m}\frac{dx}{dt} + \frac{k}{m}x = \frac{f_o}{m}\cos\omega t$$

The above equation can be modified as below

$$\frac{d^2x}{dt^2} + \frac{\omega_o}{Q}\frac{dx}{dt} + \omega_o^2 x = \omega_o^2 A_{LF}\cos\omega t \quad \text{-------} \quad [1]$$

$$\frac{k}{m} = \omega_o^2$$

$$\frac{b}{m} = \gamma$$

$$Q = \frac{\omega_o}{\gamma}$$

$$A_{LF} = \frac{F_o}{k} = \frac{F_o}{m\omega_o^2}$$

The equation [1] becomes equation [2] by substituting the mechanical variables by electrical parameters.

$$L\frac{d^2q}{dt^2} + R\frac{dq}{dt} + \frac{q}{c} = V_o\cos\omega t \quad \text{--------} \quad [2]$$

and all the other equations can be rewritten in terms of the electrical parameters.

In the series LCR circuit, an inductor (L), capacitor (C) and resistance(R) are connected in series with a variable frequency sinusoidal emf source and the voltage across the resistance is measured. As the frequency is varied, the current in the circuit (and hence the voltage across R) becomes maximum at the resonance frequency. In the parallel LCR circuit there is a minimum of the current at the resonance frequency.

If V_i is the driving voltage a current, I will flow in the circuit. At an angular frequency ω_0 of the *ac* source, the current I will be in phase with the voltage V. This condition is called as resonance and the circuit is referred to as a series resonant LCR circuit. If the inductance L is connected in parallel with a capacitance C and a resistance R, the circuit is called as a parallel resonant LCR circuit.

Formulae :

$$\omega_o = \frac{1}{\sqrt{LC}}$$

but $\omega_0 = 2\pi f_r$ and hence

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

$$L = \frac{1}{4\pi^2 f_r^2 C}$$

$$Q = \frac{\omega_o L}{r} \Rightarrow Q = \frac{f_r}{\Delta f}$$

= Resonant frequency f_r / Bandwidth Δf

where, $\Delta f = f_1 - f_2$ is band width which will be calculated from the graph.

Here f_2 is the point beyond the f_r, f_1 is the point before the f_r.

ω_0 is the angular frequency in hertz.

L is the inductance of the coil in Henry.

C is the capacitance of the capacitor in micro farad.

R is the resistance of the resistor in ohm.

f_r is the resonant frequency of the series or parallel resonant circuit in hertz.

Q is the quality factor of the coil.

r is the resistance of the coil in ohm.

Procedure :

I. SERIES RESONANCE CIRCUIT

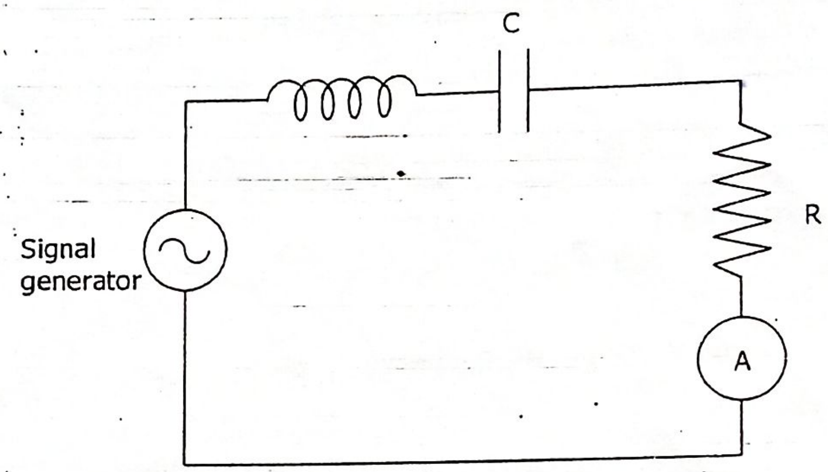


Fig. 1 : LCR Series circuit

1) The capacitance (C), inductance (L), resistance (R) and a milli ammeter (mA) are connected in series with a function generator as shown in the figure-1.

2) The capacitance (C) and resistance (R) are set to be particular values [0.1 μF, 50 ohms]

3) The frequency oscillator is adjusted to a minimum value of 1 kHz.

4) The current shown by milli-ammeter is noted.

5) Keeping the C and R values as a constant, the frequency of function generator is increased in steps, the corresponding milli-ammeter(current) readings are noted.

6) The same procedure is repeated for different resistances, for the same range of frequency and the readings are tabulated.

7) A graph is drawn with frequency along the X-axis and the current along the Y-axis. The frequency at which the current is maximum is the resonant frequency.

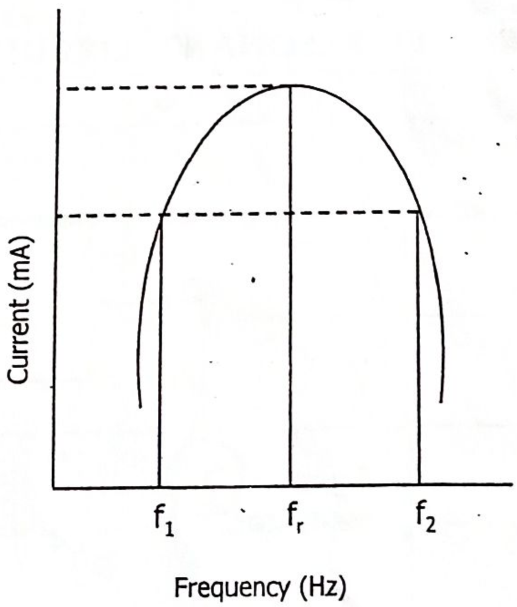
To determine resonant frequency in series mode

Tabel - 1

Capacitance (C) in μF = Resistance R in Ω =

S.No.	Frequency (Hz)	Current (mA)

Model Graph :



Graph-1 : Frequency verses current graph for series LCR circuit

From graph-1

Resonant frequency f_r =

Bandwidth $\Delta f = f_1 - f_2 =$

Calculation :

Series Resonant Circuit

a) Resonant frequency from graph (1) is found to be f_r = ... Hz.

b) $L = \dfrac{1}{4\pi^2 f_r^2 C}$ L =

'C' is the capacitance set is μF.

L = ... milli Henry.

c) Quality factor $Q = \dfrac{\omega_o L}{r}$ $\therefore Q = \dfrac{f_r}{\Delta f}$

where 'r' is the resistance, and it is practically the resistance of the inductance coil and is measured using a multimeter.

II. PARALLEL RESONANT CIRCUIT

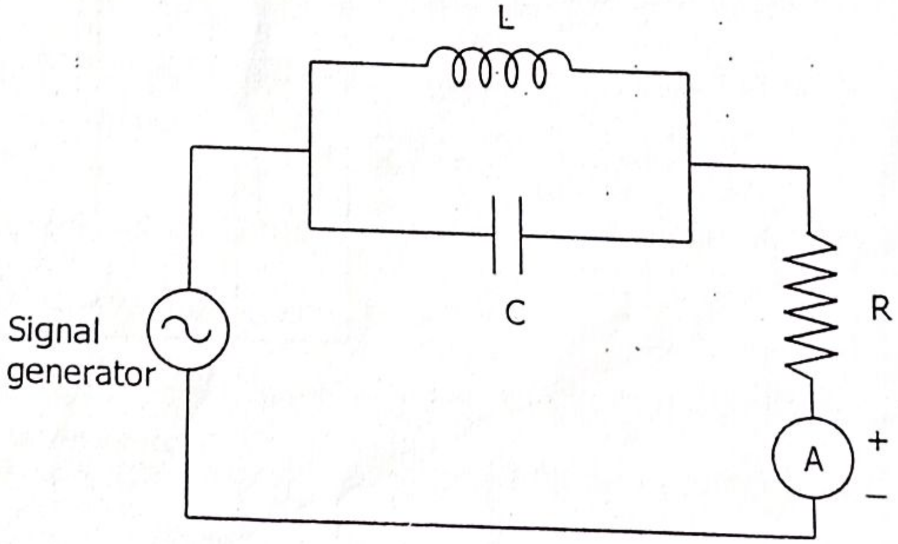


Fig. 2 : LCR Parallel circuit

1) The inductance (L), the resistance (R), are connected in parallel to the capacito (C).

2) The milli-ammeter (mA) and function generator are connected as shown in figure-2.

3) The capacitance (C) and the resistance (R) are set to be particular values [0.1 μF and 50 ohms].

4) The audio frequency of function generator is adjusted for a minimum value of frequency.

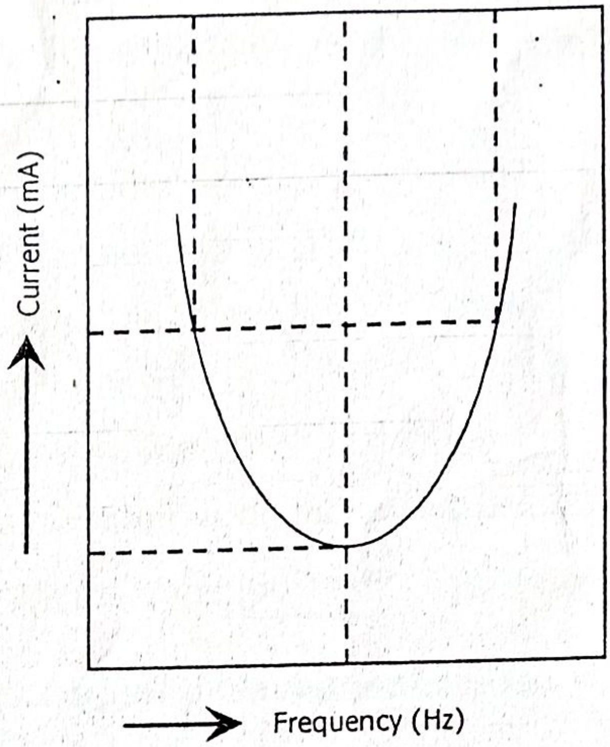
5) The current in the circuit shown by the milli-ammeter is noted.

6) Keeping the C and R values to be constant, the frequency is increased in steps, the corresponding milli-ammeter readings are noted.

7) The procedure is repeated for different resistance values for the same range of frequency and readings are tabulated.

8) A graph is drawn with the frequency along the X-axis and the current along the Y-axis. The frequency at which the current is minimum is the resonant frequency.

Model Graph :



Graph-2 : Frequency verses current graph for parallel LCR circuit

From graph-2

Resonant frequency f_r =

Bandwidth $\Delta f = f_1 - f_2 =$

Calculation :

Parallel Resonant Circuit

a) Resonant frequency from graph (2) is found to be f_r = ... Hz.

b) $L = \dfrac{1}{4\pi^2 f_r^{\,2} C}$ L =

'C' is the capacitance set is μF.

L = ... milli Henry.

c) Quality factor, $Q = \frac{\omega_0 L}{r}$ (or) $Q = \frac{f_r}{\Delta f}$

where 'r' is the resistance, and it is practically the resistance of the inductance coil and is measured using a multimeter.

Result :

For a Series Resonant Circuit

1. The resonant frequency f_r = ... Hz.
2. The inductance of the coil was found to be L = ... mH.
3. Quality factor was calculated to be Q = ...

ZENER DIODE AND PN JUNCTION DIODE CHARACTERISTICS
USER MANUAL

AIM: To find V-I Characteristics Curve of Zener Diode and PN Junction Diode.

MICRO BOARD CONSISTS OF:

1. Variable power supply (0-2V) and (0-10v).
2. Dual range Digital Ammeter.
3. Dual range Digital Voltmeter.
4. Set of PN diode and Zener diodes
5. Resistors

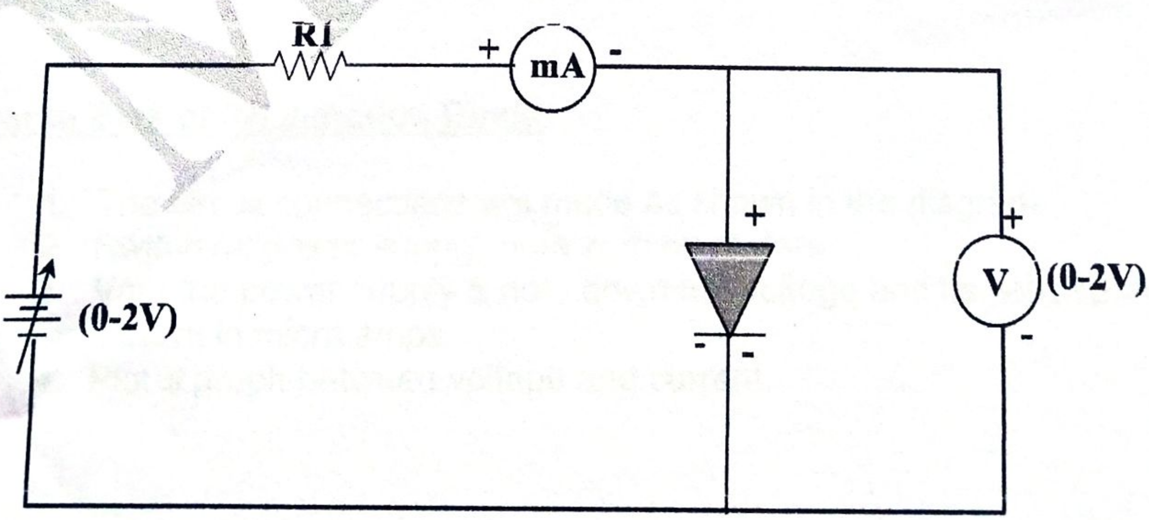
THEORY:

Forward Bias Characteristics

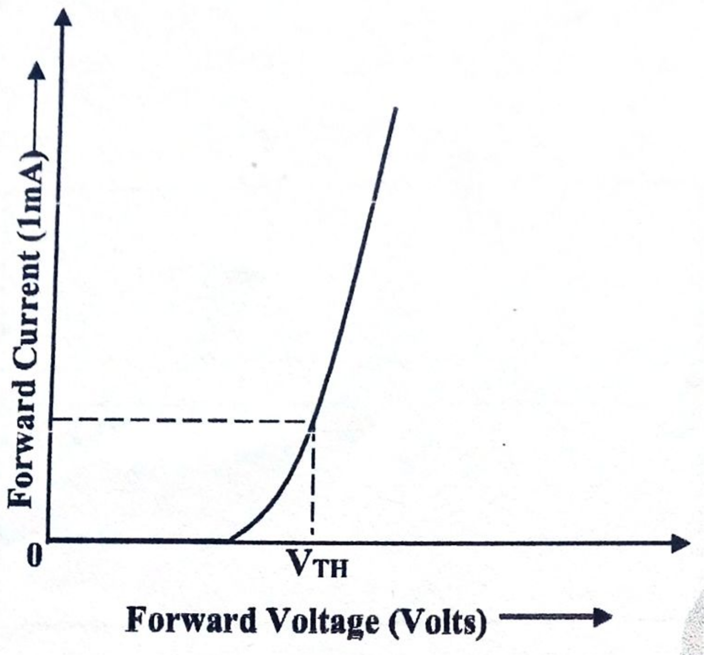
The Junction is said to be forward biased when the "P" sections of the diode is to positive terminal and "N" section of the diode is connected to negative terminal of the source, with an increase in the voltage the current also increase, for silicon diode Knee Voltage rises from 0.5 – 0.75V & for Germanium 0.2 – 0.3V.

