Date: 18.9.23

Experiment No. 3

Energy Band Gap Of Semiconductor

Circuit Diagram :

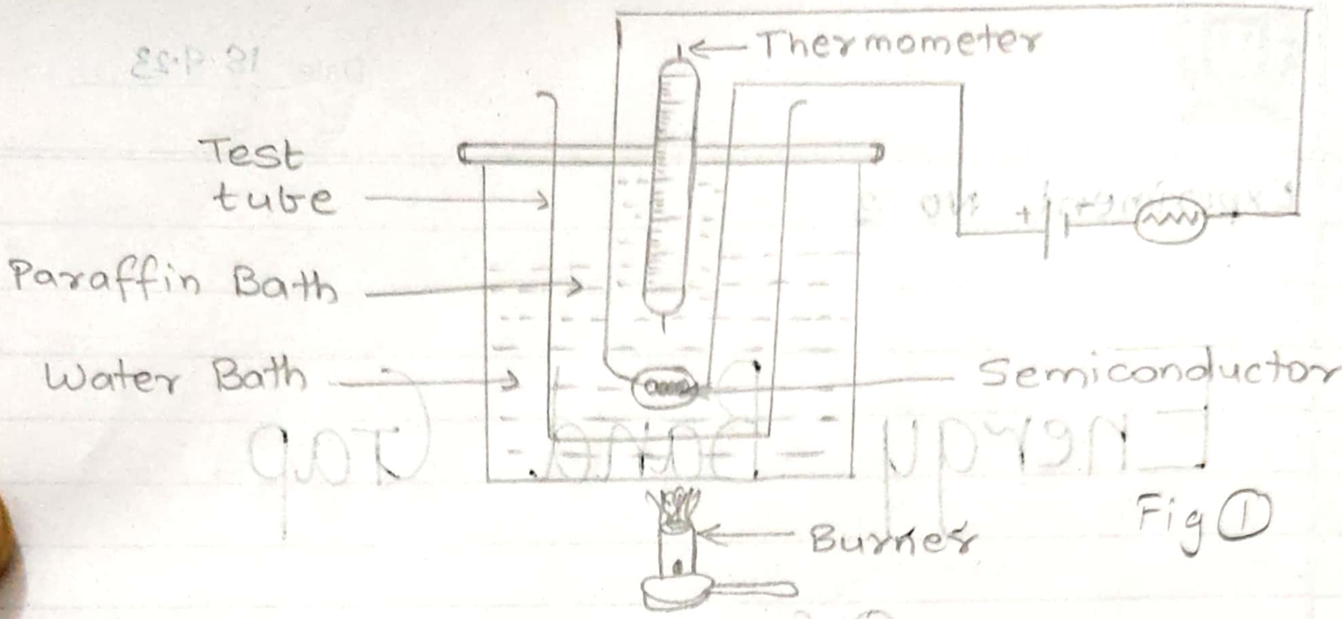
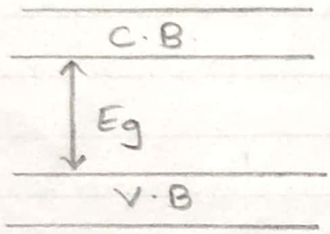
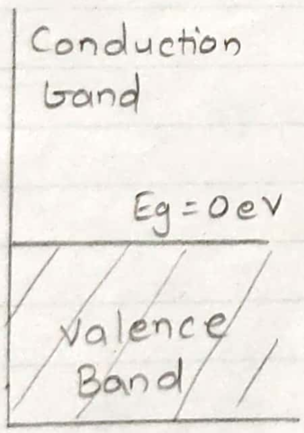


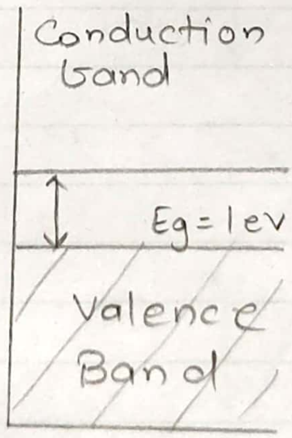
Fig ①

Fig ②

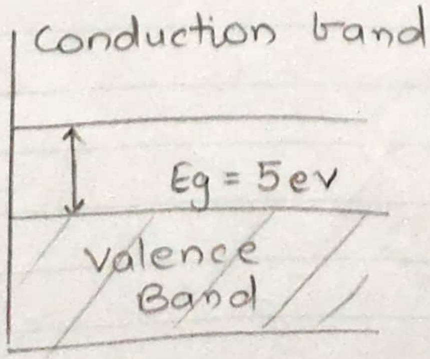




For conductors



For Semiconductors



For Insulators

Date:

Aim :- To determine forbidden gap of semiconductor

Apparatus :- Semiconductors with stone powder or oil bath, thermometer, micro ammeter, multimeter, heating coil.

Theory :- Solid are classified according to energy band structure. It consist of two bands namely valance band and conduction band separated by a gap known as forbidden gap energy gap (E_g). The band which is occupied by valance electrons and has highest occupied band energy at absolute zero temperature is called valance band. It may be partially or completely filled up depending upon the nature of solids.

The lowest unfilled energy band at absolute zero temperature is called conduction band.

The electrons in valance band can be transferred to conduction band by providing them with energy equal to E_g.

On the basis of forbidden energy gap, solids are classified into three groups, namely conductors, semiconductors, Insulators.

In conductors, $E_g = 0\,eV$

In semiconductors, $0 < E_g < 1\,eV$

In insulators, $E_g > 5\,eV$

Germanium and silicon are two good example of semiconductors. In silicon the energy gap is 1.1 eV, whereas that in germanium is 0.72 eV, as shown in Fig 2.

In a semiconductor at absolute zero, the conduction band is empty and the valance band is filled. As temperature

Date:

increase, the valaence band electron gain energy, and cross over ~~the band. As the number of ele~~ forbidden gap to move into the conduction band. As the number of electrons available for conduction increases with temperature, the resistivity of the semiconductor decreases. We have at temperature $T > 0°K$,

$$\rho_T = \rho_0 \exp\left(\frac{E_g}{2KT}\right)$$

where, ρ_T is resistivity at temperature T, ρ_0 is resistivity at absolute zero E_g is forbidden energy gap of the semiconductor, and K is Boltzmann constant.

