AP PRACTICAL FILE

CSE_B_HARDIK DHEER_53

SUBMITTED TO – REKHA BHARDWAJ MAM

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EXPERIMENT 1

AIM:
To determine the resistivity of semiconductors by Four probe Method.

APPARATUS REQUIRED:
A thin semiconductor sample(germanium or silicon), a four-probe arrangement, oil bath, ammeter, voltmeter, constant current source (0-10mA), an oven with power supply and thermometer (0-200'C).

THEORY:
In four probe method, four pointed, collinear, equally spaced probes are placed in pressure contact with plane surface of sample. A current is injected into sample through outer two probes. The resulting electric potential distribution is measured via two inner probes if:
Surface of sample is assumed to be flat with no surface leakage
Diameter of contact between each probe and sample is small compared to distance between the probes.
Thickness(w) of sample should be small compared to distance between probes($\triangle$)
Thickness(d) is very small, then:

$$V = (\rho \times \ln 2)/(\prod w)$$

where, ρ is resistivity of semiconducting sample.
Now temperature variation is:

$$\rho = \rho_o \times \exp(E_g/KT)$$

where E_g – energy band gap of semiconductor

$$E_g = 2K \times 2.302x(\log_{10} \rho)x(1/T) \text{ eV}$$

where, K= 8.6 x 10^{-5} eV/deg (Boltzman Constant) and ρ is resistivity of semiconductor given by:

$$\rho = \rho_o/f(w/s) \quad ; \rho_o = (V \times 2\prod s)/I$$

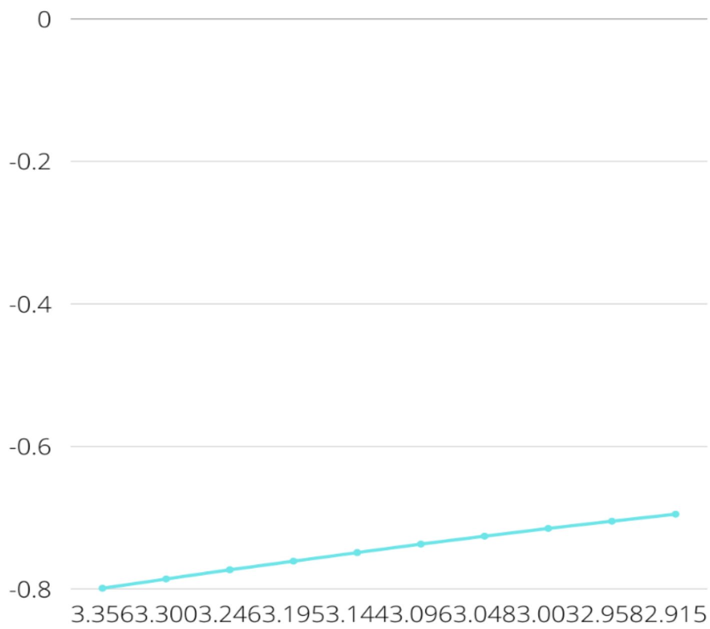
where function f(d/s) refers to specific value for a crystal depending upon d/s and V & I are voltage and current across and through crystal respectively.

PROCEDURE:
1. Put the four-probe arrangement in the oven and again check the continuity between each pair of leads.
2. Connect the probes 1 and 4 to constant current source.
3. Connect a voltmeter between probes 2 and 3.
4. Switch on the current and set the current to a constant value.
5. Note down the voltage V in voltmeter.
6. Switch on the oven and not down V for different temperature while heating the sample.
7. From the values of w and f(w/s), calculate ρ for each reading and plot graph b/w ρ and T to see variation of resistivity with temperature.
8. Plot a graph between 10^3/T and $\log_{10}\rho$

OBSERVATIONS:
f(w/s) = 5.8
Material of semiconductor = Germanium (Ge)
Thickness of sample(w) = 0.05cm = 5×10^{-4}
Distance between probes(s) = 0.2cm = 2×10^{-3}
Value of Boltzman Constant(K) = 8.6×10^{-5} eV/k
Value of current(I) = 3mA = 3×10^{-3}A (constant)

OBSERVATION TABLE:

S.NO.	Temperature		Voltage	ρ_o	ρ	$-\log_{10}(\rho)$	$10^3/T$
	('C)	(K)	(mV)	(ohmm)	(ohmm)		
1.	25	298	87.24	36.52448	6.29732	0.799	3.355705
2.	30	303	84.65	35.44013	6.11036	0.786	3.30033
3.	35	308	82.22	34.42277	5.93496	0.773	3.246753
4.	40	313	79.94	33.46821	5.77038	0.761	3.194888
5.	45	318	77.78	32.56389	5.61446	0.749	3.144654
6.	50	323	75.75	31.714	5.46793	0.737	3.095975
7.	55	328	73.83	30.91016	5.32933	0.726	3.04878
8.	60	333	72.01	30.14818	5.19796	0.715	3.003003
9.	65	338	70.30	29.43226	5.07452	0.705	2.95858
10.	70	343	68.67	28.74984	4.95686	0.695	2.915452



Slope = (0.749-0.737)/(3.144654-3.095975) = 0.246

K = 8.625x 10^{-5} eV/k

E_g= 2 x K x Slope x 2.306 x 1000

= 2 x 8.625 x 10^{-5} x 0.246 x 1000

= 0.09785 J

RESULT:

Resistivity of semiconductor = 5.575408 ohmm.

Band Gap of semiconductor = 0.09785 J.

EXPERIMENT: 2

Aim: To study the I-V Characteristics of the Zener Diode.