PROCEDURE: Forward Bias of PN Junction Diode

1. The circuit connections are made as shown in the diagram.
2. Switch on power supply note zero on meters.
3. Vary the power supply note down the readings of voltage and the correspondingly current in milli amps.
4. Plot a graph between voltage and current.
5. Note the forward voltage at which a significant amount of current starts flowing through the diode is the knee voltage of the diode.
6. Diodes IN4007& IN4148 are silicon diodes OA79 is Germanium diode.



IDEAL GRAPH:



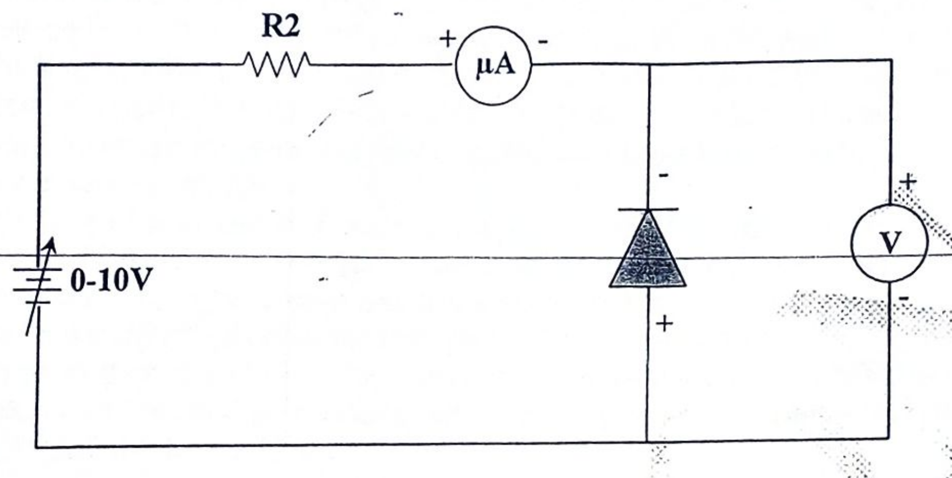
V_{TH} FOR SILICON DIODE 0.5V- 0.7V
V_{TH} FOR GERMANIUM DIODE 0.2V- 0.3V

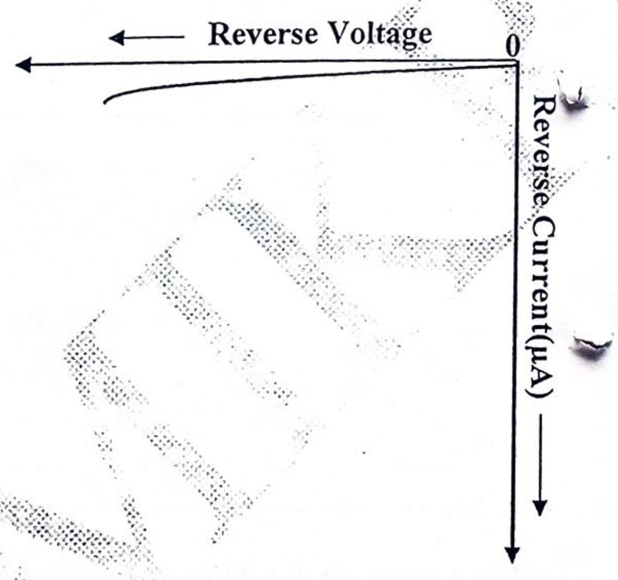
Reverse bias Characteristics

The Junction is said to be reverse biased when the "P" section of the diode is connected to Negative terminal and" N" section of the diode is connected to positive terminal of the source, with an increase in the voltage there is a small change in the current, reverse current increases to higher value with an increase in the voltage.

Reverse Bias of PN Junction Diode

1. The circuit connections are made as shown in the diagram.
2. Switch on power supply, note zero on meters.
3. Vary the power supply & note down the voltage and its correspondingly current in micro amps.
4. Plot a graph between voltage and current.


R2
μA
V
0-10V

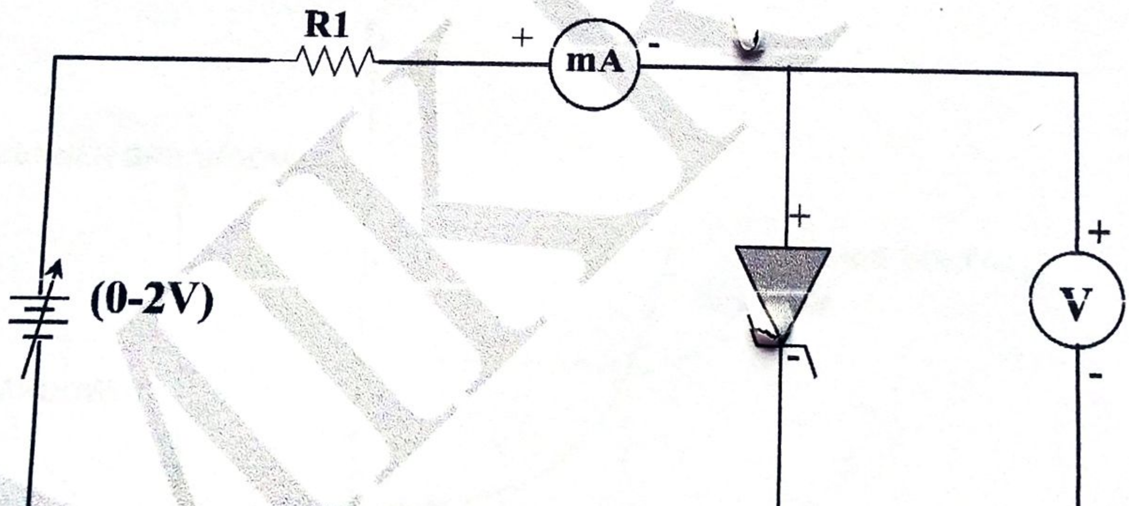

Reverse Voltage
0
Reverse Current(μA)

THEORY:

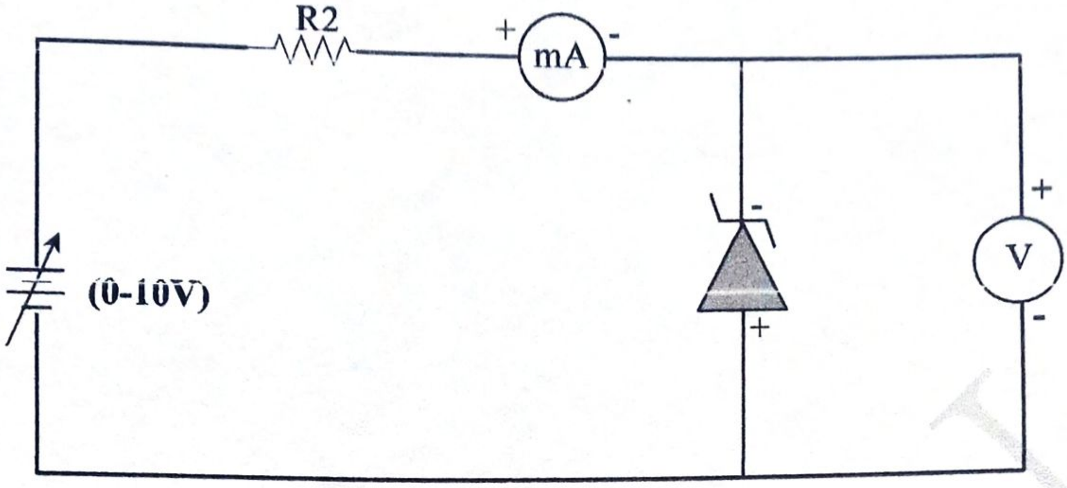
Zener diode is a heavily doped PN junction diode. Due to heavily doped, its depletion layer is very thin and is order of micrometer. The forward bias characteristic of Zener diode is same as the normal PN junction diode but in reverse bias it has different characteristic. Initially, a negligible constant current flow through the Zener diode in its reverse bias but at certain voltage, the current becomes abruptly large. This voltage is called as Zener voltage. This sudden and sharp increase in Zener current is called as Zener breakdown.

Avalanche Breakdown:

This type of breakdown occurs in the presence of a high electric field. When we apply a high electric field in a reverse biased condition, the electrons start gaining high kinetic energy. These electrons start breaking other covalent bonds and start creating more hole-electron pairs. These pairs start crossing the depletion region and contribute to a high reverse reverse biased current. The breaking of bond is an irreversible process, and the p-n junction is completely destroyed after an avalanche breakdown.

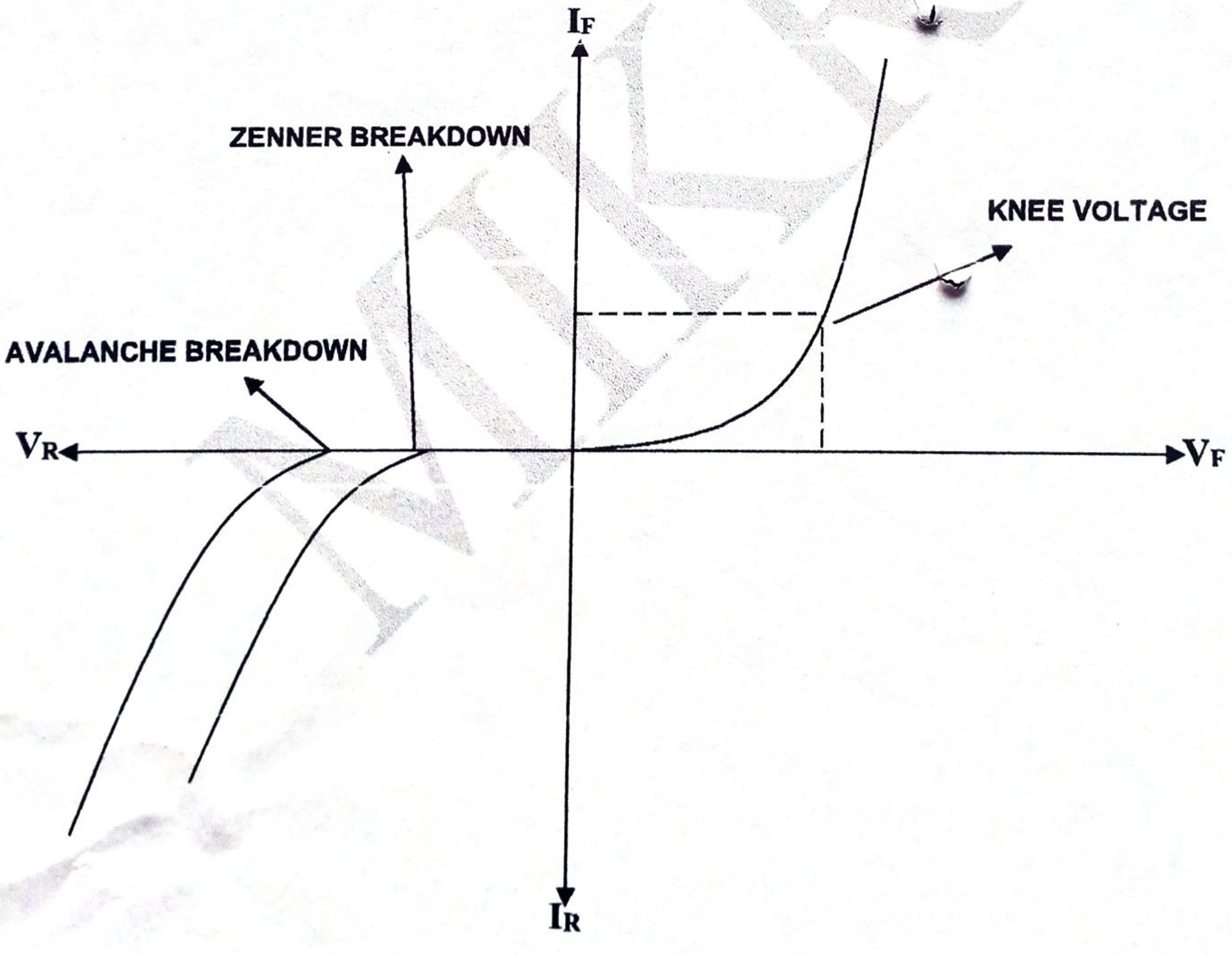


FORWARD BIAS OF ZENER DIODE



REVERSE BIAS OF ZENER DIODE

IDEAL GRAPH:



TRANSISTOR CHARACTERISTICS USER MANUAL

AIM: To Study and plot the input and output Characteristics of both PNP and NPN transistors for CE, CB, CC configurations.