Since resistance of a given specimen is poportional to resistivity, we can write,

$$R_T = R_0 \exp\left(\frac{E_g}{2KT}\right)$$

Taking logarithm on both sides, we get

$$\ln R_T = \ln R_0 + \frac{E_g}{2KT}$$

This equation has the form $y = mx + c$, where, $y = \ln R_T$ and $x = 1/T$. Thus, the graph of $\ln R_T$ vs $1/T$, is a straight Line with slope equal to $E_g/2k$ and intercept equal to $\ln R_0$. In this experiment, the above considerations have been used to estimate the forbidden energy gap of the given semiconductor material Number of electron or hole in intrinsic semiconductor Like Si or Ge depends on temperature at T°K it will be

$$n_i = A T^{3/2} e^{-E_g/2KT} \quad \text{——} \quad (1)$$

So Conductivity of intrinsic semiconductor increases with temperature At T°K it will be

$$\sigma_T = \sigma_0 e^{-E_g/2KT}$$

Resistivity of intrinsic semiconductor which decreases with

Date:

temperature at $T^\circ K$ & $T_o^\circ K$ will be

$$\rho_{T_o} = \frac{1}{\sigma_{T_o}} = \rho_o e^{\beta/T_o}$$

$$\rho_T = \frac{1}{\sigma_T} = \rho_o e^{\beta/T} \quad \text{— (2)}$$

Where A, σ_0, ρ_0 are some ~~curre~~ constant,
E_g = energy band gap of intrinsic semiconductor,
K = boltzmanns constant
T = temperature in degree Kelvin
T_o = reference temperature
$\beta = E_g/2K$

Now $\frac{\rho_T}{\rho_{T_o}} = e^{\beta}\left(\frac{1}{T} - \frac{1}{T_o}\right)$ — (3) i.e $\rho_T = \rho_{T_o} e^{\beta}\left(\frac{1}{T} - \frac{1}{T_o}\right)$

Similarly $R_T = R_{T_o} e^{\beta}\left(\frac{1}{T} - \frac{1}{T_o}\right)$ — (4)

where R_T = resistance of semiconductor at $T^\circ K$
R_{T_o} = resistance of semiconductor at $T_o^\circ K$
Where T_o is some reference temperature like room temperature
Now by taking natural logarithm of equation 4 we get

$$\ln R_T = \ln R_{T_o} + \beta\left(\frac{1}{T} - \frac{1}{T_o}\right)$$

This is an equation of a straight line having slope $m = \beta = \frac{E_g}{2K}$

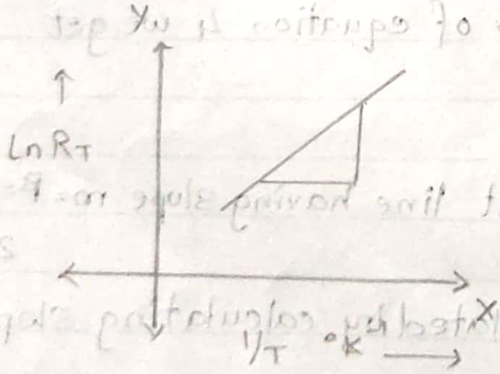
So energy band gap can be calculated by calculating slope β i,e. $E_g = 2K\beta$
where K = Boltzmann's constant = 1.37×10^{-23} J/oK

Procedure :-

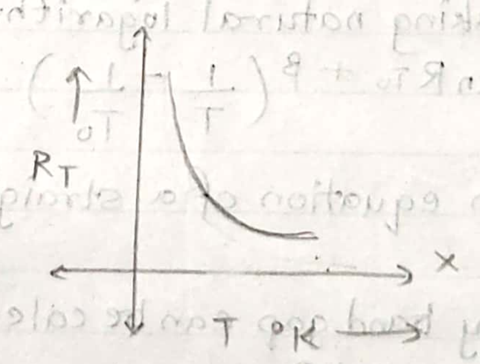
1) Measure voltage of a given cell.
2) Connect the circuit as shown in the diagram and get it checked.

Observation Table :-

Sr. no.	Temperature $t°C$	$I \times 10^{-6}$ (μA)	V (Volts)	$T=(t+273)K$	$R_T = V/I$	$\frac{1}{T} \times 10^{-3}$	$Ln R_T$
	28	8	0.025	301	3125	3.32	8.04
	30	9	0.025	303	2777	3.30	7.92
	35	9	0.024	308	2666	3.24	7.88
	40	9	0.023	313	2555	3.19	7.84
	45	10	0.022	318	2200	3.14	7.69
	50	10	0.021	323	2100	3.09	7.64
	55	10	0.020	328	2000	3.04	7.60
	60	11	0.019	333	1727	3.00	7.45
	65	11	0.018	338	1636	2.95	7.40
	60	11	0.018	333	1636	3.00	7.40
	55	11	0.019	328	1727	3.04	7.45
	50	11	0.020	323	1818	3.09	7.50
	45	10	0.021	318	2100	3.14	7.64
	40	10	0.022	313	2200	3.19	7.69
	35	10	0.022	308	2200	3.24	7.69
	30	9	0.024	303	2666	3.30	7.88
	28	8	0.025	301	3125	3.32	8.04



(Graph of LnRT vs 1/T)



(Graph of RT vs T)

Date:

3) Measure the normal temperature and corresponding leakage current.

4) Start heating white stone powder or oil bath by using heater or burner.

5) Measure current at 35°c and then upto 75°c in step 5°c each

6) Alternatively, heat the diode upto 75°c, turn of the heater and measure the current as the diode cools down to 35°c in steps of 5°c each.

7) Calculate R_T $\ln R_T$ & $1/T$

8) Plot a graph of R_T vs $1/T$ and find the slope of graph as β

9) Substitute β in the given formula to find 'Eg' in joules and then in electron volt.

10) Compare it with the standard value for given diode

11) Also plot graph of R vs T to verify that R falls non linearly with increase in temperature.