MaterialRequired:

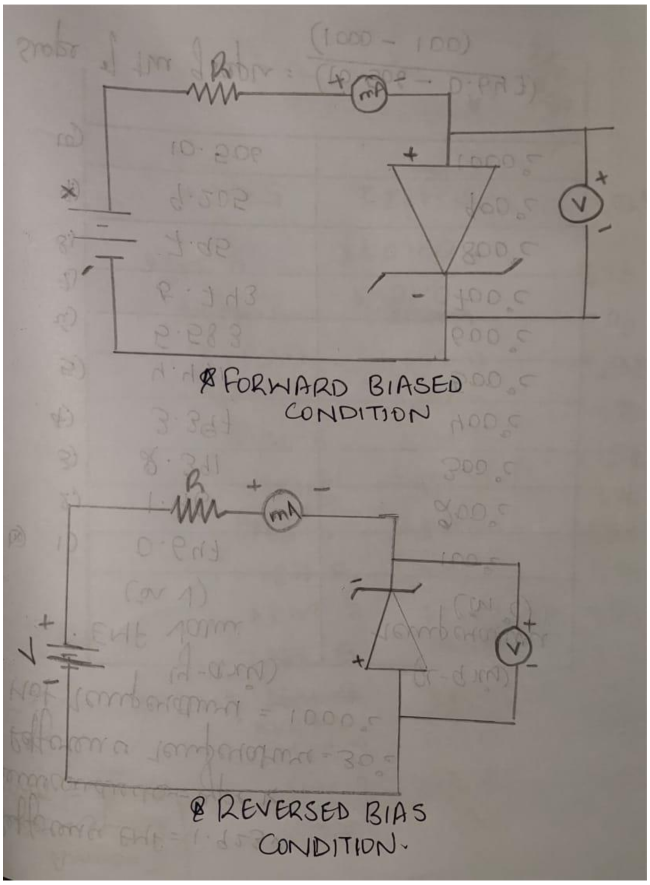
- A Zener Diode
- A Variable Power Supply
- Voltmeter
- Milliammeter
- Microammeter

Principle:

- A Zener Diode is a highly doped *pn*junctional diode. Due to heavy doping on both *p* and *n* side, the junction is relatively arrow as compared to the normal diode.
- As seen in *pn*junctional diode, when a reverse bias is applied to Zener Diode, a very small current flows through it due to the minority charge carriers.
- However, at some reverse voltage, the reverse current in the junction increases rapidly as shown in the figure below. The current through the device increases while the voltage remains essentially constant, i.e., the reverse resistance decreases.
- In such a condition, the diode is said to have reached the Breakdown point.
- There are 2 possible mechanisms for such a breakdown.
    - The first of the type occurring in the Zener Diode is called *Zener Breakdown.* Here, due to heavy doping, the depletion layer is very thin and hence the electric field becomes large for even a small reversed bias voltage.
    - A very sharp increase in the current is observed causing the breakdown of the junction. The value of the reverse voltage at which the breakdown occurred is called the Breakdown Voltage, or the Zener Voltage (V_z)

- Another mechanism responsible for the breakdown of a normal*pn*junctional diode us avalanche multiplication. It occurs when a large reverse voltage applied cause a long electric field and a number of covalent bonds are broken with consequent increase in the current.
- The high acceleration carriers collide with the ions and release many more mobile charges and the process is multiplicative in nature and results in an avalanche discharge.
- This type of junction breakdown is called the Avalanche Breakdown.

Diagram:



Procedure:

- *For Forward Biasing Characteristics*
  - Make all the connections in the circuit as shown in the circuit diagram.
  - Knob of the potentiometer is kept to its full value.
  - Now, switch on the unit and set the voltage to 0 V.

- Increase the voltage in small steps and note down the corresponding currents.
- Plot the graph between the voltage and current.

- *For Reversed Biasing Characteristics*
  - Make all the connections in the circuit as shown in the circuit diagram.
  - Knob of the potentiometer is kept to its full value.
  - Now, switch on the unit and set the voltage to 0 V.
  - Increase the voltage in small steps and note down the corresponding currents.
  - Plot the graph between the voltage and current.

Observations:

For Forward Biased Connection

Potential V (in Volts)	Current I (in mA)
0.10	0
0.30	0
0.50	0
0.60	0
0.70	0.5
0.72	1.2
0.74	2
0.76	3.2
0.78	5
0.8	6.4