MICRO BOARD CONSISTS OF:

1. Variable Power Supply (0-3V) -01, (0-10V)-01
2. Dual Range Digital Ammeter µA/mA - 01
3. Digital Voltmeter- 02
4. Digital Ammeter (mA) – 01
5. SL 100 – NPN Transistor
6. SK 100 – PNP Transistor
7. Resistors

THEORY: Since the transistor is a three terminal device it can be connected in a circuit in three different ways.
1.Common Base Configuration
2.Common Emitter configuration
3.Common Collector Configuration

COMMON BASE CONFIGURATION: -

INPUT CHARACTERISTICS: - It is the curve between emitter current I_E and emitter –base voltage V_{EB} at constant collector-Base V_{CB}. The emitter current is generally taken along y-axis and emitter base voltage along x-axis. Fig (1) shoes the input characteristics of a typical transistor in CB arrangement. The following points may be noted from these characteristics.
1. The emitter current I_E increase rapidly with small increase in emitter-base voltage V_{EB}. It means that input resistance is very small.
2. The emitter current is almost independent of collector-base voltage V_{CB}. This leads to the conclusion that emitter current (and hence collector current) is almost independent of collector voltage.

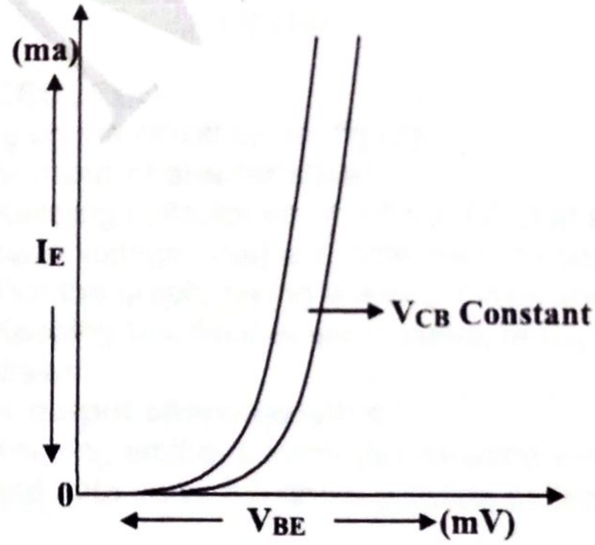


Fig (1)

OUTPUT CHARACTERSISTICS: - It is the curve between collector current I_C and collector-base voltage V_{CB} at constant emitter current IE. Generally, collector current is taken along y-axis and collector-base voltage along x-axis. Fig (1a) shows the output characteristics of a typical transistor in CB arrangement.

The following points may be noted from the characteristics:

1. The collector current I_C varies with V_{CB} only at very low voltages (<1V). The transistor is never operated in this region.
2. When the value of V_{CB} is raised above 1-2v, the collector current becomes constant as indicated by straight horizontal curves. It means that now I_C is independent of V_{CB} and depends upon I_E only. This is consistent with the theory that the emitter current flows almost entirely to the collector terminal. The transistor is always operated in this region.
3. A very large change in collector-base voltage produces only a tiny change in collector current. This means that resistance is very high.

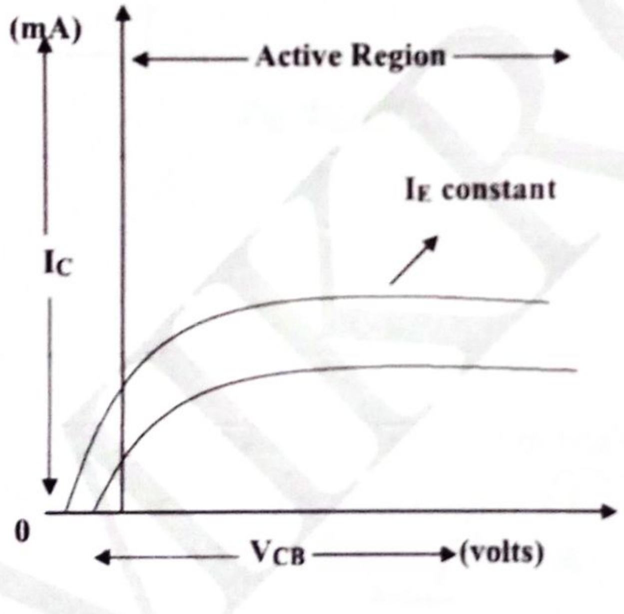


Fig (1a)

PROCEDURE: -

1. Rig up the circuit as per fig (2).
2. **For input characteristics:**
   (a) Keeping collector base voltage (V_{CB}) at some fixed voltage. Vary the emitter base voltage (V_{EB}) and note the corresponding emitter current.
   (b) Plot the graph, taking I_E along Y-axis and V_{CE} along X-axis, at constant V_{CB}.
   (c) Keeping V_{CB} fixed at some value, family of input characteristics can be drawn.
3. **For output characteristics:**
   (a) Keeping emitter current (I_E) constant vary the collector base voltage (V_{CB}) and note down the corresponding collector current (I_C).

(b) Plot the graph taking Ic along Y-axis and VCB along X-axis, at constant emitter current.

(c) Keeping emitter current fixed at some value, family of output characteristics can be drawn.

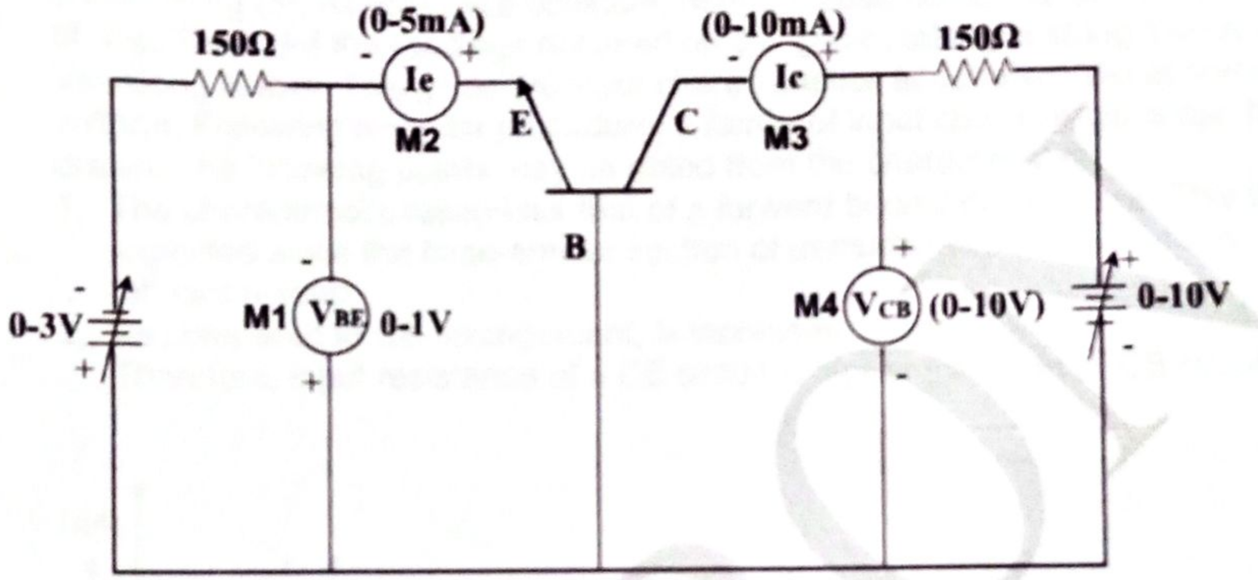
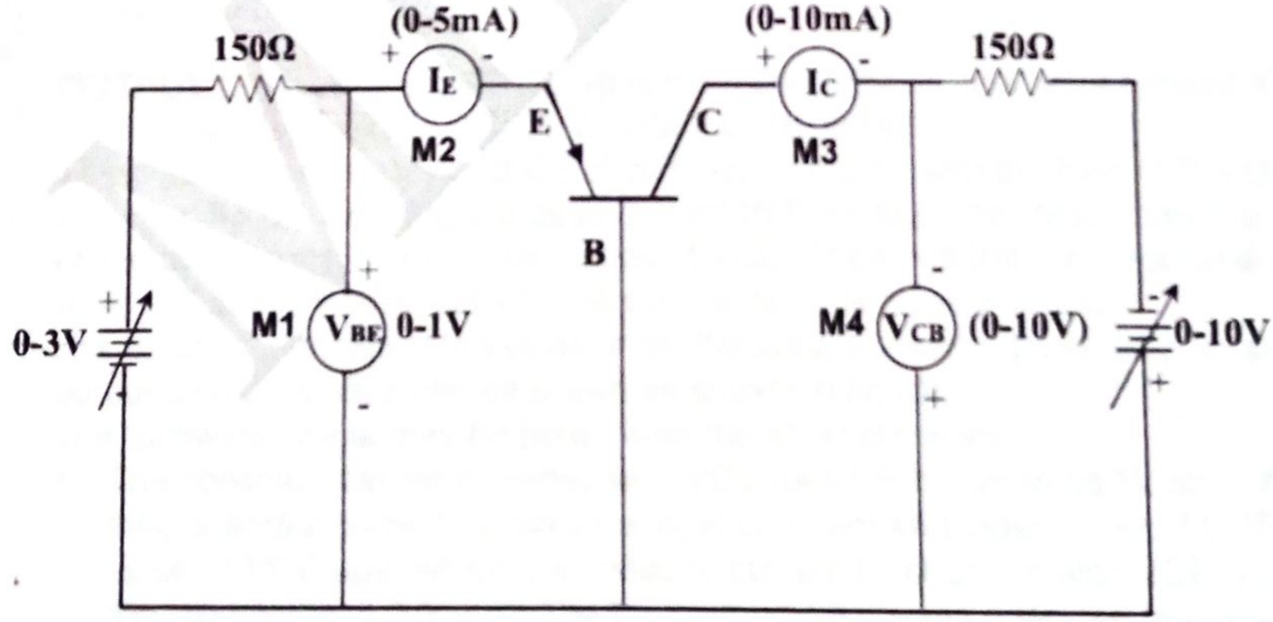


Fig (2) <u>NPN CONFIGURATION</u>



Fig(2a) <u>PNP CONFIGURATION</u>

COMMON EMITTER CONFIGURATION:-

INPUT CHARACTERISTICS: -It is the curve between the base current I_B and base emitter voltage V_{BE} at constant collector-emitter voltage V_{CE}.
The input characteristics of a CE connection can be determined by the circuit shown in fig (3). Keeping V_{CE} constant, note the base current I_B for various values of V_{BE}. Then plot the readings obtained on the graph, taking I_B along Y-axis and V_{BE} along X-axis. This gives the input characteristics at constant V_{CE} at some voltage. Following a similar procedure, a family of input characteristics can be drawn. The following points may be noted from the characteristics.

1. The characteristic resembles that of a forward biased diode curve. This is expected since the base-emitter section of transistor is a diode and it is forward biased.
2. As compared to CB arrangement, I_B increases less rapidly with V_{BE}. Therefore, input resistance of a CE circuit is higher than that of CB circuit.

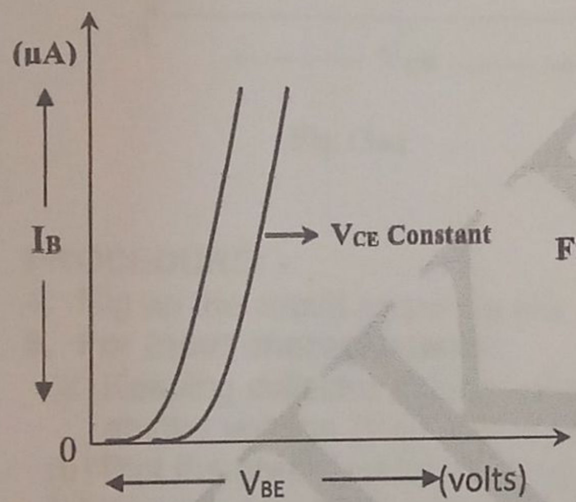


Fig (3)

OUTPUT CHARACTERISTICS: -It is the curve between collector current IC and collector emitter voltage VCE at constant base current.
The output characteristics of CE circuit can be drawn with the help of the circuit shown in fig (2). Keeping the base current IB fixed to some value, note the collector current IC for various values of VCE. Then plot the readings on a graph taking IC along Y-axis and VCE along X-axis. This gives the output characteristics at different values of IB. following the same procedure, a family of output characteristics can be drawn as shown in fig (3a)).
The following points may be noted from the characteristics.

1. The collector current IC varies with VCE for VCE between 0&1V only. After this, collector current becomes almost constant and independent f VCE. This value of VCE upto which the collector current IC changes with VCE is called the knee voltage (Vknee). The transistors are always operated in the region above knee voltage.
2. Above knee voltage, IC is almost constant. However, a small increase in IC with increasing VCE is caused by the collector depletion layer getting wider and capturing a few more majority carriers before electron hole combinations occur in the base area.