Calculation :- We have

$E_g = 2K\beta$

$= 2 \times 1.37 \times 10^{-23} \times 1672.07$ (slope of graph of $\ln R_T$ vs $1/T$)

$= 4.58 \times 10^{-20}$ Joules $\frac{4.58 \times 10^{-20}}{1.6 \times 10^{-19}}$ eV

$E_g = 2.86 \times 10^{-39}$ eV

$= 0.286$ eV

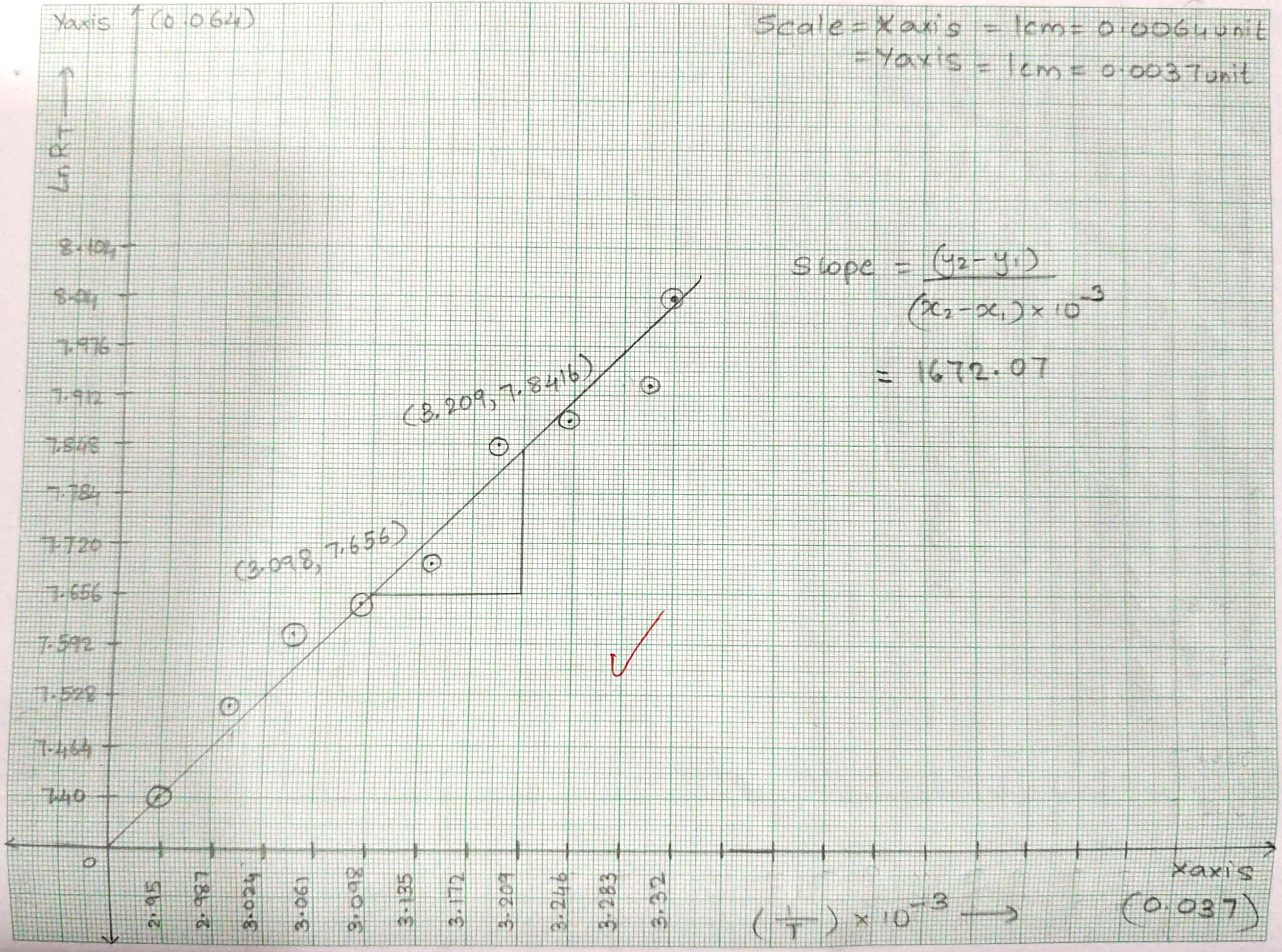
Result :-

The energy gap of given semiconductor diode

~~2.86 × 10⁻³⁹~~ eV

0.286

Scale = X axis = 1cm = 0.0064 unit
= Y axis = 1cm = 0.0037 unit



$$\text{Slope} = \frac{(y_2 - y_1)}{(x_2 - x_1)\times 10^{-3}}$$

$$= 1672.07$$

Date: 9.10.23

Experiment No: 4

Semiconductor Diode Characteristics

Date:

Aim :- To study semiconductor diode characteristic

Apparatus :- Silicon diode, voltmeter.

Objective :-

1) To trace the CKT
2) Measure the current through diode for particular value of input voltage
3) Plot the forward characteristic of si diode.
4) Calculate the forward dynamic resistance of the diode at a particular operating points.

At a given operating point, we can determine static resistance Rf and dynamic resistance rf. The static forward resistance is defined as ratio of the dc voltage to dc current.

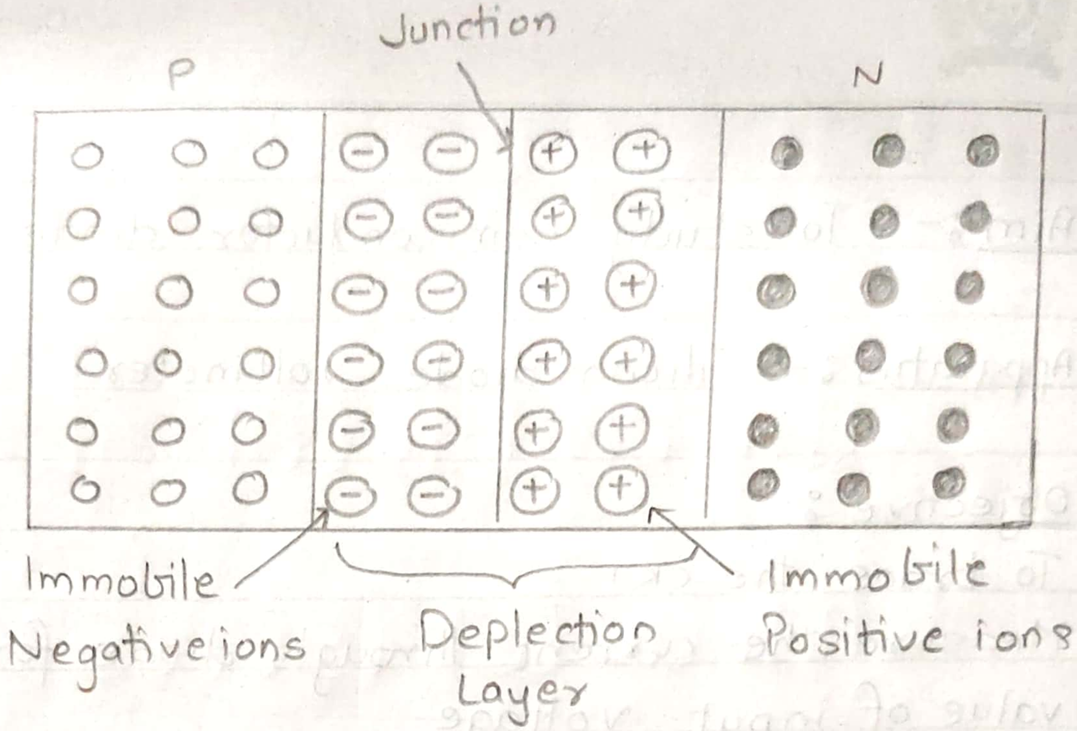
$Rf = \Delta V / \Delta I \ \Omega$

Procedure :-

1) Trace the ckt and identify the different component
2) Connect the voltmeter and ammeter of a suitable range.
3) Switch on power supply with help of pot. Increase voltage slowly
4) Note down miliammeter and voltmeter reading carefully
5) Draw the graph between V and I
6) At suitable operating point calculate Rf and rf