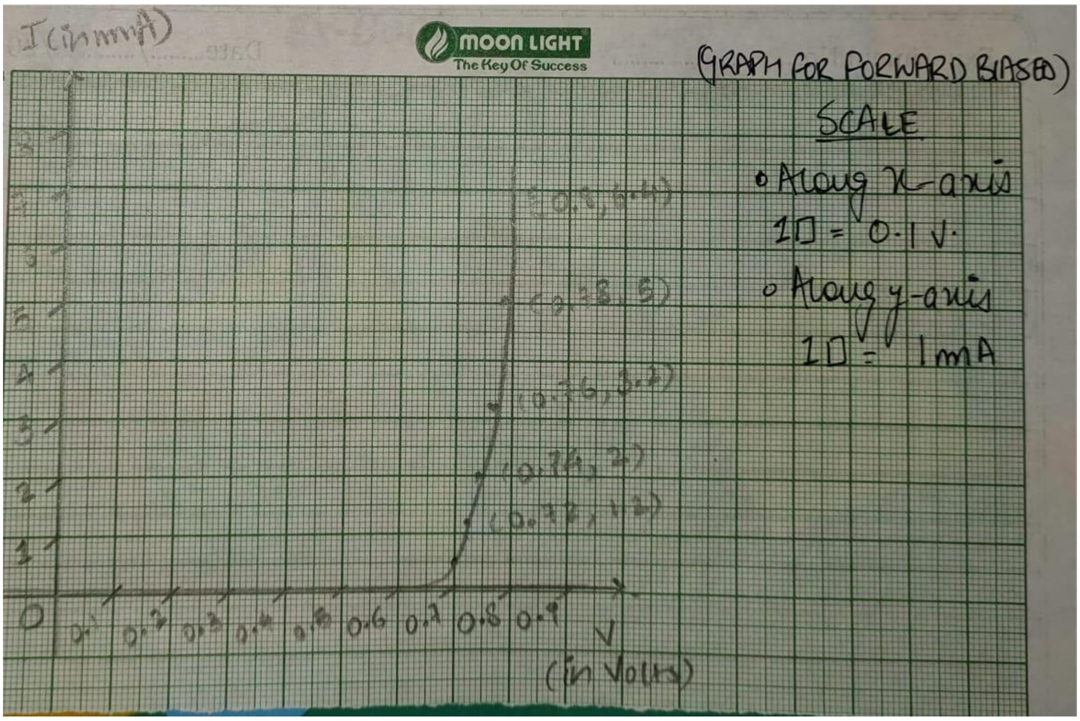
For Reversed Biased connection

Potential V (in Volts)	Current I (in mA)
0	0
2	0
3	0
4	0
5.3	0.10
5.5	0.20
5.6	0.80
5.6	4

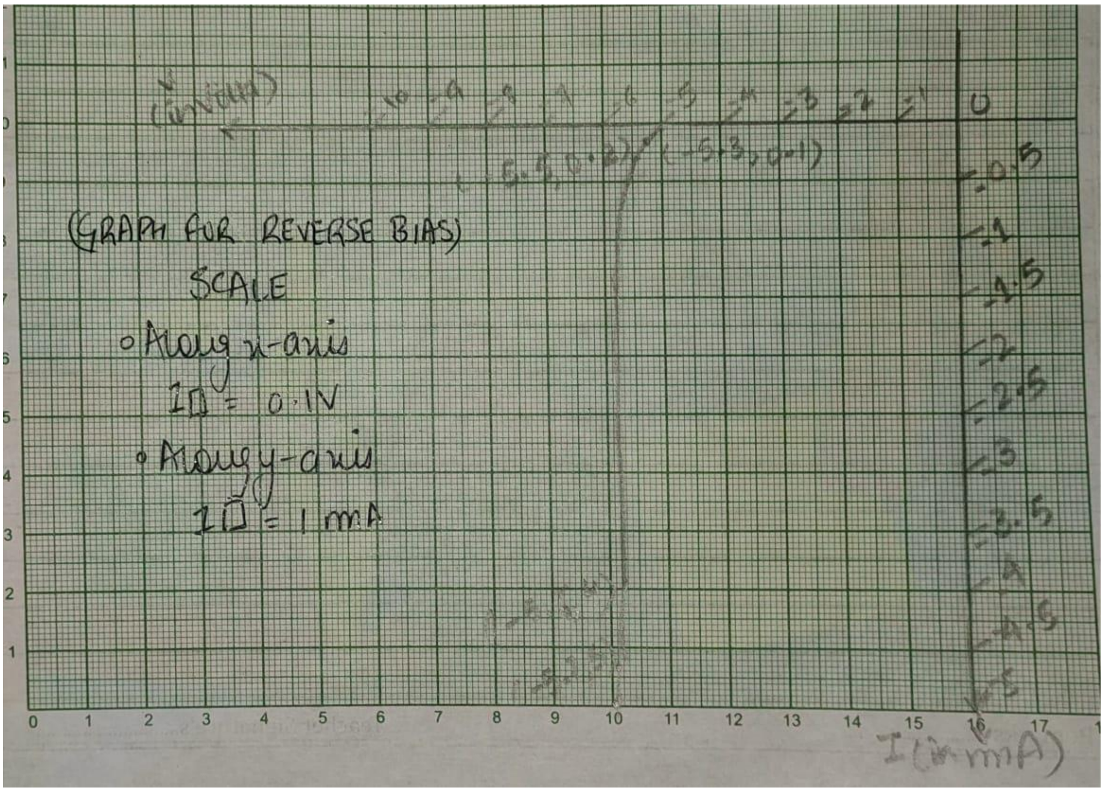
5.7	5
5.7	10

Graphs:

For Forward Biased Connection:



For Reversed Biased Connection:



Results:

- The graphs plotted for the Forward and the Reversed Biased connections of the Zener Diode depicts the I-V Characteristics of the Zener Diode.
- As the reverse voltage V_R is increased, the reverse current remains negligible. However, at the reverse voltage $V_s$the Breakdown effect begins.
- The Breakdown Voltage of the Zener Diode is found out to be 5.7 V.
- The Knee Voltage of the Zener Diode is found out to be 0.8 V.

PrecautionsandSourcesofErrors:

- In both the Forward Biased and the Reverse Biased conditions, the sliding contact id the Rheostat should be kept so as to give minimum voltage before switching on the power supply.
- The Reverse Biased Voltage should be kept below the Breakdown Voltage of the Zener Diode.
- In Forward Biased mode, the voltage should be increased in the steps of 0.1 V and a Milliammeter should read the current.
- The Reverse Biased mode, the voltage should be increased in steps of 1 V and a Microammeter should read the current.

EXPERIMENT: 03

Aim: To verify the relation between Thermo-EMF of a Thermocouple and Temperature Difference between the 2 Hot Junctions.