3. For any value of V_{CE} above knee voltage, the collector current I_C is approximately equal to $\beta \times I_B$.

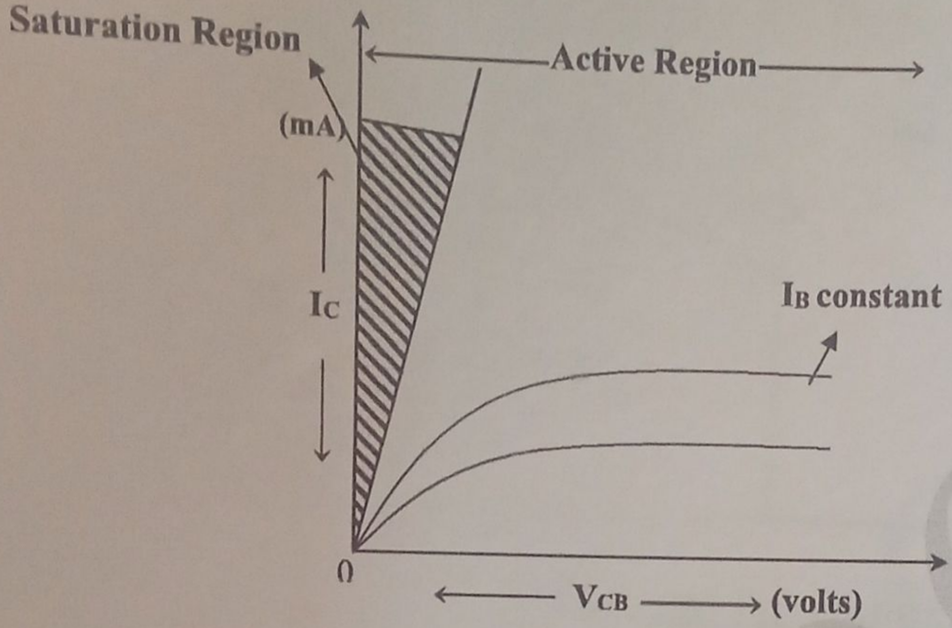


Fig (3a)

PROCEDURE: -

4. Rig up the circuit as per fig (4).
5. **For input characteristics:**
   (a) Keeping collector emitter voltage (V_{CE}) at some fixed voltage. Vary the base emitter voltage (V_{BE}) and note the corresponding base current.
   (b) Plot the graph, taking I_B along Y-axis and V_{BE} along X-axis, at constant V_{CE}.
   (c) Keeping V_{CE} fixed at some value, family of input characteristics can be drawn.
6. **For output characteristics:**
   (a) Keeping base current (I_B) constant vary the collector emitter voltage (V_{CE}) and note down the corresponding collector current (I_C).
   (b) Plot the graph taking I_C along Y-axis and V_{CE} along X-axis, at constant base current.
   (c) Keeping base current fixed at some value, family of output characteristics can be drawn.

CIRCUIT DIAGRAM: -

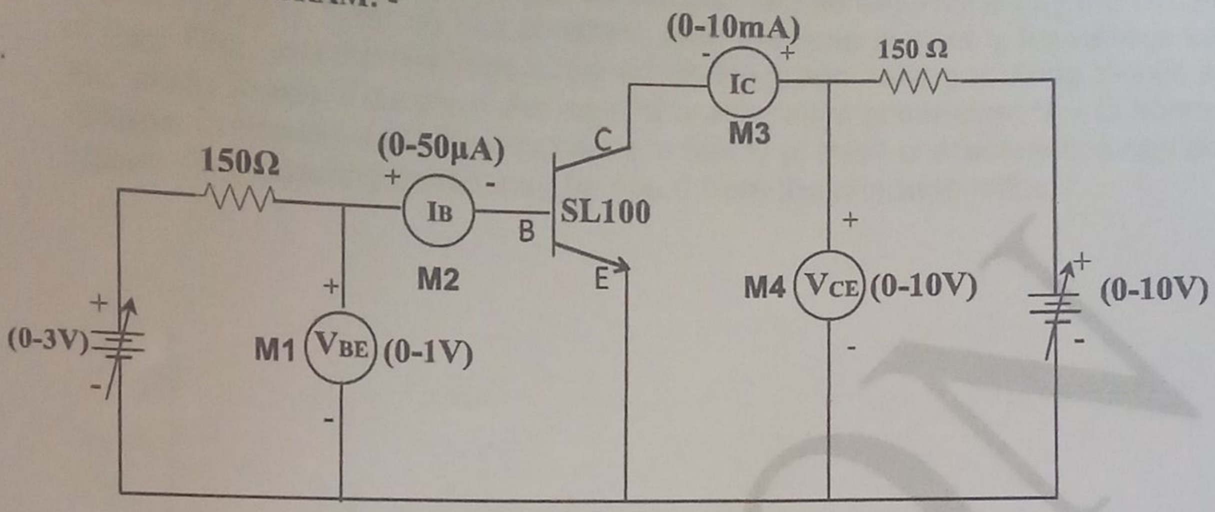


Fig (4) **NPN CONFIGURATION**

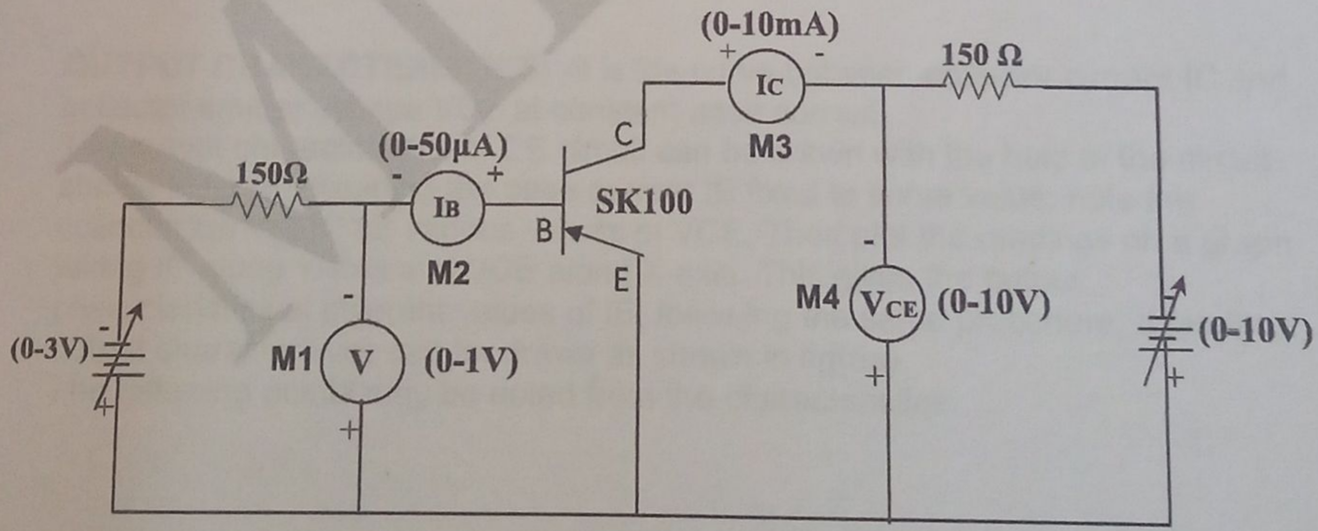


Fig (4a) **PNP CONFIGURATION**

COMMON COLLECTOR CONFIGURATION: -

INPUT CHARACTERISTICS: -It is the curve between the base current I_B and base collector voltage V_{BC} at constant collector-emitter voltage V_{CE}.
The input characteristics of a CC connection can be determined by the circuit shown in fig (5). Keeping V_{CE} constant, note the base current I_B for various values of V_{BC}. Then plot the readings obtained on the graph, taking I_B along Y-axis and V_{BC} along X-axis. This gives the input characteristics at constant V_{CE} at some voltage. Following a similar procedure, a family of input characteristics can be drawn. The following points may be noted from the characteristics.

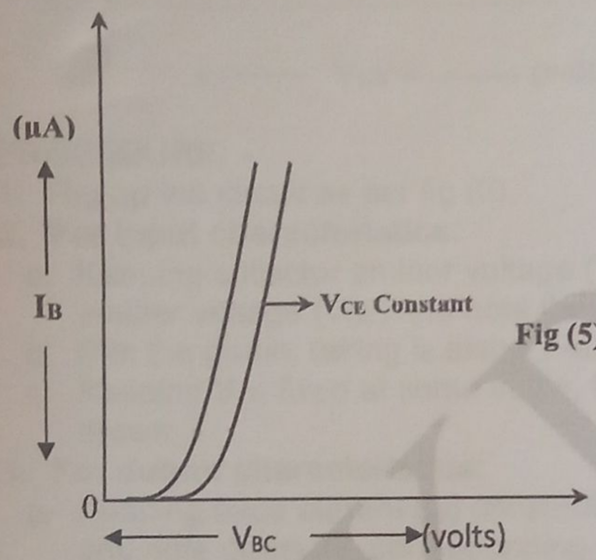
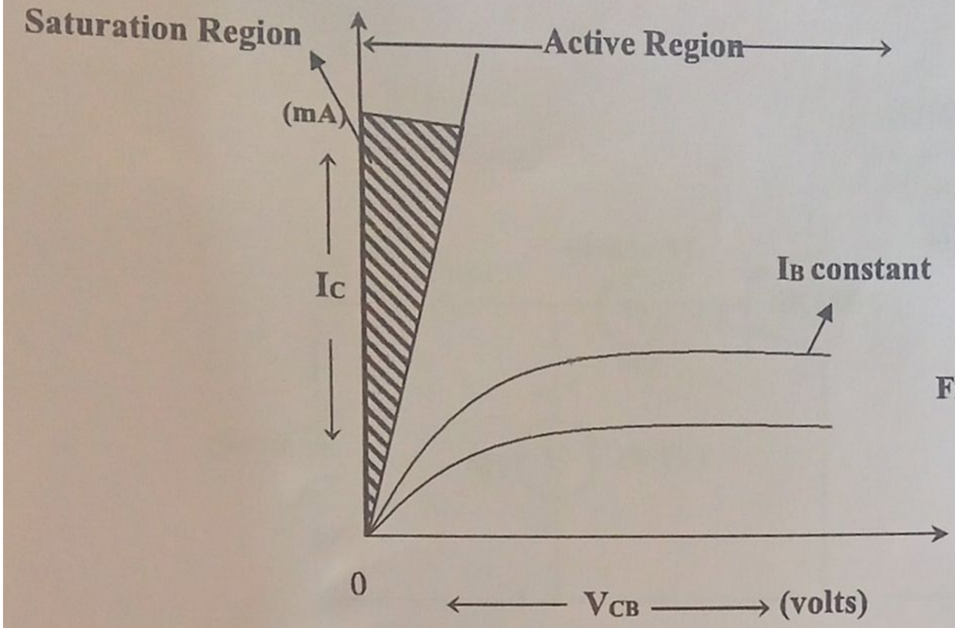


Fig (5)

OUTPUT CHARACTERISTICS: -It is the curve between collector current IC and collector emitter voltage VCE at constant base current.
The output characteristics of CE circuit can be drawn with the help of the circuit shown in fig (6). Keeping the base current IB fixed to some value, note the collector current IC for various values of VCE. Then plot the readings on a graph taking IC along Y-axis and VCE along X-axis. This gives the output characteristics at different values of IB. following the same procedure, a family of output characteristics can be drawn as shown in fig(5a).
The following points may be noted from the characteristics.



Fig(5a)

PROCEDURE: -

1. Rig up the circuit as per fig (6).
2. **For input characteristics:**
   a. Keeping collector emitter voltage (V_{CE}) at some fixed voltage. Vary the base emitter voltage (V_{BE}) and note the corresponding base current.
   b. Plot the graph, taking I_B along Y-axis and V_{BE} along X-axis, at constant V_{CE}.
   c. Keeping V_{CE} fixed at some value, family of input characteristics can be drawn.
3. **For output characteristics:**
   a. Keeping base current (I_B) constant vary the collector emitter voltage (V_{CE}) and note down the corresponding collector current (I_C).
   b. Plot the graph taking I_C along Y-axis and V_{CE} along X-axis, at constant base current.
   c. Keeping base current fixed at some value, family of output characteristics can be drawn.