Theory :-

when a P-type semiconductor is fused to N-type semiconductor, the crystal so formed is called P-N diode


Junction
P
N
Immobile
Negative ions
Deplection
Layer
Immobile
Positive ions

Date:

The area of the crystal common to both regions is called P-N junction.

In the formation of a P-N junction, some of the majority carriers i.e. holes from P-reigion diffue into N region because of the concentration gradient. Similarly, electrons from N region diffuse into P region because of the concentration gradient. These diffused charge carriers combine near the junction to neutralize each other. Due to this a charge free space called 'Depletion Layer is formed near the junction. Width of this layer is of the order of a few microns.

Due to the diffusion of holes from P to N region, negative ions are produced in P region near the junction. Similarly, due to the diffusion of electrons from N to P region, positive ions are produced in N region. These ions are immobile in nature and form parallel rows or plates of opposite charges facing each other across the depletion layer

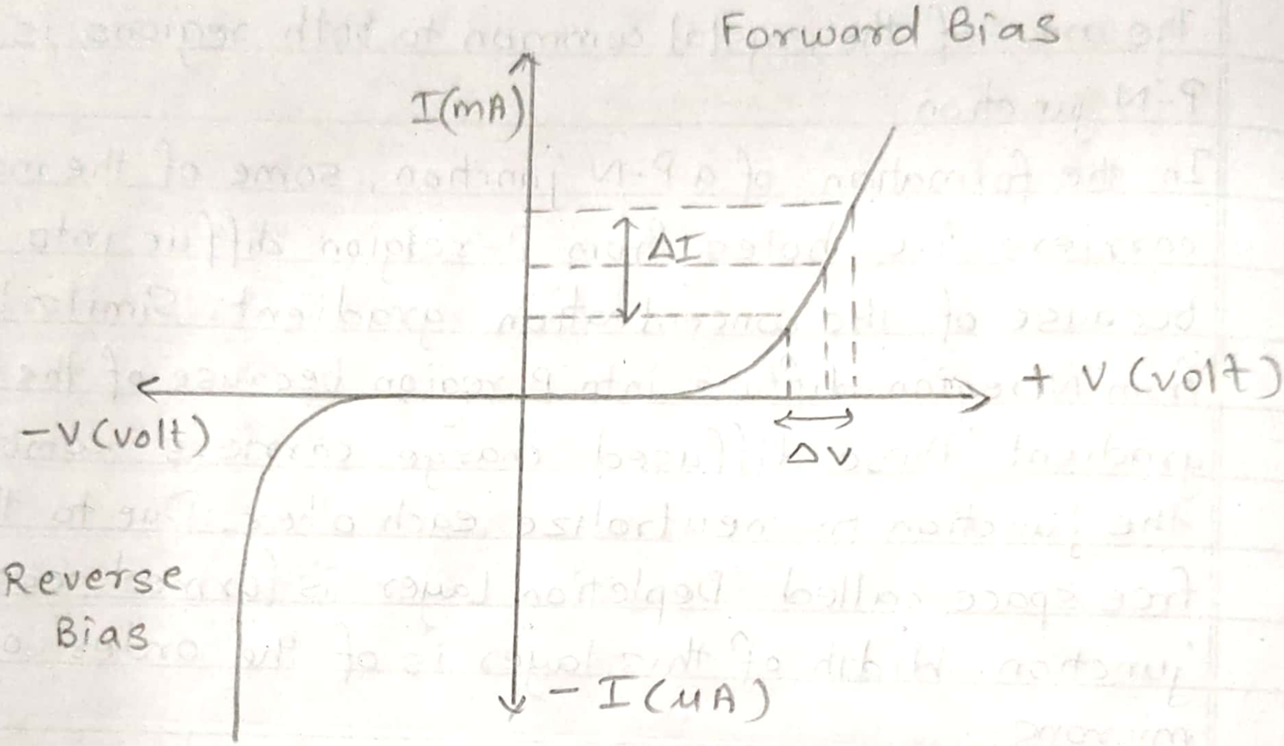
Because of this charge separation, an electric potential develops across the junction under equilibrium condition. This potential gradient is called junction potential or barrier potential. It can be represented by an equivalent battery. It prevents further diffusion of majority charge across the junction.

A P-N junction diode is a unidirectional device, because it conducts in only one direction when an external voltage is applied across the diode terminals.

Forward Biasing of P-N Diode:

when a P-N diode is connected to a battery such, that positive terminal of the battery is connected to P region while negative terminal is connected to N region than the

Graph :-



Date:

diode is said to be in forward biased condition.
The positive terminal of battery repels the majority carriers i.e holes in P region and the negative terminal of battery repels the majority carriers i.e. electron in N region towards the junction. The movement of charge carriers leads to a current in P-N diode, which can be recorded by an ammeter connected in series with the diode. The diode is said to be in condiuction. In this case barrier pontential is reduced.
The relationship between forward voltage and forward current is shown in the graph. Initially as the applied voltage overcomes the barrier potential, very small current flows. Once the barrier pontential is completely overcome the current increases sharply and rapidly with increasing voltage. The voltage corresponding to the transition in the rate of chonge of increase in the current is called the knee voltage.