MaterialRequired:

- Thermocouple (Type: R/K/E/J/T)
- A Voltmeter
- Connecting Wires
- Thermometer(s)

GeneralTerminologies:

- Thermocouple
    - A thermocouple is an electrical device consisting of two dissimilar electrical conductors forming an electrical junction.
    - A thermocouple produces a temperature-dependent voltage as a result of the Seebeck effect, and this voltage can be interpreted to measure the temperature of the thermocouple.

- Thermoelectric effect
    - The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa via a thermocouple.
    - A thermoelectric device creates a voltage when there is a different temperature on each side.

Principle:

- In 1981, Thomas Johann Seebeck found that a circuit with two dissimilar metals with different temperature junctions would deflect a compass magnet.
- He noticed that there was an induced electric current, which by the Ampere's law, deflect the magnet.
- Moreover, electric potential or voltage due to the temperature difference can drive the electric current in the closed circuit.

- To measure this voltage, one must use a second conductor material which generates a different voltage under the same temperature gradient.
  - If the same material is used for measurement, the voltage generated by the measuring conductor would simply cancel that of the first conductor and hence will be equal to zero.
- The voltage difference generated by the two materials can then be measured and related to the corresponding temperature gradient.
- It is thus clear that, based on the Seebeck principle; Thermocouples can only measure temperature differences and need a known reference temperature to yield the absolute readings.
- There are three major effects involved in a thermocouple circuit: the Seebeck, Peltier, and Thomson effects.
  - The Seebeck effect describes the voltage or electromotive force (EMF) induced by the temperature difference (gradient) along the wire.
  - The change in material EMF with respect to a change in temperature is called the Seebeck coefficient or thermoelectric sensitivity. This coefficient is usually a nonlinear function of temperature.
  - Peltier effect describes the temperature difference generated by EMF and is the reverse of Seebeck effect.
  - Finally, the Thomson effect relates the reversible thermal gradient and EMF in a homogeneous conductor.
- Since thermocouple voltage is a function of the temperature difference between junctions, it is necessary to know both voltage and reference junction temperature in order to determine the temperature at the hot junction.
- Consequently, a thermocouple measurement system must either measure the reference junction temperature or control it to maintain it at a fixed, known temperature.

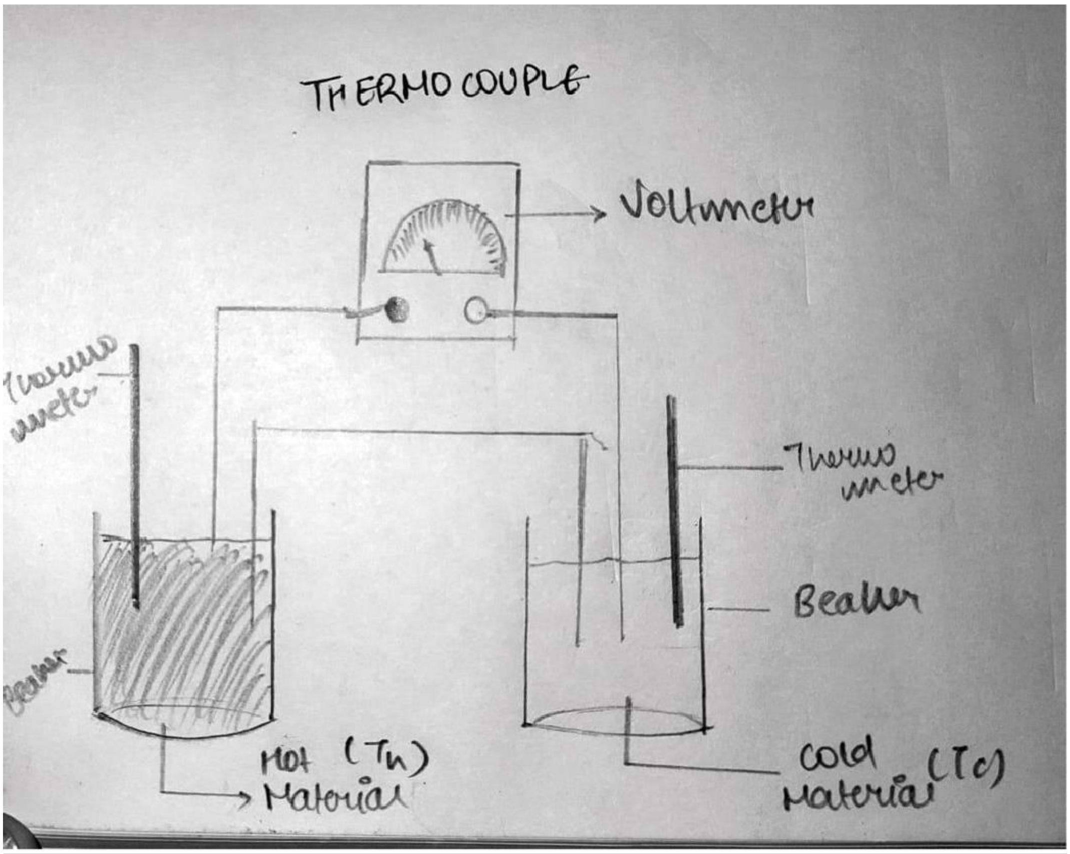
FormulaUsed:

$$V = \alpha\,(T_h - Tc)$$

- Where…
  - V: Voltage Difference between the 2 dissimilar metals
  - α: Seebeck Coefficient
  - T_h: Temperature of the Hot Metal
  - T_c: Temperature of the Cold Metal

- $T_h - T_c$: Temperature Difference between the Hot and the Cold Metal

Diagram:



Procedure:

- Connect the terminals of the Thermocouple to the Voltmeter as shown in the diagram.
- On one end of the Thermocouple, set the temperature that would be the Reference Temperature.
- On the other end of the Thermocouple, set the temperature that would be the Hot Temperature.
- Note the reading of the Voltmeter and perform the experiment again for different Hot Temperatures.
- Plot the graph between the EMF and the Temperature and find its slope.