CIRCUIT DIAGRAM: -

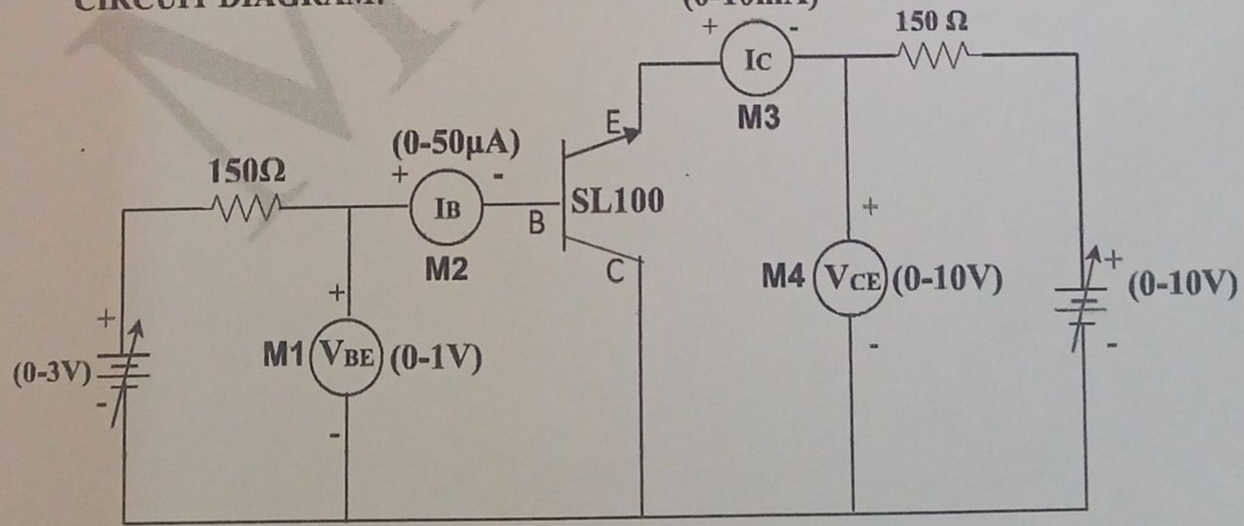
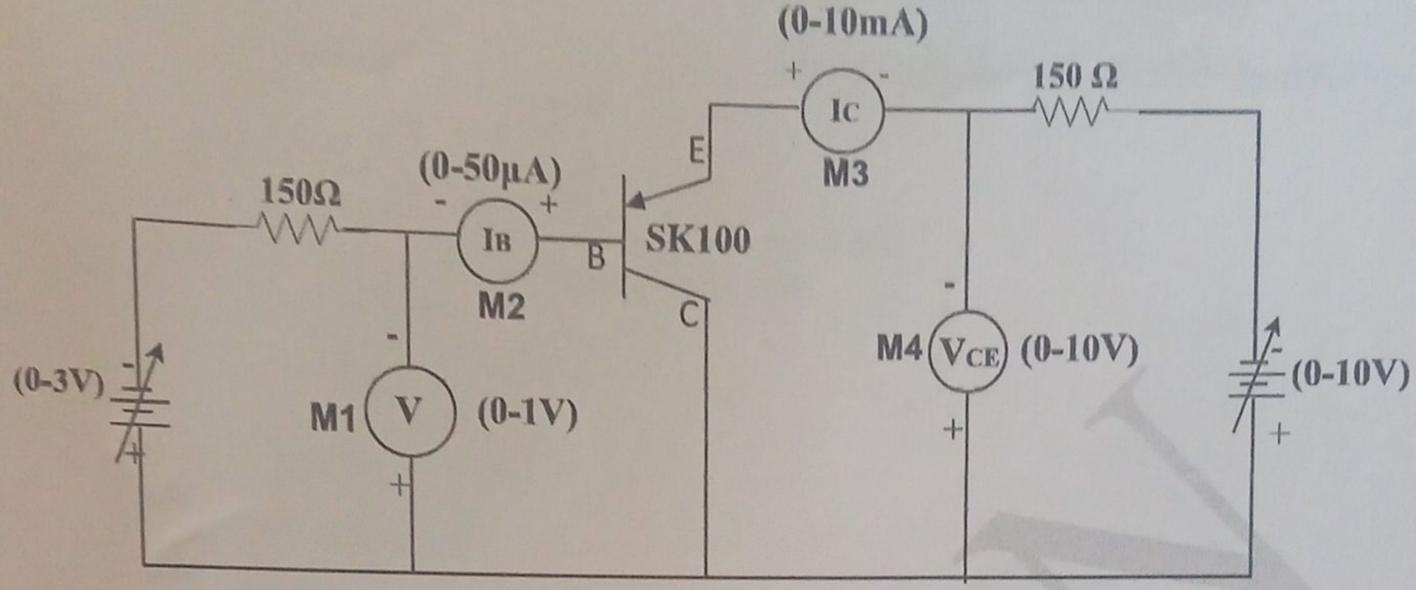


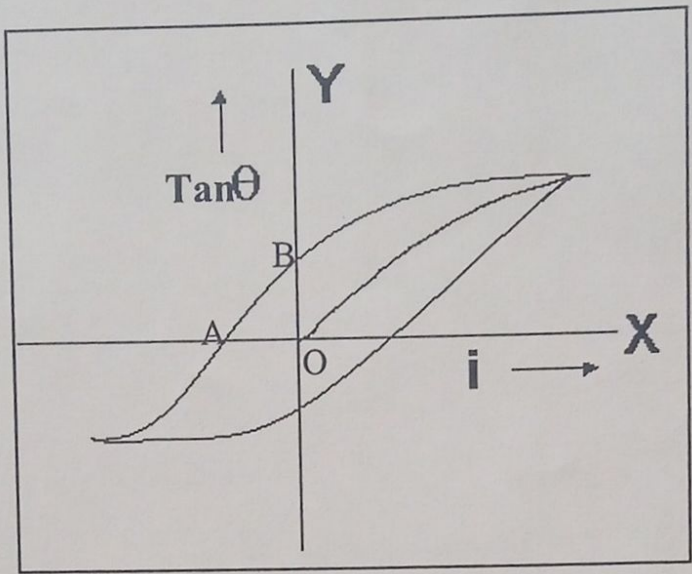
Fig (6) <u>NPN CONFIGURATION</u>



Fig(6a) **PNP CONFIGURATION**

Graph:

Now plot a graph taking current (I) on x-axis and tanθ on y-axis. It looks like loop called hysteresis loop or BH curve. The area under the curve gives energy loss.



Formulae:

1. $H = 4\pi nI/10$(Amps) $= K_1 I$ Amp/meter.
   Where $K_1 = 4\pi n/10$
   n = No. of turns/cm. in the solenoid =**10** turns/cm.
2. The magnetic induction is given by:

$$B = \frac{\mu_o H_e (d^2 - l^2)^2 tan\theta}{(2d)(2la)} = K_2 . \tan\theta$$

$$K_2 = \frac{\mu_o H_e (d^2 - l^2)^2}{(2d)(2la)}$$

l = 5/12 of the geometric length of the specimen = ... cm
d = distance between center of solenoid, to center of DM = ... cm
H_e = Horizontal component of the Earth's magnetic field = **3.024×10^{-5}** Amp-turn/m
a = Area of cross-section of the specimen = ... cm^2

8 Study the characteristics of LED sources

Aim :

To study the characteristics of light emitting diode (LED) sources.

Apparatus :

Light emitting diode, volt meter and ammeter

Introduction :

Light emitting diodes are semiconductor p-n junctions that under proper forward biased conditions.They can emit external spontaneous radiation in the ultra violet, visible and infrared region of electromagnetic spectrum. Usually GaAs, GaP or SiC materials are used as light emitting materials. They emit light only when external applied voltage is operated in forward bias mode and above a minimum threshold value. The gain in electrical potential energy delivered by this voltage is sufficient to force electron to flow out of n-type material, across the junction barrier, into the p-type region.

Basic mechanism of LED is		
Input energy is electrical energy	⟹	Output energy is Photons (bundles of light energy)

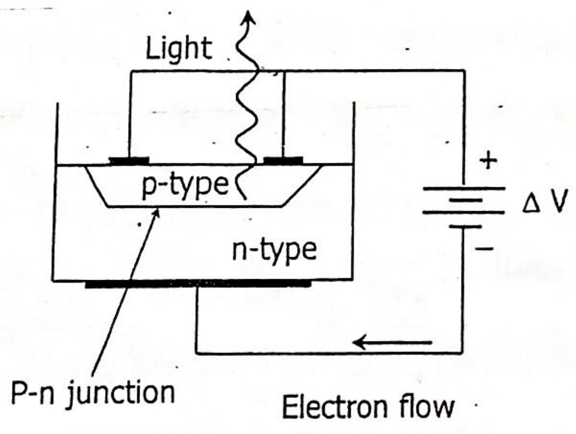


Fig. 1 : Schematic diagram of light emitting diode

The LED involves basically three processes

1) The first one is an excitation process in which electron-hole pair generated.
2) Second process is recombination process in which the excited carriers are give-up their energy either through radiative or non-radiative process.
3) The third process is extraction of emitted photons from the active region of semiconductor to the observer.

What are radiative and non-radiative processes?

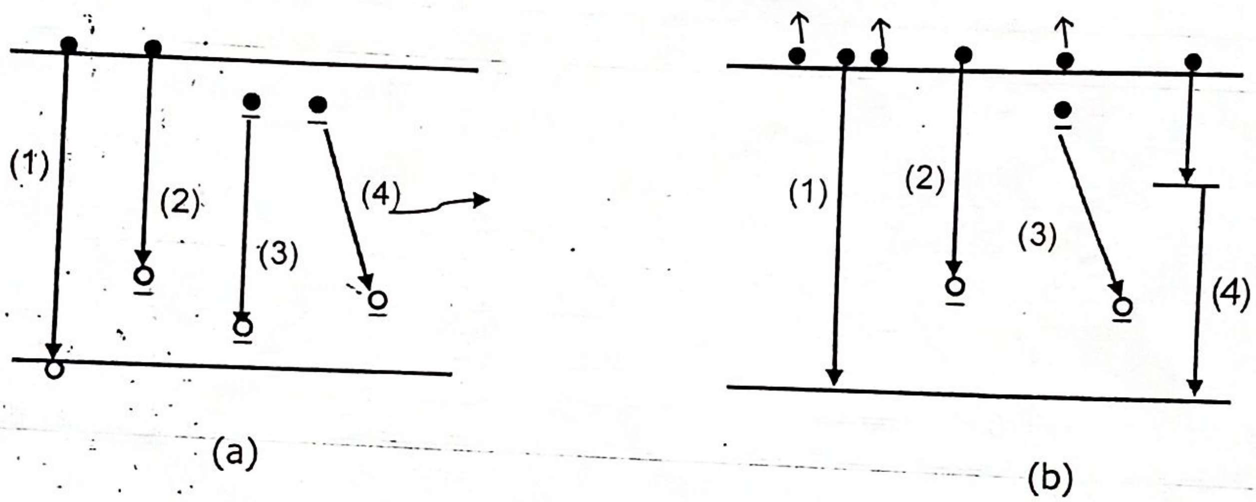


Fig. 2 : Schematic diagram of (a) radiative and (b) non-radiative transitions.

An atom can be represented by an energy level diagram. Horizontal lines in these diagrams represent the allowed energies that an electron in the atom can possess. Electrons like to have the lowest possible allowed and available energy.

Fig (a) path (1) depicts intrinsic band-to-band transition involving the recombination of an electron-hole pair. This process has a high probability of occurrence only in a direct gap semiconductor, and the emitted photon energy is then hf = E_g. Path 2 shows an extrinsic recombination between a hole bound to a neutral acceptor and a free electron in the conduction. Path 3 depicts the exciton recombination involving acceptor–type trap. Path (4) shows the extrinsic process of donor-acceptor pair recombination. Here electron from the conduction band is captured by ionized donor, and a hole is captured by the ionized acceptor. The subsequent transition of the electron to the acceptor state emits a photon equal to the difference between the two energy levels.

Fig (b) Path (1) shown band–to–band auger recombination involving two electron and one trap assigned recombination can also occur. Path (2) depicts an Auger transition involving two free electrons and trapped hole and path (3) shows the same involving an occupied donor-acceptor pair and a free electron. Finally path (4) depicts the non-radiative recombination process via a deep-level recombination center.

Theory :

A fundamental of quantum mechanics is that the electromagnetic spectrum is quantized into photons. A photon of wavelength λ and frequency f has energy E

$$E = hf = hc/\lambda \qquad \text{——— (1)}$$

where h is Planck's constant, h = 6.626×10^{-34} Js

In this experiment we will use the properties of light-emitting diodes (LED's) to determine the value of h. In a simple electrical circuit of a resistor connected to a voltage source, the source supplies a voltage V which causes a current I to flow through the resistor. For an ideal resistor Ohm's law states that the relationship between voltage and current is

$$V = IR \qquad \text{—— (2)}$$

where R is the resistance.

Energy is dissipated through the resistor. Microscopically, this happens via collisions of electrons with the atoms in the resistor, converting electron kinetic energy to heat.

The I-V relationship of a diode is quite different. A diode has almost infinite resistance when the voltage is applied in one direction. Even the voltage is large (up to a "breakdown value"), no appreciable current flows. Conversely, a diode has extremely low resistance when current is passed through it in the other direction. Thus, a diode is a "rectifier." However, even in the forward direction, no appreciable current flows until a little more than half a volt has been supplied. Furthermore, in a light-emitting diode, much of the energy of the electrons is lost not in heating up the lattice of the junction material, but in creating photons. The wavelength of the photons depends on the type of diode; each diode produces photons of a particular characteristic wavelength or set of wavelengths.

If a voltage V is applied across a diode, the maximum energy that any electron could acquire is eV, where e is the charge on the electron. If this energy is less than the energy required to produce a photon of wavelength λ, then no such photon can be produced. Thus, as a function of applied voltage we would expect to see photon production only above a characteristic voltage

$$V_0 = hf/e = hc/\lambda e$$

The threshold voltage V_0 can be measured very easily if we substitute electronic charge 'e' and in the above equation. Fig. 3 shows the schematic diagram of operation of LED.

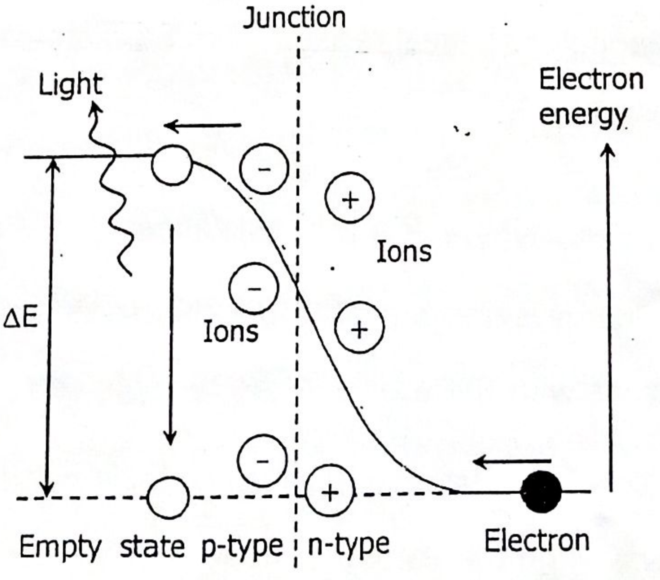


Fig. 3 : Operation of LED

Procedure :

1) The main component of the apparatus is circuit board containing LEDs, each with a different emission wavelength. A particular LED can be connected to the circuit as shown in figure.