Reverse Biasing of P-N Diode :
When a P-N diode is connected to a battery such that negative terminal of the battery is connected to P-region and positive is connected to N-region then the diode is said to be in reverse biased condition
The majority charge carriers i.e. holes in P-region and electrons in N-region are attracted by negative and positive terminals of the battery ~~rep~~ respectively. Therefore these majority carriers start moving away from the junction. This results into the increase of the width of deplection layer and also in the increase of barrier potential. No flow of electrons across the junction is obtained in the process. Therefore no conduction of electric

Observation Table :-

Forward bias

Sr. no.	Vtg. Drop across diode VF (volts)	Current through diode - IF (mA)
1	0	0
2	0.1	0.02
3	0.2	0.05
4	0.3	0.10
5	0.4	0.43
6	0.5	6.60
7	0.6	38.1

Reverse bias

Sr. no.	Vtg. drop across diode VR (Volts)	Current through diode - IR I (μA) × 1000
1	0	0
2	1	50
3	2	140
4	3	210
5	4	280
6	5	350
7	6	430
8	7	580
9	8	630
10	9	660
11	10	830

Date:

current takes place and the diode is said to be in non-conduction.

Initially, a small negligible amount of current may flow. This current is due to the minority charge carriers present in P and N regions. The relationship between the reverse voltage and reverse current is shown in the graph. With very large reverse bias, current flow is extremely small. When the reverse voltage exceeds a certain value called Zener or Break down voltage, the reverse current sharply increases. This curve indicates zero resistance at this point. This property is widely used in voltage regulator circuits.

Result :-

1. Dynamic forward resistance-rf $= \Delta V / \Delta I$ kΩ

$Rd = \frac{(V_2 - V_1)}{(I_2 - I_1)} = 4.66 \times 10^{-3}$ kΩ

2. Static forward resistance-Rf $= V/I = 0.016$ kΩ

3. Dynamic reverse resistance - rr $= \Delta V / \Delta I$

$Rd = 0.0125$ MΩ

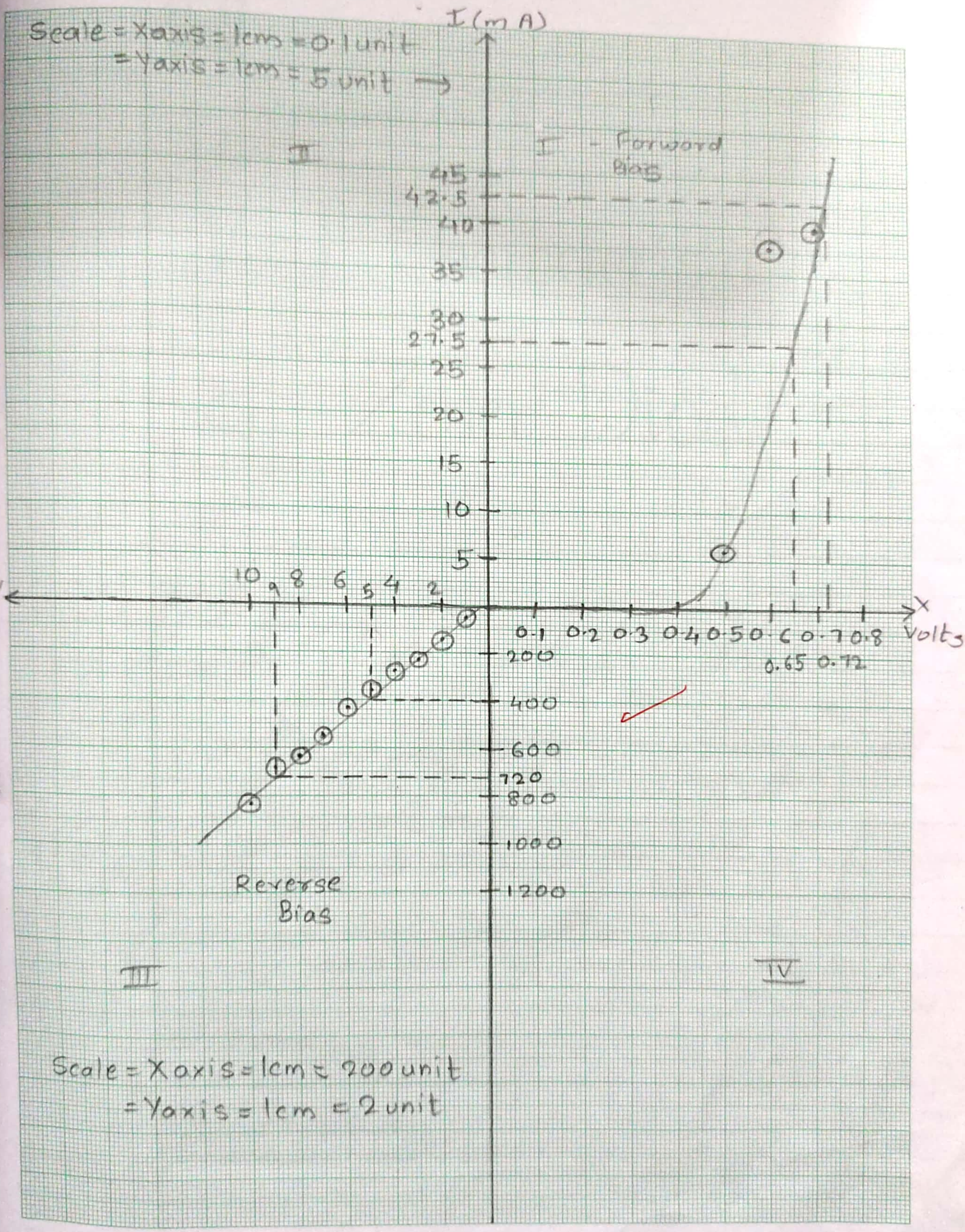
4. Static reverse resistance - Rf $= V/I = 0.0125$ MΩ