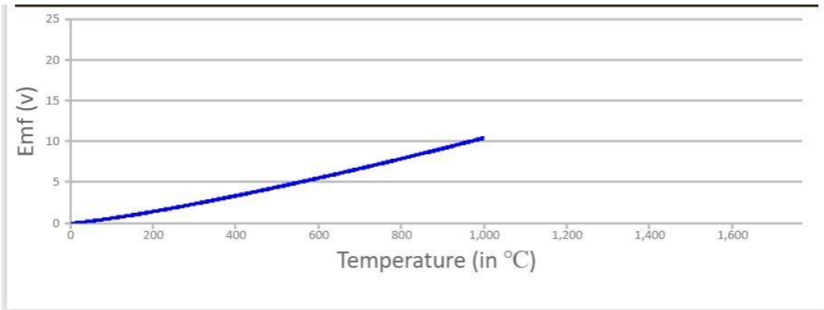


Figure 1: Graph

ObservationsandCalculations:

- Refference EMF = 1.923 V
- Semiconductor = Type K
- Refference Temperature = 30°c
- Hot Temperature = 1000°c

	EMF Value (in V) (y-axis)	Temperature (in °C) (x-axis)
1.)	0.647	100°c
2.)	1.46	200°c
3.)	2.391	300°c
4.)	3.397	400°c
5.)	4.471	500°c
6.)	5.583	600°c
7.)	6.743	700°c
8.)	7.95	800°c
9.)	9.205	900°c
10.)	10.506	1000°c

Slope of the graph $= \dfrac{(10.506 - 0.647)}{(1000 - 100)}$

$= \dfrac{9.859}{900}$

$= 0.010954$

Seen Back coefficient $= 0.010954$ V / °c

$= 4.012 \times 10^{-5}$ V/K

Figure 2: Observations and Calculations

Result:

1. There exists a linear relationship in between the EMF generated by the Thermocouple and the difference in the Temperature of the 2 bodies of the Thermocouple.
2. The Seebeck Coefficient (α) of the Thermocouple is found out to be 4.012 x 10^{-5} V / K

PrecautionsandSourcesofErrors:

- Temperature must be recorded carefully before initializing the experiment.
- Connections must be correct and proper.
- If a Thermocouple Kit is being used, the apparatus must be calibrated before the initialization of the experiment.

EXPERIMENT 4

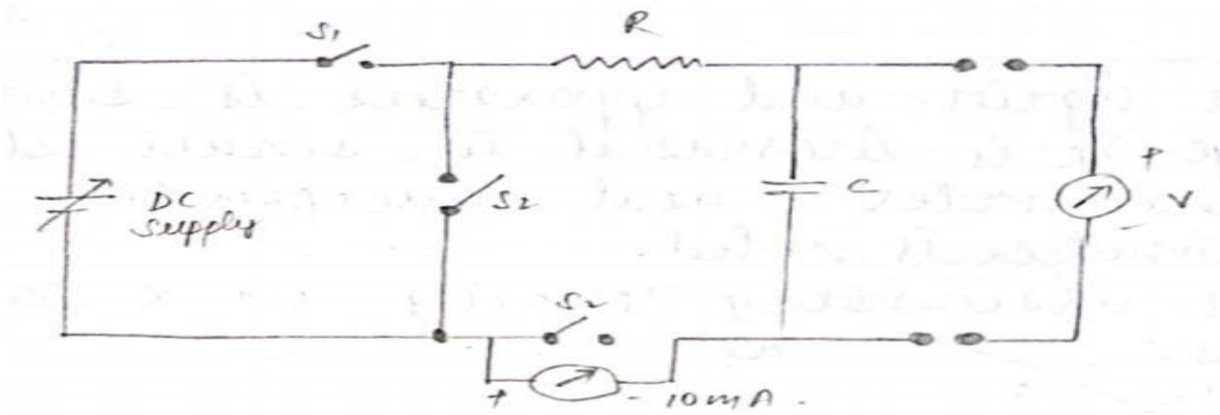
AIM:

To study discharging of a capacitor through a resistor and plot a graph of voltage(V) across the condenser against time(t).

APPARATUS REQUIRED:

DC supply(15V, 25mA), Resistor(10kΩ, 50kΩ), Capacitors(500 and 1000uF), DC voltmeter(0-25V), DC milliammeter(0-100mA), toggle switches, stopwatch.

CIRCUIT DIAGRAM:



Formula Used:

I. Charging equation for capacitor through resistor,
$q=q_o(1-e^{-t/RC})$, where RC is time constant and q_o is maximum charge acquired by capacitor .
Now current equation,
$Idq/dt = q_oe^{-t/RC}/RC = CEe^{-t/RC}/RC = i_oe^{-t/RC}$

II. The charge equations are: $q = q_oe^{-t/RC}$
$I = i_oe^{-t/RC}$
where, i_o = E/R and time constant is RC.

PROCEDURE:

1. Switch ON the main supply to the training board. Adjust DC supply to 15V.
2. Keep switch S1 and S2 open and S3 closed.
3. Close switch S1 and keep it closed till the voltage across the condenser reaches 15V.
4. Now open switch S1. Close switch S2 and simultaneously start the stop watch. Take readings of voltage across the condenser at certain intervals of time till the voltage approaches approximately zero.
5. Plot a graph of these two quantities.
6. Draw a horizontal line at 15/2 = 7.5 volts position. Read the value of time on the x-axis where the horizontal line intersects the graph.
7. Calculate the time constant.
8. Compare it with theoretical time constant.