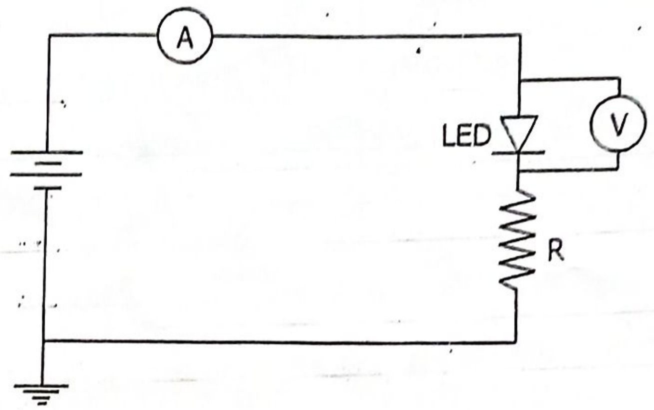


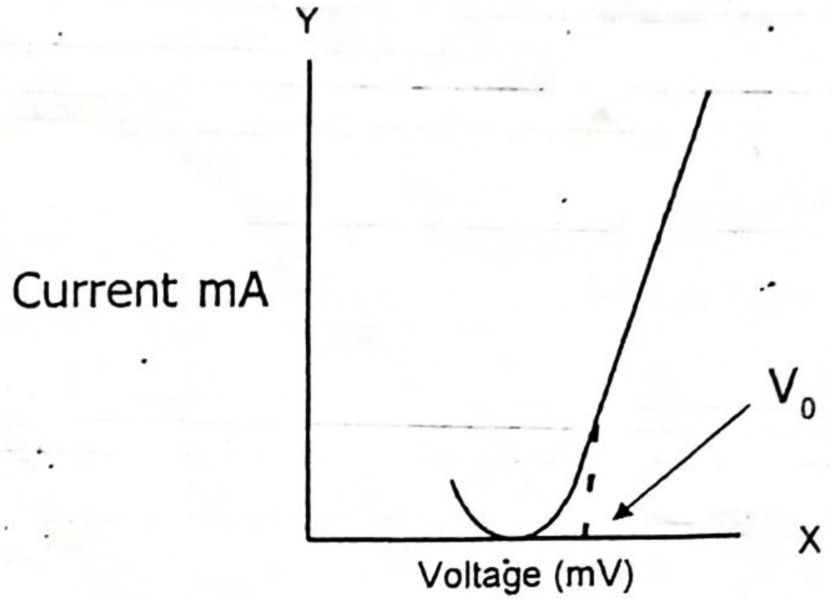
Fig. 4 : The circuit diagram for the measurement of current-voltage characteristics

2) The voltage is varied with the help of power supply which is externally connected.
3) Turn the power supply on and very slowly increase the voltage until the LED just starts to glow.
4) Continuously monitor the current as function of voltage across the LED.
5) Plot the graph voltage on X-axis and current on Y-axis, which gives the current voltage characteristics of LED.
6) To avoid errors plotting I-V data on a semi-log graph. Data should fit in a straight line, indicating the exponential nature of the current voltage relationship. The threshold voltage (V_0) is the voltage when the current reaches 0.01 mA. Extrapolate I-V curves to where they cross 0.01 mA current and that as the working value of V_0.

Observations :

S.No.	Voltage (mV)	Current (mA)

Model graph :



Precautions :

1. Make sure that the volt meter is measuring the voltage across the LED only.
2. Increase the power supply very slowly until LED just starts to glow.
3. Continuously monitor the current so that it do not exceed the maximum current. With this the damage of the LED with high current can be avoided.

Result :

The I-V characteristic of LEDs are studied and threshold value of voltage =

SOLAR CELL CHARACTERISTICS USER MANUAL

AIM: To plot the V-I characteristics of Solar cell.

MICRO BOARD CONSISTS OF:

1. Solar Cell/Photovoltaic cell mounted on the wooden base.
2. Single directional mercury coated variable intensity source.
3. Voltmeter.
4. Ammeter.
5. Load resistance.

THEORY:

Sunlight consists of a little particles of solar energy called photons. As the photovoltaic cell is exposed this sunlight, many of the photons are reflected, pass right through or absorbed by the solar cell.

When enough photons are absorbed by the negative layer of the photovoltaic cell, electrons are freed from the negative semiconductor material. Due to the manufacturing process of the positive layer, these freed electrons naturally migrate to the positive layer creating a voltage differential, similar to a household battery.

When the 2 layers are connected to an external load, the electrons flow through the circuit creating electricity. Each individual solar energy cell produces only 1-2 watts. To increase power output, cells are combined in a weather-tight package called a solar module. These modules (from one to several thousand) are then wired up in serial and/or parallel with one another, into what's called a solar array, to create the desired voltage and amperage output required.

Due to the natural abundance of silicon, the semi-conductor material that PV cells are primarily made of, and the practically unlimited resource in the sun, solar power cells are very environmentally friendly. They burn no fuel and have absolutely no moving parts which makes them virtually maintenance free, clean, and silent.

PROCEDURE:

1. Connect the circuit as per the circuit diagram shown in fig (1).
2. Place the solar cell at a particular distance say 1cm from the variable light source.
3. Vary intensity of the light source, note down the voltage and current in the tabular column.
4. Next note the short circuit current Isc, when the voltage across the solar cell is zero & open circuit voltage Vo by removing the load resistance across the solar cell.
5. Calculate power P=VI for each reading.
6. Plot the graph between the voltage Vs Current , mark the maximum power point,
7. Repeat the experiment by changing the distance between the solar cell & light source.

CIRCUIT DIAGRAM:

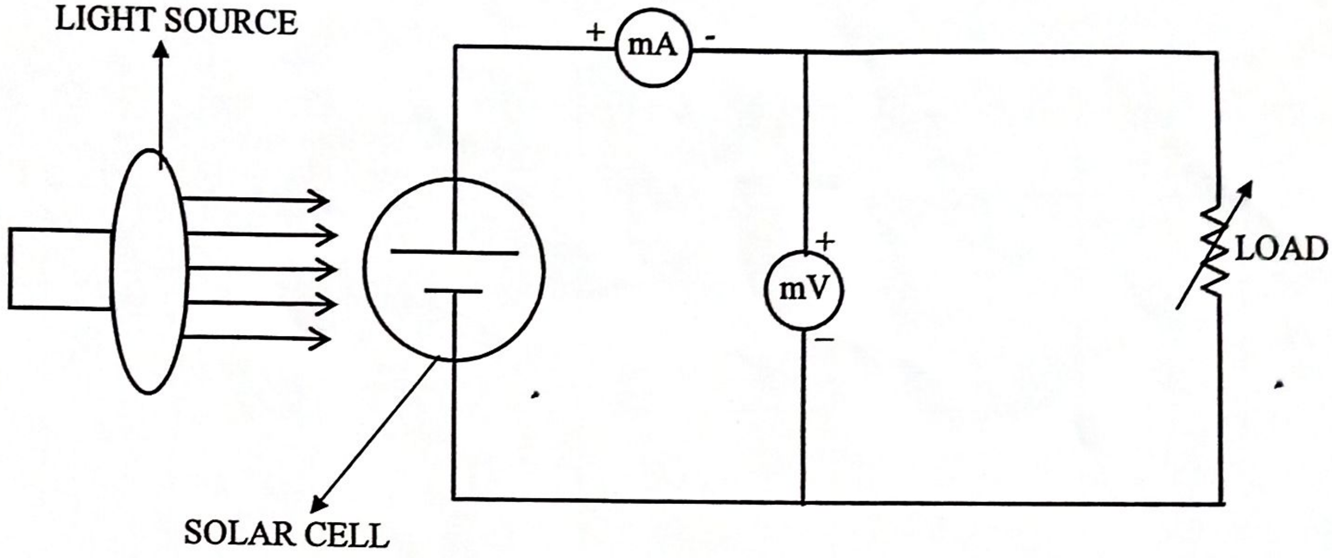
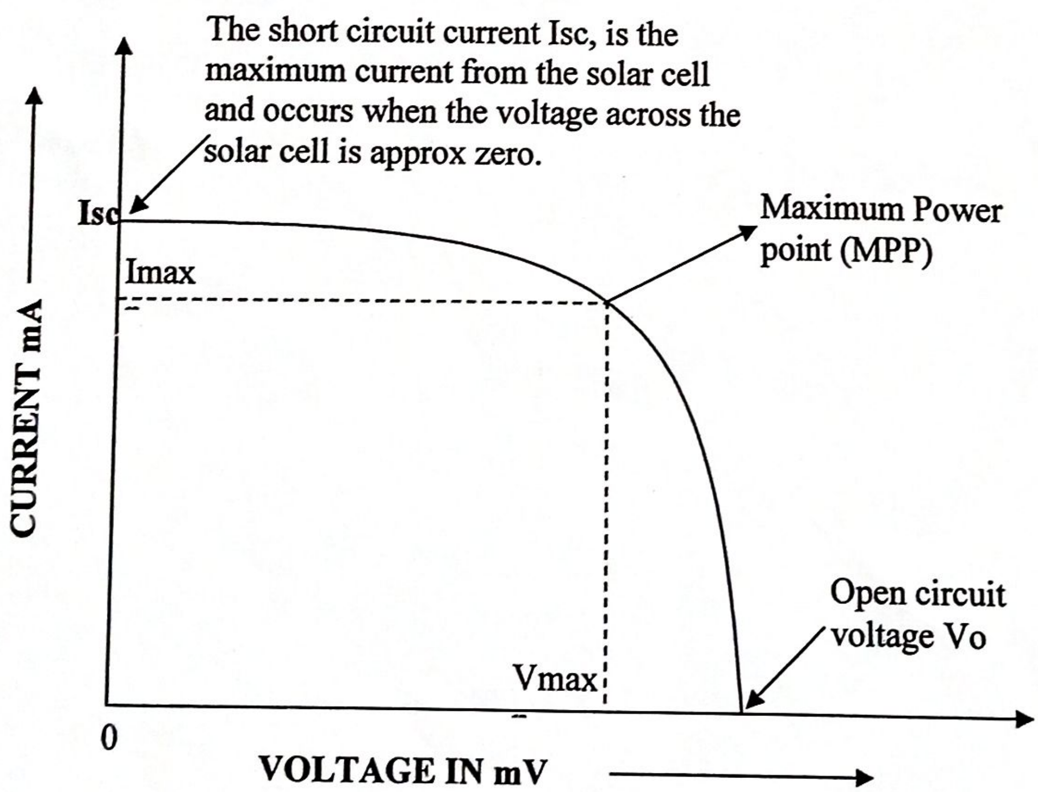


Fig (1)

IDEAL GRAPH:



TABULAR COLUMN:

SI NO	DISTANCE BETWEEN THE LIGHT SOURCE & SOLAR CELL IN CMS	VOLTAGE IN mV	CURRENT IN mA	P=VI

OBSERVATION:

1. SHORT CIRCUIT CURRENT Isc
2. OPEN CIRCUIT VOLTAGE Vo
3. MAXIMUM PEAK POINT

21 Energy gap of a material of p-n junction

Aim :

To determine the energy band gap of a p-n junction.

Apparatus :

p-n junction diode, thermostat, volt meter, ammeter, thermometer and battery.

Introduction and theory :

p-n junction is made up of semiconducting material. It consists of valence and conduction band which is separated with a small distance. Semiconductor material have almost empty conduction band nearly filled valence band with a narrow band gap of. 1 eV. The narrow band gap which is separated is called energy gap of the semiconductors. The semiconductors are of two types intrinsic and extrinsic semiconductors. Intrinsic semiconductors are pure semiconductors. By adding very small amount of impurities, such as one part in a million to a pure semiconductor in a controlled manner, a large increase in conductivity can be achieved. Extrinsic semiconductors are formed by adding impurity (doping) to pure semiconductors. The n-type of semiconductor is formed by adding pentavalent impurity to pure semiconductor. Similarly p-type of semiconductor is formed by adding trivalent impurity to pure semiconductors. The schematic diagrams of intrinsic and extrinsic semiconductors are as shown in figure 1.

The p-n junction is a device made with p- and n-type of semiconductors. p-n junctions are of two types. Homo junctions and hetero-junctions. Homojunction is made up with the same material which is available in both n- and p-type conductivities (eg. Si junction made with n- and p-types). Heterojunctions are made with two types of materials having n- and p- type of conductivities (eg. GaAs). In the present experiment p-n junction which made with the same material, but available in both the conductivities (homojunction) is used.