Rangnekde
18/10/23

Calculation

1. Dynamic forward resistance $= \frac{V_2 - V_1}{I_2 - I_1} = \frac{0.72 - 0.65}{42.5 - 27.5} = 4.66 \times 10^{-3}$

2. Dynamic reverse ~~Static forward~~ resistance $= \frac{V_2 - V_1}{I_2 - I_1} = \frac{720 - 400}{9 - 5} = 0.0125$

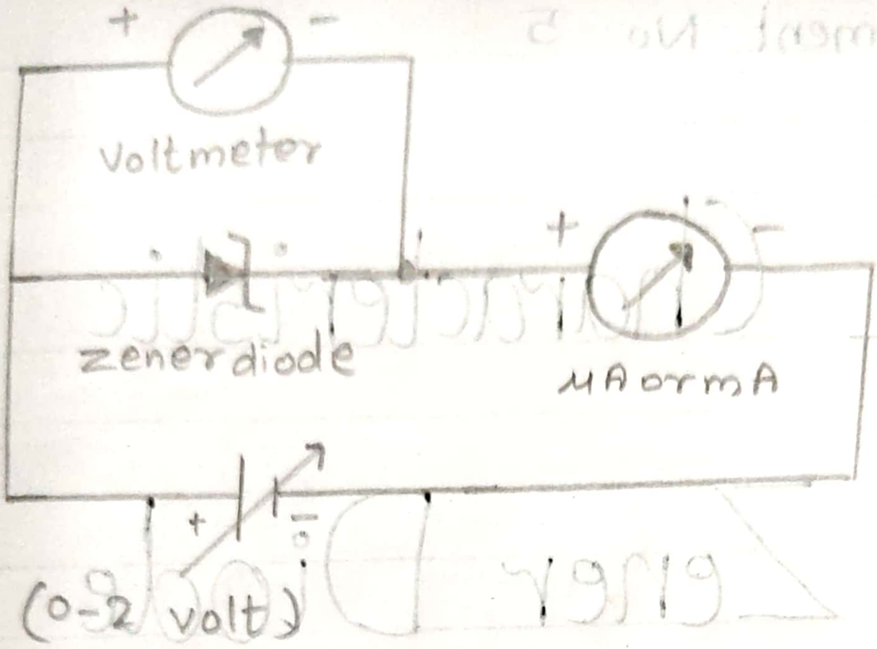

Scale = X axis = 1cm = 0.1 unit
= Y axis = 1cm = 5 unit
I (mA)
II
I - Forward Bias
45
42.5
40
35
30
27.5
25
20
15
10
5
V
10 9 8 6 5 4 2
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 Volts
0.65 0.72
X
200
400
600
720
800
1000
1200
Reverse Bias
III
IV
Scale = X axis = 1cm = 200 unit
= Y axis = 1cm = 2 unit

Date:

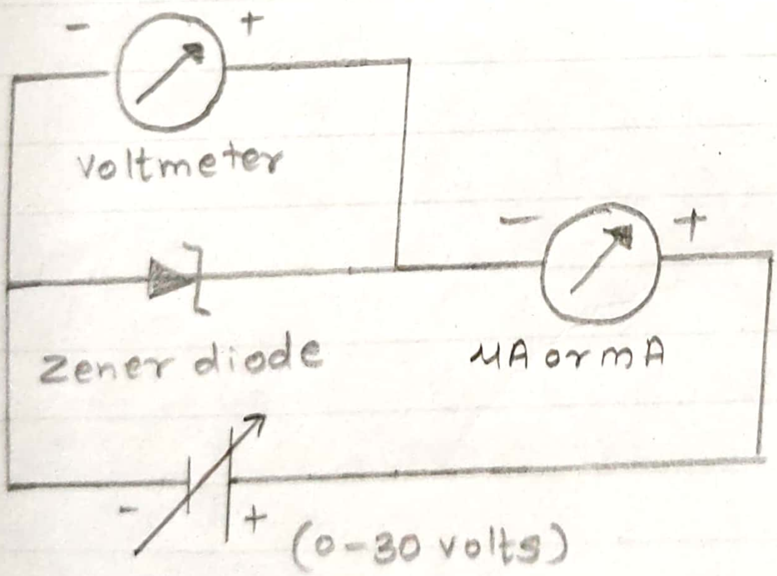
Experiment No: 5

V-I Characteristic of Zener Diode

Circuit diagramme :



Zener Diode in FB



Zener Diode in RB

Date:

Object: To draw the V-I characteristic of zener diode and to determine zener breakdown voltage.

Apparatus used: Zener diode, voltmeter (0-2 volt), voltmeter (0-30 volt), mili-ammeter, micro-ammeter, variable source (0-2 volt and 0-30 volt)

Theory:

Zener Diode: 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.

Precautions:

1. The connection should be tight ~~observation~~ otherwise fluctuation in voltage and current will happen.
2. At the turning point of curve, more reading should be taken
3. For the plot of Graph, current should be taken mA for both forward and reverse biased diode
4. The reading should be in multiple of least count.

Observation:

1. Least count of voltmeter (0–2 volt) = 0.02 volt
2. Least count of voltmeter (0–30 volt) = 0.5 volt
3. Least count of miliammeter = 0.2 mA
4. Least count of micro-ammeter = 5 μA

5. VF and IF for PNjunction Diode (in F.B)

Sr. No	VF (Volt)	IF (mA)
1	0	0
2	0.1	0.03
3	0.2	0.05
4	0.3	0.07
5	0.4	0.08
6	0.5	0.11
7	0.6	0.22
8	0.7	4.24
9	0.8	95.4

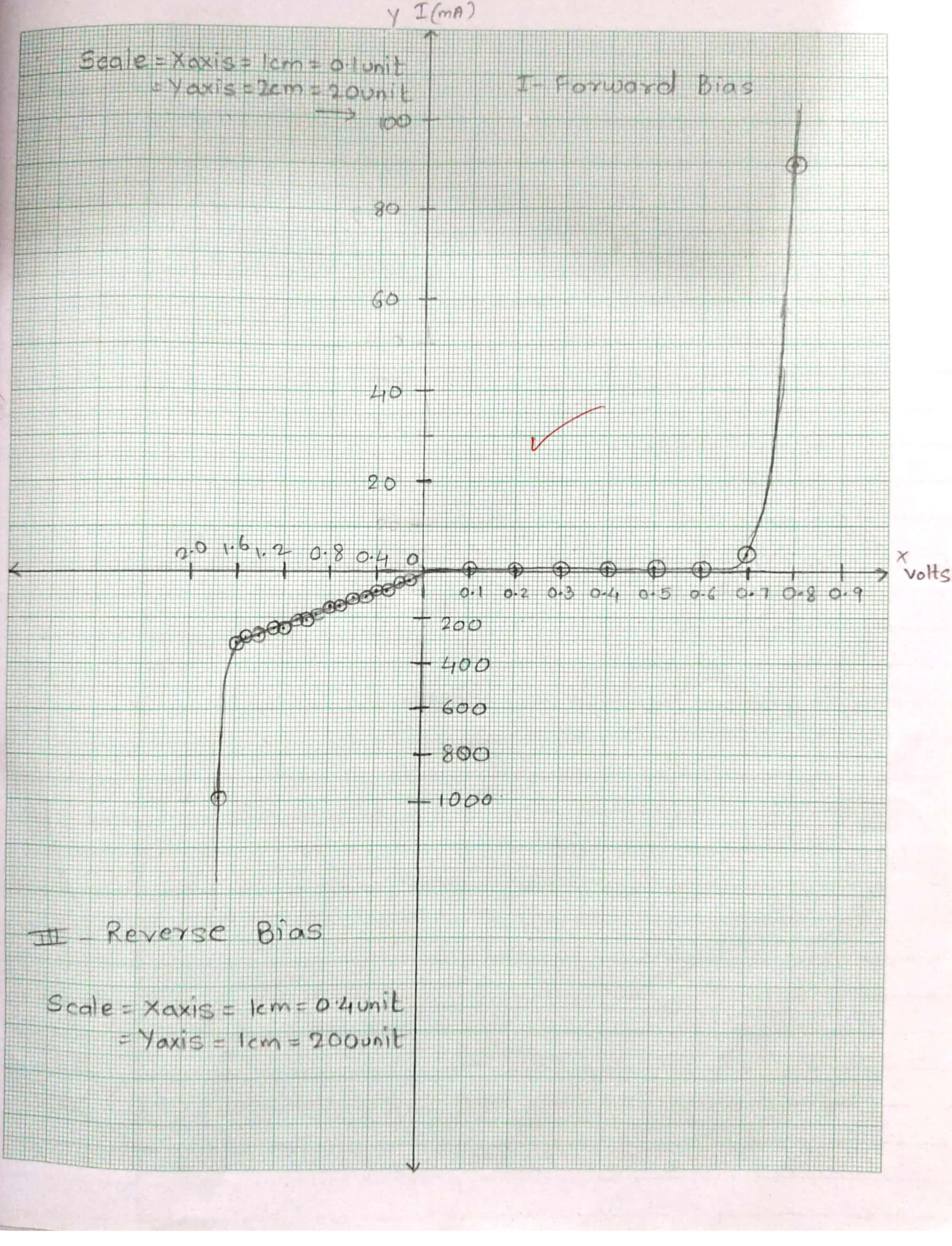
6. VR and IR for PN junction diode in R.B.