OBSERVATIONS:

R=10 kΩ, C=4700Uf

S.NO.	Time(t)sec	Voltage(V)
1.	0	11
2.	5	3.25
3.	10	1.25
4.	15	0.5
5.	20	0

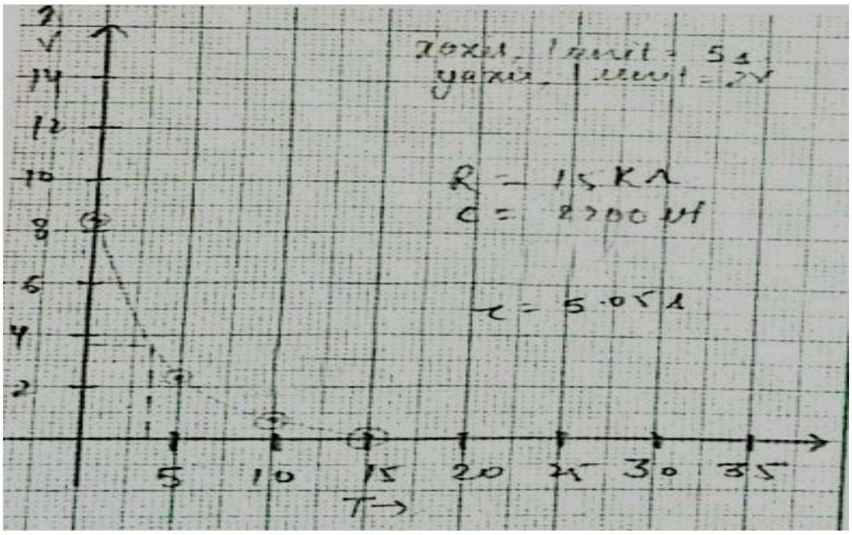
R=18 kΩ, C=1000uF

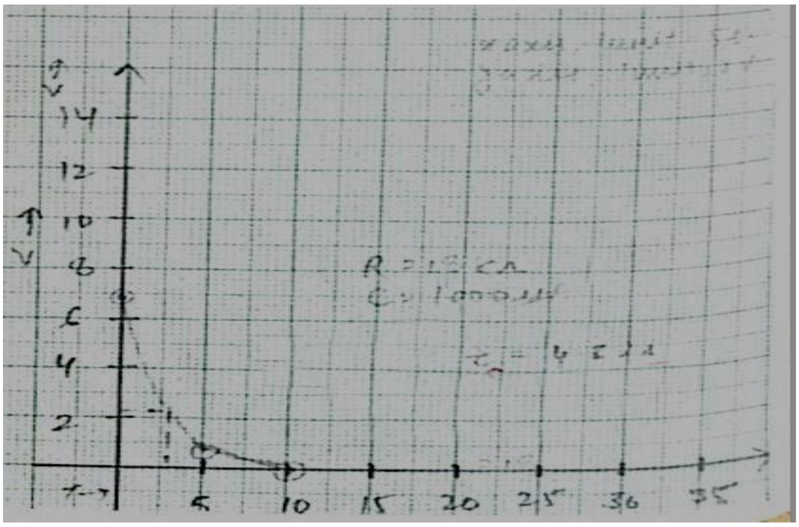
S.NO.	Time(t)sec	Voltage(V)
1.	0	6.75
2.	5	0.75
3.	10	0

R=15 kΩ, C=2200uF

S.NO.	Time(t)sec	Voltage(V)
1.	0	8.25
2.	5	2.25
3.	10	0.75
4.	15	0

GRAPHS:





RESULT:

Time constant r = RC

1. For R = 15 kΩ, C = 2200uF, r = 5.05s
2. For R = 18 kΩ, C = 1000uF, r = 4.32s
3. For R = 10 kΩ, C = 4700uF, r = 4.32s

EXPERIMENT 5

AIM:

To determine the conductivity of poor conductor by the method of Lee's Disk method.

APPARATUS REQUIRED:

Lee's apparatus with circular disc of a poor conductor, tow sensitive thermometer, steam generator, stand and threads, stopwatch, screw gauge and vernier caliper.

THEORY:

The coefficient of thermal conductivity K is given by the formula:

$$K=\frac{ms.d}{\pi r^2(\theta_1 - \theta_2)}\left[\frac{d\theta}{dt}\right]_{\theta=\theta_2}$$

Where, m -> mass of disc placed over slab s -> specific heat

of material of discd -> thickness of experimental

discr -> radius of experimental disc

θ_1, θ_2 -> steady temperature of two surfaces of the experimental

disc

$d\theta/dt$ -> rate of radiation of two surface of disc

APPARATUS DESCRIPTION:

In Lee's arrangement, a hollow metallic box known as steam chamber is suspended from a stand in such a way that suppersurface is horizontal. Steam is passed over from one end which comes out from the other end. The experimental disc C is placedon the steam chamber. Another disc B of brass, well polished is also placed over C such that C is pressed between the steam chamber and brass disc. The steam chamber A and disc B are provided with two thermometer T_1 and T_2 to note temperature θ_1 and θ_2 of steam and slab B respectively.