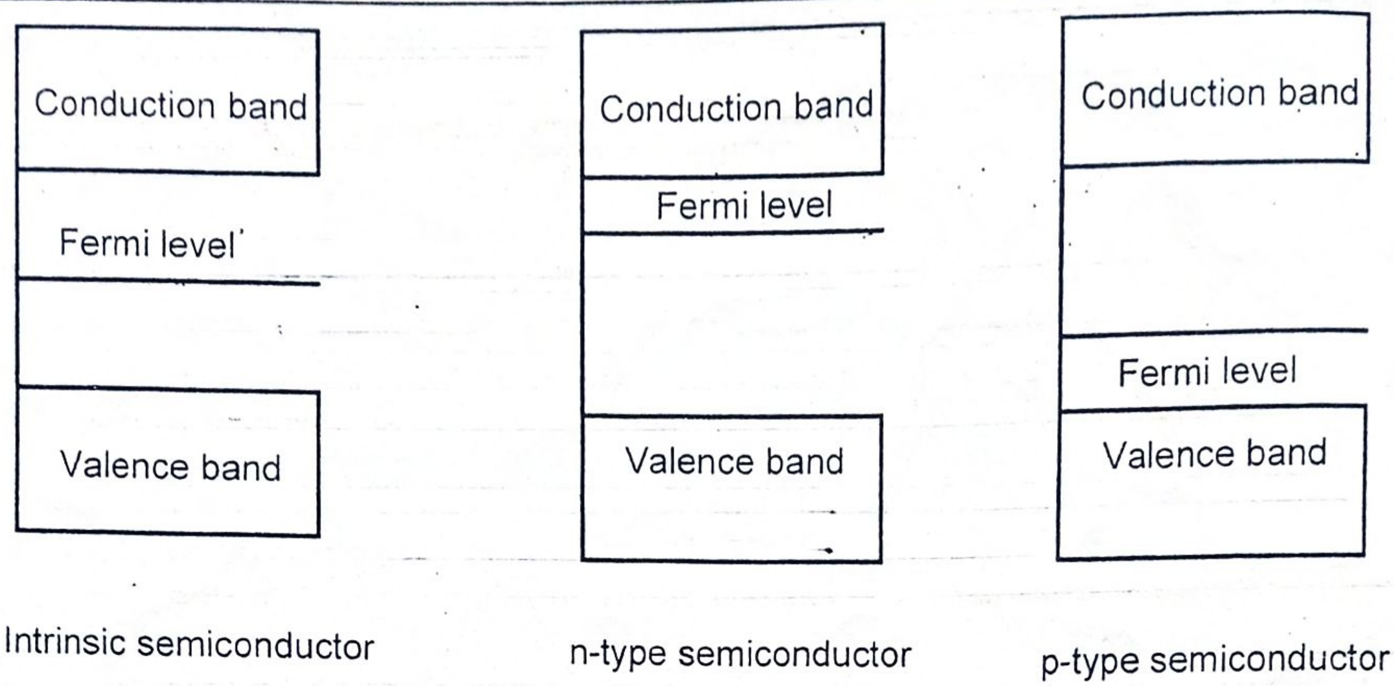


Fig. 1 : Energy band diagram of intrinsic and extrinsic semiconductors

Theory :

The current I through a p-n junction for both signs of applied voltage V

$$I = I_0 = [(\exp) eV)/(kT) - 1] \quad \ldots\ldots\ldots(1)$$

where e = fundamental electronic charge,

K = Boltzmann's constant,

T = Absolute temperature.

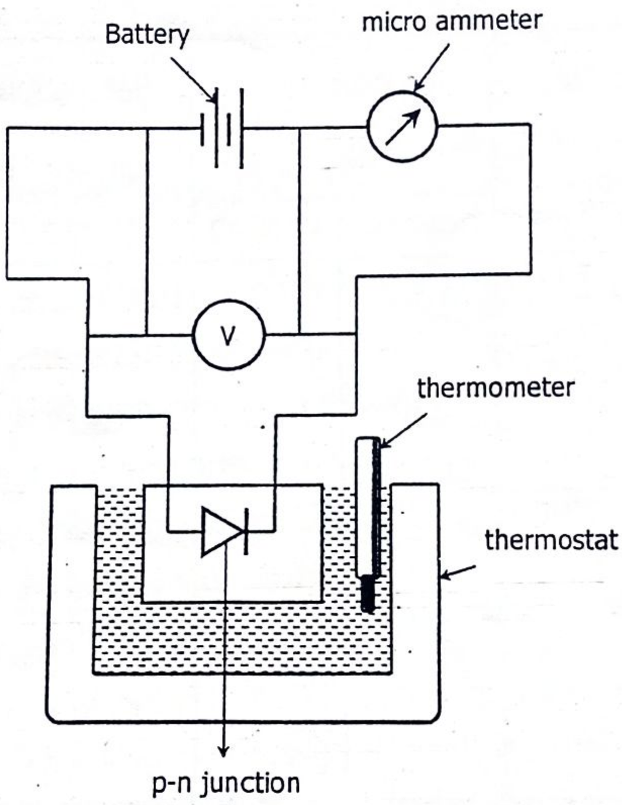
For the silicon p-n junctions and positive values of V the exponential term becomes greater than 1. The current through the junction will increase exponentially with V. The dependence on energy gap occurs through the factor I_0. I_0 is due to that current that flows when the junction is biased negatively and is due to the thermal excitation of electrons across the energy gap after which they flow freely across the junction. A complete treatment of the problems shows that I_0 is proportional to the factor f which is given by

$$f \propto T^{3/2} e^{-Eg/kT}$$

E_g = energy gap of the semiconducting material. The I_0 can be determined by a simple measurement with a negative bias applied to the junction. However, I_0 is so small and careful measurement is necessary. It is essential to generate curves representing equation (1) at several temperatures in order to obtain several values for I_0.

Procedure :

The circuit diagram of the experimental setup for the measurement of energy gap in shown in figure.



1. The point contact diode connected in a reverse bias as shown in the diagram.
2. It is placed in a oil bath and heated uniformly.
3. Saturation current is noted for various temperatures.
4. The bias voltage is maintained at constant value.
5. The readings in the micro-ammeter is noted a function of temperature in steps of 5 °C.

6. A graph is drawn between with log (1/T) in Kelvin on X-axis and logI_0 is on Y-axis
7. The slope of the graph is calculated and substituted in the formula.

Formula :

$$\text{Band gap energy } E_g = \frac{2.303 \times 2 \times k \times \text{slope}}{1.6 \times 10^{-19}} \text{eV}$$

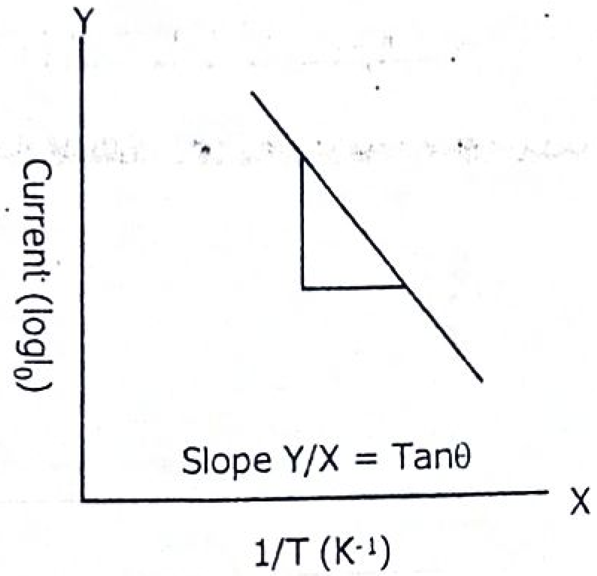
Observations :

S.No.	Temperature (K)		Saturation current (I_0)	$\frac{1}{T}$ for graph (K^{-1})	Log I_0
	heating	cooling			

Precautions :

1. The current flow should not be too high, if the current is high then the internal heating of the device will occur. This will cause actual temperature of the junction to be higher then the measured value. This will produce non-linearity in the curve
2. There may be contact potentials, thermo emfs and meter dc offsets which must be add and subtract from the readings.
3. Poor contacts result in huge variations in the results and must be carefully soldered.
4. It is better to repeat a few measurements at end of each run to check the source of error.

Model graph :



Result : The energy gap of the p-n junction material is calculated = eV

B-H Curve

Aim: To draw B-H curve between the magnetizing field (H) and Magnetic Induction (B) of the specimen and to find Coercivity (H_c), Remanence (B_r) and Hysteresis loss.

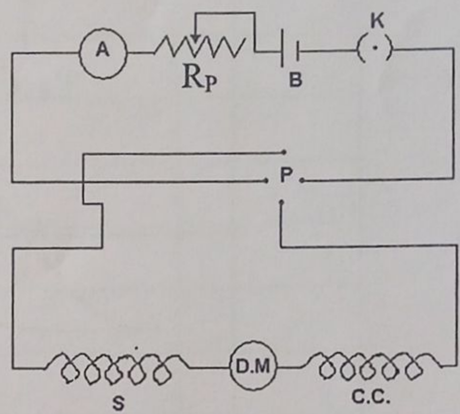
Apparatus: Deflection Magnetometer (DM), A wooden bench with sliding magnetizing coil (Solenoid) and a compensating coil, DC power supply, a Rheostat, a commutator, plug key, iron rod specimen and ammeter.

B - Battery

K - Plug Key, P - Commutator

S - Solenoid,DM - Deflection Magnetometer

CC - Compensating Coil, A - Ammeter, R_P - Rheostat



Procedure:

1. Remove all magnets / magnetizing materials form the vicinity of the magnetometer.
2. Keep the deflection magnetometer in Tan A position so that the arms are in the East and west dirction. Aluminium pointer is made parallel to the arms of DM. Set the aluminum pointer to read 0-0 and make the circuit connection as shown.

   2(a) Plug in all four keys of the commutator and connect the circuit as shown in the circuit diagram.
3. Without placing the specimen rod in the solenoid, close the circuit and increase the current gradually up to 3amp.

   3(a) Demagnetize the given sample ferromagnetic rod (iron rod) by gently hitting or dropping down
4. Place the un-magnetized specimen in the solenoid and switch on the power supply.
5. Remove two opposite keys in the commutator.
6. With minimum current note the readings at the two ends of the aluminum pointer in the DM without parallax error as θ_1 and θ_2.
7. Increase the current by using Rheostat in steps of 0.25 amps till the maximum current is reached. At each step note the readings in DM in the tabular form 1
8. Now decrease the current from the maximum value in steps of 0.25 amps till it reaches the minimum current, and note the readings in DM. in the table 2
9. Change the positions of the keys in the commutator so that the direction of the current flow gets reversed.
10. Repeat the whole process of increasing and decreasing of current and the readings are tabulated in the tabular forms 3 and 4 respectively.
11. Again reverse the direction of current by changing the positions of the keys in the commutator.
12. Now increase the current and note the readings in DM and enter the readings table 5.
13. The relation between the magnetic fled **H,** magnetization **I** and magnetic induction **B** is given by **B**= μ_0(**H+I**).

Observations:

Table: Forward direction: Increasing Current

S. No.	Current(I) Amperes	Deflection			Tan θ
		θ_1	θ_2	Mean θ	
	0				
	0.25				
	0.50				
	0.75				
	1.00				
	1.25				
	1.50				
	1.75				
	2.00				
	2.25				
	2.50				
	2.75				
	3.00				

Table: 2: Forward direction: Decreasing current

S. No.	Current (I) Amperes	Deflection θ			Tan θ
		θ_1	θ_2	Mean θ	
	3.00				
	2.75				
	2.50				
	2.25				
	2.00				
	1.75				
	1.50				
	1.25				
	1.00				
	0.75				
	0.50				
	0.25				
	0				

Table:3: Reverse Direction: Increasing current

S. No.	Current (I) Amperes	Deflection θ			Tan θ
		θ_1	θ_2	Mean θ	
	0				
	0.25				
	0.50				
	0.75				
	1.00				
	1.25				
	1.50				
	1.75				
	2.00				
	2.25				
	2.50				
	2.75				
	3.00				

Table:4: Reverse Direction: Decreasing current

S. No.	Current (I) Amperes	Deflection θ			Tan θ
		θ_1	θ_2	Mean θ	
	3.00				
	2.75				
	2.50				
	2.25				
	2.00				
	1.75				
	1.50				
	1.25				
	1.00				
	0.75				
	0.50				
	0.25				
	0				

Table:5 Forward Direction: Increasing current

S. No.	Current (I) Amperes	Deflection θ			Tan θ
		θ_1	θ_2	Mean θ	
	0				
	0.25				
	0.50				
	0.75				
	1.00				
	1.25				
	1.50				
	1.75				
	2.00				
	2.25				
	2.50				
	2.75				
	3.00				

CALCULATIONS:

From the plot calculate the following parameters using the formulae given above:

1. Coercivity (H_c) = K_2. OA (from graph) amp/meter=____________
2. Remanence (I_r) = K_1 x OB (from graph) web/m^2=____________
3. Hysteresis loss = K_1 x K_2 x Area under the BH Curve- Joules=____________

PRECAUTIONS:

1. Demagnetize the specimen before use. This could be done by heating it or by repeatedly allowing it to fall on the ground from a height.
2. Once the cycle of magnetization starts increase / decrease the current continuously.
3. The cycle consists of five segments. Complete them before you stop your observations.
4. Keep the points on graph carefully for the 3rd quarter and 5th quarter

Result

1. Coercivity (H_c) =
2. Remanence (I_r) =
3. Hysteresis loss =

BEAM DIVERGENCE OF LASER USER MANUAL

AIM: -To Calculate the Beam Divergence of the given LASER Beam.

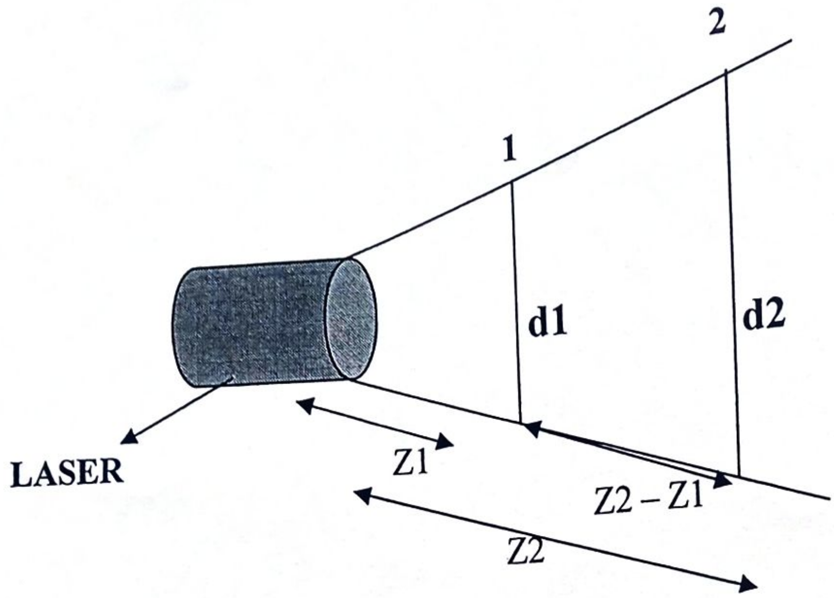
APPARATUS: -

1. LASER diode fitted on base.
2. Screen Provided to fit graph sheet
3. Meter Scale.
0.

THEORY: - The term LASER is acronym for light amplification by stimulated emission of radiation.
It is a mechanism for emitting electro magnetic radiation via the process of stimulated emission. The LASER was the first device capable of amplifying light way wave themselves. The emitted LASER light is spatially coherent narrow low divergence beam. When the waves (or photons) of beam of light have same frequency phase and direction it is said to be coherent.
According to encyclopedia of LASER Physics and technology beam divergence of LASER beam is a measure of how fast the beam expands far from beam waist. A LASER beam with a narrow beam divergence is greatly used to make LASER pointer devices.