Sr No.	VR (Volt)	IR (mA)	IR (μA)
1	0	0	0
2	0.1	0.04	40
3	0.2	0.04	40
4	0.3	0.07	70
5	0.4	0.07	70
6	0.5	0.11	110
7	0.6	0.11	110
8	0.7	0.15	150
9	0.8	0.15	150
10	0.9	0.18	180
11	1.0	0.21	210
12	1.1	0.22	220
13	1.2	0.25	250
14	1.3	0.25	250
15	1.4	0.29	290
16	1.5	0.29	290
17	1.6	0.31	310
18	1.7	0.96	960

Date:

Result: The V-I characteristic of zener diode indicate that characteristic of zener diode in forward bias is same as PN junction diode. In reverse bias, a negligible constant current flow through the zener diode but the current becomes abruptly large at certain voltage. This voltage is called as zener voltage. This sudden and sharp increase in zener current is called as zener breakdown. $V_{Knee} = 0.7$ volt and $V_Z = 9$ volt.

Dr. Angurde 25/10/23



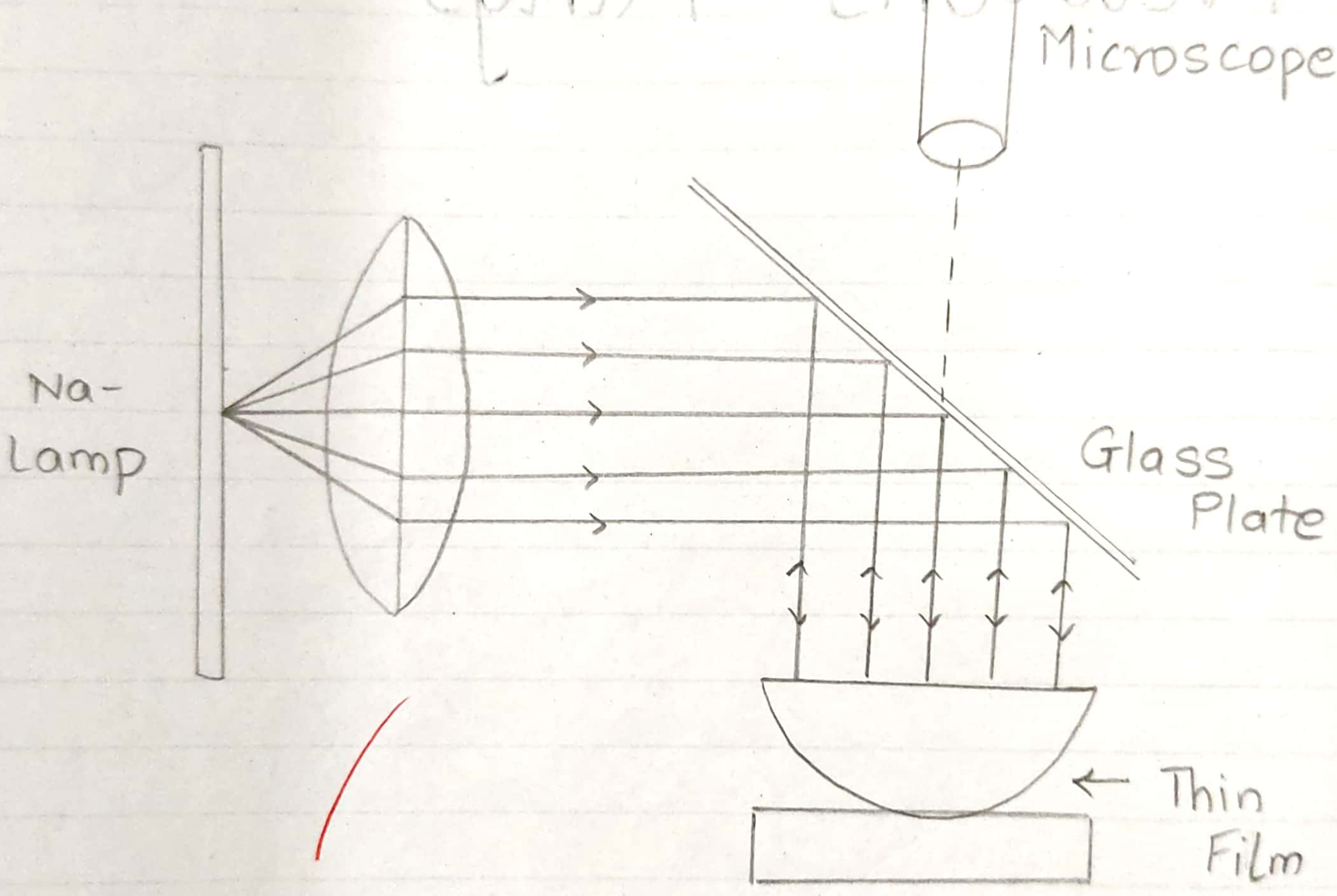
Scanned with CamScanner

Date: 18.9.23

Experiment No. 2

Newtons Rings

DIAGRAM :- As follows



Date:

NEWTONS RINGS

Aim :- To determine the radius of curvature of the convex surface of lens by means of Newtons ring.