PROCEDURE:

1. Note the mass of the brass disc as quoted over it.
2. Note the radius r and thickness d of the experiment as discC as quoted over it otherwise measure the quantities.
3. Insert the two thermometer T_1 and T_2 in the steam chamberaA and brass disc B respectively and let the arrangement sit.
4. Allow the steam to pass in steam chamber.
5. Obtain the steady state and note readings of 2thermometer.
6. To measure $(d\theta/dt)$ the experimental disc is removed anddisc B is directly placed on the steam. Remember to increase the temperature by 10^oC above θ_2. The disc B is suspended separately and allowed to cool.
7. A graph is plotted between temperature and time which comes out to be a curved time and from the point to curveat the temperature θ_2, draw a tangent.
8. Calculate value of K, taking S as specific heat.

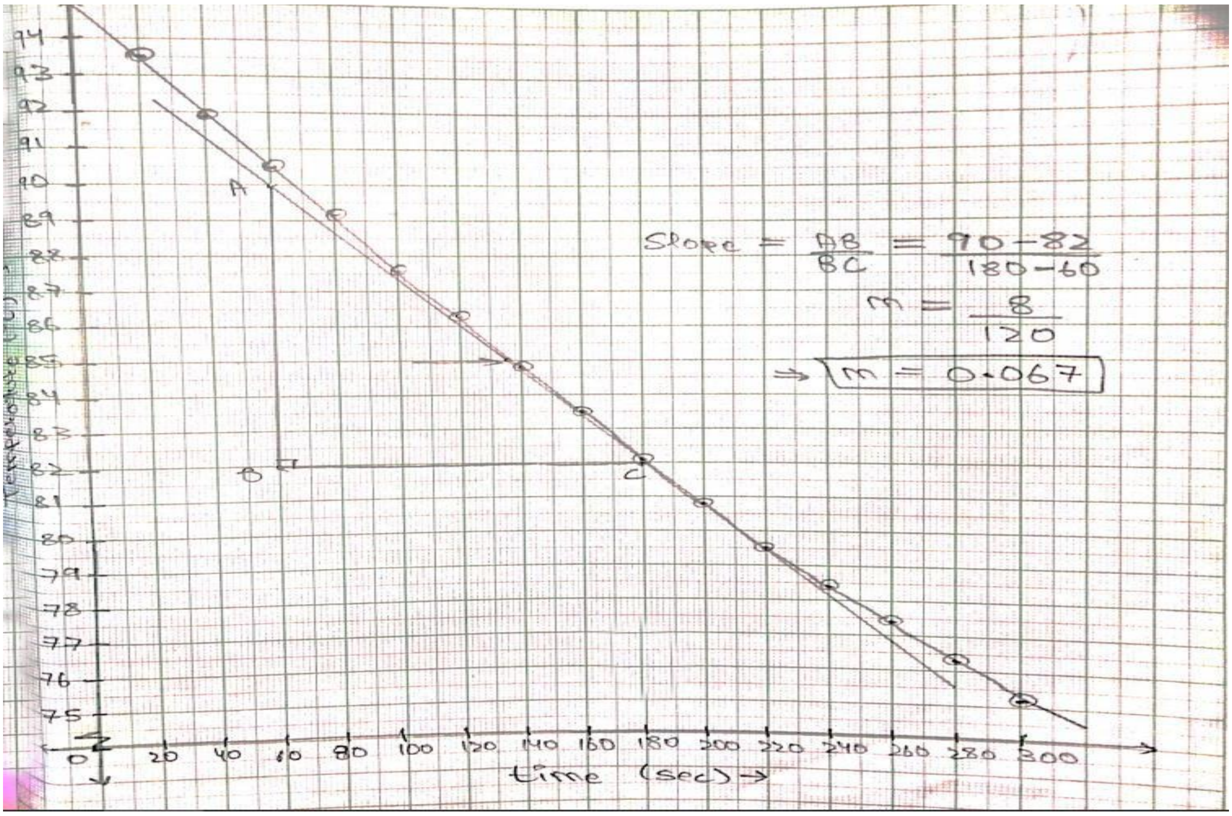
OBSERVATIONS:

- Radius of experimental disc(r) = 5.56 x 10^{-2}m
- Thickness of experimental disc(d) = 0.27 x 10^{-2}m
- Mass of glass disc(m) = 0.76kg
- Specific heat of glass(s) = 3J/KgK
- Steady state temperatures: θ_1 = 100°C ; θ_2 = 85°C

OBSERVATION TABLE:

Serial Number	Time(sec)	Reading of thermometer T_2 (θ_2°C)
1.	20	93.5
2.	40	91.9
3.	60	90.5
4.	80	89.2
5.	100	87.6
6.	120	86.3
7.	140	84.8
8.	160	83.5
9.	180	82.1
10.	200	80.7
11.	220	79.5
12.	240	78.4
13.	260	77.4
14.	280	76.3
15.	300	75.2

GRAPH:



CALCULATIONS:

From graph $\left[\frac{\mathbf{d\theta}}{\mathbf{dt}}\right]_{\boldsymbol{\theta_2}}$=0.067

Therefore, **K=** $\frac{\boldsymbol{ms.d}}{\boldsymbol{\pi r^2(\theta_{1-}\theta_2)}}\left[\frac{\mathbf{d\theta}}{\mathbf{dt}}\right]_{\boldsymbol{\theta=\theta_2}}$ **=** $(0.76\times377\times0.27\times10^{-2}\times0.067)/$ $(3.14\times(5.56\times10^{-2})^{-2}\times(100\text{-}85))$

K=0.356 J/m^{o}Csec

RESULT:

The coefficient of thermal conductivity, K of given non-metallicsolid, K = 0.356J/m^{O}Csec

PRECAUTIONS:

1. The steady state should be obtained very accurately.
2. The experimental disc should be thin.
3. The value of dθ/dt from graph should be obtained attemperature θ2.
4. Observations of d and r of experimental disc should betaken before starting the experiment.