Divergence means "Departure from norm or Deviation". The beam divergence of LASER is the measure of increase of diameter or radius.
A LASER beam consists of very nearly parallel light rays the beam diameter increases far more slowly with distance from light source as compare to light bema from other light sources.

Beam Divergence: The light emitted by a LASER is confirmed to rather narrow one. But when the beam propagates outward it slowly diverges out. For electromagnetic beam divergence is the angular measure f the increase in the radius with distance from optical aperture as beam emerges. The divergence of the LASER beam can be calculated if the beam diameter d1 and d2 at two separate distances are know n. Let Z1 and Z2 are the distances along the LASER axis from the end of LASER to points 1 and 2.



Divergence angle is taken s the full angle of opening of the beam.

$$\theta = \frac{d2 - d1}{Z2 - Z1}$$

Half of divergence angle can be calculated as

$$\theta = \frac{W2 - W1}{Z2 - Z1}$$

Where W1 and W2 are radius of beam at

Like all electromagnetic beams LASER'S are subject to divergence which is measured in milli radians.

PROCEDURE:

1. Place the LASER diode on stand.
2. With the help of scale provided keep stand the screen with graph paper at distance of 300 cm from LASER Diode.
3. Switch on the LASER such that beam falls on the graph paper.
4. With the help of pencil circle the beam light measure with scale horizontal and vertical beam radius and find the mean.
5. Repeat the procedure at 50 cm below the scale taken.
6. Note down the values of diameter of beam of LASER calculate.

Divergence Angle $\Theta = \frac{W2 - W1}{Z2 - Z1}$ milliradians

CALCULATED VALUE:

S.NO	DISTANCE FROM LASER	BEAM RADIUS HORIZONTAL	BEAM RADIUS VERTICAL	MEAN	$\Theta = \frac{W2 - W1}{Z2 - Z1}$
01	300cm	0.4cm	0.4cm	0.4	1×10^{-3} mrad
02	250cm	0.35cm	0.35cm	0.35	

Divergence angle $\Theta = \frac{W2 - W1}{Z2 - Z1}$ milliradians

$$= \frac{0.4 - 0.35}{300 - 250}$$

$$= \frac{0.05}{50} = 1 \times 10^{-3} \text{ mrad}$$

Evaluation of numerical aperture of given fibre

Objective :

To determine the acceptance angle and using laser light the numerical aperture of different types of fibres.

Equipment :

Digital multimeter, Different fibers optical cables, connectors, power supply, Numerical aperture measurement jig.

Introduction and theory :

Background information of Fibre Numerical Aperture :

An optical fibre consists of a core that is surrounded by a cladding. The core and cladding are normally made of silica glass, although polymer materials are also in use. The function of the core is to transmit an optical signal while the purpose of the cladding is to guide the light within the core, in effect to confine the light within the core. A fibre is sometimes called an optical waveguide because light is guided through the fibre. The basic construction of a fibre is shown in figure 1(a).

In order to confine the optical signal to the core of the fibre the core and cladding materials are deliberately given different refractive indices, so that the refractive index of the core (n_1) is higher than that of the adding (n_2). The refractive index of a material decides whether the material transmits or reflects a light ray that intersects the surface of the material. The simplest type of fibre is called a step index fibre, since in such a fibre there is a step in the value of the refractive index at the boundary between the core and the cladding. This is shown in figure 1 (b) which displays the so called refractive index profile of a step index fibre. The refractive index profile of a fibre is a graph which shows how the refractive index varies with distance from the centre of the fibre.

In a step index fibre the refractive index is constant at n_1 until the core cladding boundary is reached, where the refractive index falls to n_2. The core diameter of step index multimode fibre is typically 200 nm, with a cladding diameter of 300 nm. A light ray that enters the fibre does not merely travel straight down through the centre of the core. Instead light rays within the core are continually reflected at the core/cladding boundary so that the rays remain within the core. This process is called total internal reflection.

In order to understand the process in more detail consider in figure 2 light ray (i) entering the core at point A and then traveling through the core until it reaches the core cladding boundary at point B. As long as the light ray intersects the core/cladding boundary at a small enough angle the ray will be reflected back into the core to travel on to point C where the process of reflection is repeated. If a ray enters the fibre at a steep angle, for example light ray (ii), then when this ray intersects the core/cladding boundary the angle of intersection is too large and reflection back in to the core does not take place and the light ray is lost in the cladding. This means that to be guided through a fibre a light ray must enter the core with an angle that is less than the so called acceptance angle for the fibre. A ray which enters the fibre with an angle greater than the acceptance angle will be lost in the cladding. By convention the acceptance angle for a fibre can also be described by the term "numerical aperture". The fibre acceptance angle can be calculated from the refractive indices of the core and cladding.

Numerical Aperture :

Numerical aperture (NA) is a measure of the amount of light rays that can be accepted by the fibre and is more generally used term in optical fiber communication. NA is defined using a relation between the acceptance angle and the refractive index of the medium involved namely air, core and cladding. Let us consider a ray is launched into the fiber at an angle θ_1, which is less than the angle of acceptance θ_a, for a fiber see fig.3. The ray enters from medium (air) of refractive index n_0 to the fiber with core of refractive index n_1, which is slightly greater than that of the refractive index of cladding n_2.

According to Snell's law at interface of the medium (air) and fiber

$$n_0 \sin \theta_1 = n_1 \sin \theta_2$$

From figure-3, in triangle ABC

$$\theta = \pi/2 - \theta_2$$

From Equation-1 and 2

$$\text{Sin}\, \theta_1 = n_1 / n_0 \cos\theta$$

Equation (3) can be written as

$$..n_0 \text{Sin}\theta_1 = n_1(1-\text{Sin}^2\theta)^{1/2} \quad - 4$$

When the total internal reflection takes place at B (figure-3), $\theta = \theta_c$ and $\theta_1 = \theta_a$ where θ_c is called critical angle and θ_a is acceptance angle.

$$n_1 \sin \theta_n = n_2 \sin \theta_c$$

$$n_1 \sin \theta = n_2 \sin 90 \qquad \text{-----} (5)$$

From equation (4) and (5)

$$n_0 \sin \theta_o = (n_1^2 - n_2^2)^{1/2}$$

$n_0=1$ in air and $\sin e_a$ is the numerical aperture (NA).

$$NA = (n_1^2 - n_2^2)^{1/2} \qquad \text{-----} (6)$$

The numerical aperture is a parameter normally associated with light entering a fibre, however to measure numerical aperture it is easier to investigate the characteristics of the light leaving the fibre, which will provide a reasonable approximation of the numerical aperture see figure-4.

Numerical Aperture defines the maximum angle (the "cone of acceptance") at which light can be launched into a fiber.

Formula :

Light from the optical fiber end at A falls on the screen BC. Let the diameter of the light falling spot on the screen is W = BC. Let the distance between the optical fiber end and the screen is L = BC = W.

BD = DC = W/2 from geometry

$$AB = [L^2 + \frac{W^2}{4}]^{1/2} \rightarrow AB = \frac{(4L^2 + W^2)}{2}$$

$$NA = \frac{W}{\sqrt{4L^2 + W^2}} = \sin \theta_a \qquad \text{----- (7)}$$

Where θ_a is acceptance angle. By knowing the values of W and L you can compute the numerical aperture and hence acceptance angle using the equation (7).

Procedure :

1. Connect the one end of the optical fibre cable to the output power socket of the NA module and other end to the NA measurement jig.
2. The mains of power is switched on and the light passing through the cable at the other end of the fiber is observed to ensure the proper coupling is made or not.
3. A white screen with concentric circles of known diameter is hold vertically at a suitable distance (L) from the optical fibre end and light (red) spot is seen on the screen.
4. The diameter (W) of the red spot is made exactly equal to the concentric one of the circle and corresponding length (L) is noted.
5. The diameter of the red spot can be varied by varying the length (L). Repeat the same for different concentric circles by varying the length (L).
6.

Table :

S.No.	L (Distance of screen from the fiber end) mm	W (Diameter of the spot) mm	Numerical aperture	Acceptance angle

Observations :

Formula :

$$NA = \frac{W}{\sqrt{4L^2 + W^2}} = \sin\theta_a$$

Results :

Numerical aperture of the optical fibre =

Acceptance angle of the optical fibre = degrees

USER MANUAL FOR : DETERMINATION OF RIGIDITY MODULUS OF THE MATERIAL OF A WIRE (TORSION PENDULUM) EXPERIMENT

AIM: To determine the rigidity modulus (n) of the material of the given wire using torsional pendulum.

APPARATUS: - Torsion pendulum, Stop clock, meter scale, and vernier caliper, Screw Gauge Rough balance.

THEORY:
A torsional pendulum is a flat disk, suspended horizontally by a wire attached at the top of the fixed support.
When the disk is tuned through a small angle, the wire is twisted .On being released the disk performs torsional oscillations about the axis performs torsional oscillations about the axis of the support .The twist wire will exert a torque on the disk tending to return it to the original position. This is restoring torque. For small twist the restoring torque is found to be proportional to the amount of twist, or the angular displacement, so that

$$\tau = -k\theta \quad \text{------------(1)}$$

Here k is proportionality constant that depends on the properties of the wire is called torsional constant.
The minus sign shows that the torque is directly opposite to the angular displacement θ.Eq^n 1, is the condition for angular simple harmonic motion.

The equation of motion for such a system is

$$\tau = I\ \alpha = I\, d^2\theta/dt^2$$

So that, on using the equation (1) we get

$$-k\,\theta = I\, d^2\theta/dt^2$$

$$d^2\theta / dt^2 + k / I\ \theta = 0 \qquad (3)$$

The solution of the equation 3 is, therefore, a simple harmonic oscillation in the angle co-ordinate θ, namely

$$\theta = \theta_m \cos(\omega t + \delta)$$

Here θ_m is the maximum angular displacement i.e. the amplitude of the angular oscillation.

The period off oscillation is given by

$$T = 2\pi\sqrt{I/k}$$

Where I = rotational inertia of the pendulum
K= torsional constant

If k and I are known, T can be calculated.

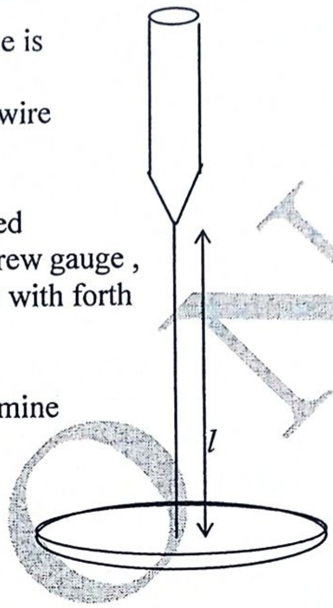
PROCEDURE:
Torsional pendulum consists of a uniform circular metal (brass or iron) disc of diameter about 10 cm and thickness of 1 cm. Suspended by a metal wire (whose n is to be determined) at the center of the disc .The other end of the wire is griped into another chuck, which is fixed to a wall bracket. The length (*l*) of wire between the two chucks can be adjusted and measured using meter scale .An ink mark is made on the curved edge of the disc. A vertical pointer is kept in front of

the disc such that the pointer screens the mark when straight. The disc is set into oscillations in the horizontal plane, by tuning through a small angle .Now stopwatch is started and time (t) for 20 oscillations is noted.

This procedure is repeated for two times and the average value is Taken. The time period T (=t/20) is calculated.
The experiment is performed for five different lengths of the wire And observations are tabulated in table.

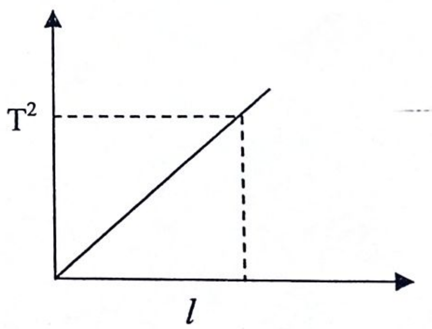
The diameter and hence the radius (a) of the wire is determined accurately at least at five different places of the wire using screw gauge , since the radius of the wire is small in magnitude and appears with forth power in the formula of rigidity modulus.

The mass (M) and the radius (R) of the circular disc are determine by using rough balance and vernier respectively.



A graph is drowning between " l " on x-axis and T^2 on Y-axis.
Rigidity modulus (n) of given wire is determine using the formula

$$n = \frac{4 \pi M R^2}{a^2} \left(\frac{l}{T^2} \right) \text{ dyne /cm}^2$$



OBSERVATION TABLE:-

Mass of the disc m = gm
Radius of the disc R = cm
Radius of the wire, a

Sr.no	PSR	HSR	L.C	PSR + (HSR*LC)	Diameter (cm)	Radius ,a (cm)

Sr. No	Length of the wire 'l' between chucks (cm)	Time taken for 20 Oscillations (sec)			time period T (sec)	T^2	l/T^2
		Trial I	Trial II	Mean			