Apparatus :-
Glass plate preferably black, convex lens of larger radius of curvature, Condensing lens small focal length Monochromatic source of light. Traveling microscope, Thin glass plate, Magnifying lens.

Formula :- $R = \frac{D_{m+n}^2 - D_n^2}{4m\lambda}$

where, R = radius of curvature of convex surface in contact with glass plate

D_{m+n} = diameter of $(m+n)^{th}$ ring

D_n = diameter of n^{th} ring

λ = wavelength of light

Procedure :-

1. Clean the lens and glass plate
2. Find the focal length of condensing lens. And keep it in front of the source at a distance equal to its focal length from the source
3. Keep the convex lens on the glass plate with its convex surface resting on the plate Clamp the thin glass plate in a standard position it above the convex lens in such a way that the centre of source, the centre of condensing lens and the centre of this glass plate are in the same horizontal line. Now

OBSERVATION :-

Least count of microscope = 0.001 cm
Wavelength of light used = 5893 Å U.

Observ. No.	Serial no. of ring	Microscope reading (cm)						Diameter $D = \lvert X - Y \rvert$ cm	Diameter^2 D^2 cm^2
		(X) Left			(Y) Right				
		msr	csr	Total	msr	csr	Total		
1.	20	4.3	68	4.368	3.8	13	3.813	0.555	0.308025
2.	16	4.3	57	4.357	3.8	75	3.875	0.482	0.232324
3.	12	4.3	10	4.310	3.8	72	3.872	0.438	0.191844
4.	8	4.2	96	4.296	3.9	9	3.909	0.387	0.149769
5.	4	4.2	33	4.233	3.9	60	3.960	0.273	0.074529

Total Reading (TR) = msr + (LC × vsr/csr)

10x of lens
Sodium lamp
$\lambda = 5893 \times 10^{-8}$

Date:

turn this glass plate in such a way that the horizontal beam of light is reflected by it vertically downward on the lens kept on the glass plate.

4. Looking vertically to the centre of lens through the glass plate a number of rings would be visible to the naked eye. Focus the eyepiece on the cross wire. Level the microscope so that the scale along which it slide horizontal and the axis of microscope is vertical. Focus the microscope on the rings till there is no parallax between the rings and cross wire.

5. Move the lens carefully till the centre of ring coincides with the point of intersection of the crosswire. Now move the microscope slowly and ensure that the travel of microscope is along the diameter of the rings.

6. Displace the microscope to the left counting the no. of bright rings passed and set it on bright ring so that the point of intersection of cross wire is at the middle of bright ring. Take the corresponding microscope reading on its horizontal scale using slow motion screw. Shift the microscope towards centre of rings recording the microscope reading for every alternate ring you see. Cross over to the other side of centre and record in succession the microscope reading for same ring with the continuous movement of microscope.

7. Plot a graph of D_n^2 against square of diameter of ring against corresponding ring no.

CALCULATION :—

1) $n=4,\ m=4 \Rightarrow R_1 = \dfrac{0.1497-0.0745}{4\times4\times5893\times10^{-8}} = 79.75\text{ cm}$

2) $n=4,\ m=8 \Rightarrow R_2 = \dfrac{0.1918-0.0745}{4\times8\times5893\times10^{-8}} = 62.20\text{ cm}$

3) $n=4,\ m=12 \Rightarrow R_3 = \dfrac{0.2323-0.0745}{4\times12\times5893\times10^{-8}} = 55.78\text{ cm}$

4) $n=4\ \ m=16 \Rightarrow R_4 = \dfrac{0.3080-0.0745}{4\times16\times5893\times10^{-8}} = 61.91\text{ cm}$

5) $n=8\ \ m=4 \Rightarrow R_5 = \dfrac{0.1918-0.1497}{4\times4\times5893\times10^{-8}} = 44.65\text{ cm}$

6) $n=8\ \ m=8 \Rightarrow R_6 = \dfrac{0.2323-0.1497}{4\times8\times5893\times10^{-8}} = 43.80\text{ cm}$

7) $n=8\ \ m=12 \Rightarrow R_7 = \dfrac{0.3080-0.1497}{4\times12\times5893\times10^{-8}} = 55.96\text{ cm}$

8) $n=12\ \ m=4 \Rightarrow R_8 = \dfrac{0.2323-0.1918}{4\times4\times5893\times10^{-8}} = 42.95\text{ cm}$

9) $n=12\ \ m=8 \Rightarrow R_9 = \dfrac{0.3080-0.1918}{4\times8\times5893\times10^{-8}} = 61.61\text{ cm}$

10) $n=16\ \ m=4 \Rightarrow R_{10} = \dfrac{0.3080-0.2323}{4\times4\times5893\times10^{-8}} = 80.28\text{ cm}$

$$(R_{cal})_{avg} = \frac{79.75+62.20+55.78+61.91+44.65+43.80+55.96+42.95+61.61+80.28}{10}$$

$= 58.889\text{ cm}$

Date:

Calculation :-

$$R = \frac{D_{m+n}^2 - D_n^2}{4m\lambda} = \frac{\text{Slope}}{4\lambda}$$

Result :-

1. Slope of graph $= \frac{y_2 - y_1}{x_2 - x_1} = \frac{0.2125 - 0.0925}{14 - 6} = 0.015$

2. Radius of curvature of convex surface from calculation

$$(R_{cal})_{avg} = \frac{79.75 + 62.20 + 55.78 + 61.91 + 44.65 + 43.80 + 55.96 + 42.95 + 61.61 + 80.28}{10}$$

$(R_{cal})_{avg} = 58.889$ cm

3. Radius of curvature of convex surface from graph

$$(R_{graph}) = \frac{\text{Slope}}{4\lambda} = \frac{0.015}{4 \times 5893 \times 10^{-8}}$$

$R_{graph} = 63.63$ cm

4. Average $R = \frac{(R_{cal})_{avg} + R_{graph}}{2}$

$$R = \frac{58.889 + 63.63}{2} = 61.2595 \text{ cm.}$$

Scale = X-axis = 2cm = 4 unit
= Y-axis = 2cm = 0.05 unit

$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0.2125 - 0.0925}{14 - 6}$$

$$= 0.015$$