EXPERIMENT 6

AIM:

1. To determine the Hall voltage developed across the samplematerial.
2. To calculate the Hall coefficient and the carrierconcentration of the sample material.

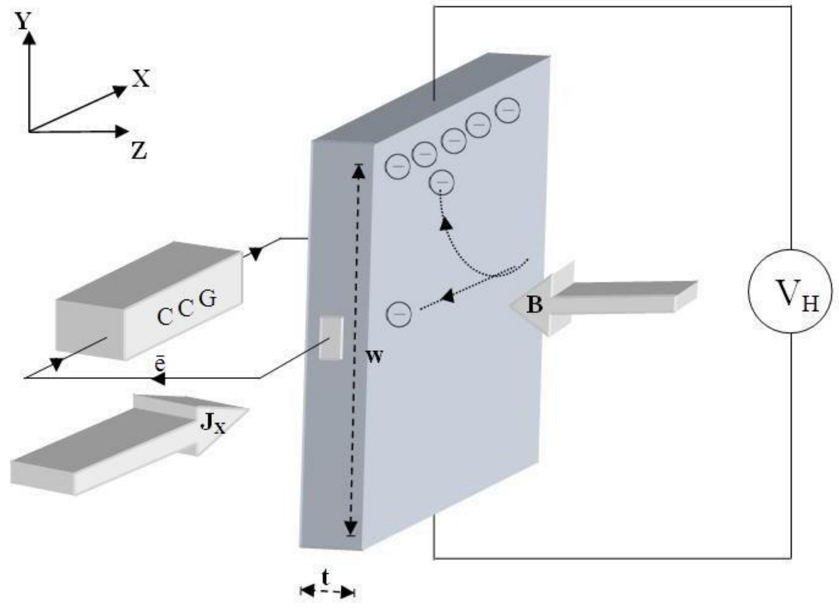
APPARATUS REQUIRED:

Two solenoids, Constant current supply, Four probe, Digital gauss meter, Hall effect apparatus (which consist of Constant Current Generator (CCG), digital milli voltmeter and Hall probe).

THEORY:

If a current carrying conductor placed in a perpendicular magnetic field, a potential difference will generate in the conductor which is perpendicular to both magnetic field and current. This phenomenon is called Hall Effect. In solid state physics, Hall effect is an important tool to characterize the materials especially semiconductors. It directly determines both the sign and density of charge carriers in a given sample.

Consider a rectangular conductor of thickness t kept in XY plane. An electric field is applied in X-direction using Constant Current Generator (CCG), so that current I flow through the sample.
If w is the width of the sample and t is the thickness. There for current density is given by:
Jx=I/wt



CCG – Constant Current Generator, J_X – current density
$\bar{e}$ – electron, B – applied magnetic field
t – thickness, w – width
V_H – Hall voltage

If the magnetic field is applied along negative z-axis, the Lorentz force moves the charge carriers (say electrons) toward the y- direction. This results in accumulation of charge carriers at the top edge of the sample. This set up a transverse electric
field Ey in the sample. This develop a potential difference along y-axis is known as Hall voltage VH and this effect is called Hall Effect.

A current is made to flow through the sample material and the voltage difference between its top and bottom is measured using a volt-meter. When the applied magnetic field B=0,the voltage difference will be zero.
We know that a current flows in response to an applied electric field with its direction as conventional and it is either due to the flow of holes in the direction of current or the movement of electrons backward. In

both cases, under the application of magnetic field the magnetic Lorentz force, F_m=q(v×B) causes the carriers to curve upwards. Since the charges cannot escape from the material, a vertical charge imbalance builds up. This charge imbalance produces an electric field which counteracts with the magnetic force and a steady state is established. The vertical electric field can be measured as a transverse voltage difference using a voltmeter.

In steady state condition, the magnetic force is balanced by the electric force. Mathematically we can express it as

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

Where 'e' the electric charge, 'E' the hall electric field developed, 'B' the applied magnetic field and 'v' is the drift velocity of charge carriers.

And the current 'I' can be expressed as,

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

Where 'n' is the number density of electrons in the conductor of length l ,breadth 'w' and thickness 't'.

Using (1) and (2) the Hall voltage VH can be written as,

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

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

by rearranging eq(4) we get

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

Where R_H is called the Hall coefficient.

$$RH=1/ne \qquad (6)$$

PROCEDURE:

- Connect ‘Constant current source’ to the solenoids.
- Four probe is connected to the Gauss meter and placed at the middle of the two solenoids.
- Switch ON the Gauss meter and Constant current source.
- Vary the current through the solenoid from 1A to 5A with the interval of 0.5A, and note the corresponding Gauss meter readings.
- Switch OFF the Gauss meter and constant current source and turn the knob of constant current source towards minimum current.
- Fix the Hall probe on a wooden stand. Connect green wires to Constant Current Generator and connect red wires to milli voltmeter in the Hall Effect apparatus
- Replace the Four probe with Hall probe and place the sample material at the middle of the two solenoids.
- Switch ON the constant current source and CCG.
- Carefully increase the current I from CCG and measure the corresponding Hall voltage VH. Repeat this step for different magnetic field B.
- Thickness t of the sample is measured using screw gauge.
- Hence calculate the Hall coefficient RH using the equation 5.
- Then calculate the carrier concentration n. using equation 6.

PRECAUTIONS:

- Turn on water before turning on magnet coil.
- Do not exceed magnet current of 10 A.
- Do not exceed Hall probe current of 0.4 A