Course Name:	**Elements of Electrical and Electronics Engineering**	**Semester:**	**I**
Date of Performance:	**03-10-2023**	**Batch No:**	**C5_3**
Faculty Name:		**Roll No:**	**16010123325 (53)**
Faculty Sign & Date:		**Grade/Marks:**	**/ 25**

Experiment No: 6
Title: Zener diode voltage regulator

Aim and Objective of the Experiment:

- To understand the working of Zener diode as voltage regulator
- To calculate line and load regulation of Zener diode based shunt regulator

COs to be achieved:

CO4: Explain rectifier-filter circuits using PN junction diode and voltage regulator circuits using Zener diode

Requirements:

Zener diode, resistor, potentiometer, voltmeter, ammeter, DC source and bread board.

Theory:

The Zener diode is like a general-purpose signal diode. When biased in the forward direction it behaves just like a normal signal diode, but when a reverse voltage is applied to it, the voltage remains constant for a wide range of currents.

Avalanche Breakdown: There is a limit for the reverse voltage. Reverse voltage can increase until the diode breakdown voltage reaches. This point is called Avalanche Breakdown region. At this stage maximum current will flow through the Zener diode. This breakdown point is referred as "Zener voltage".

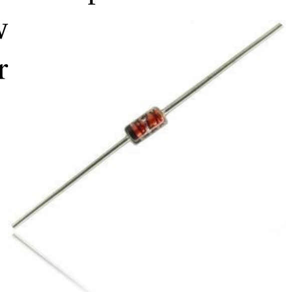


Fig 1: Zener Diode

The Zener Diode is used in its "reverse bias". From the I-V Characteristics curve we can study that the zener diode has a region in its reverse bias characteristics of almost a constant negative voltage regardless of the value of the current flowing through the diode and remains nearly constant even with large changes in current as long as the zener diodes current remains between the breakdown current $I_{Z(min)}$ and the maximum current rating $I_{Z(max)}$.

This ability to control itself can be used to great effect to regulate or stabilise a voltage source against supply or load variations. The fact that the voltage across the diode in the breakdown region is almost constant turns out to be an important application of the zener diode as a voltage regulator.

Zener I-V Characteristics:

Figure 2 shows the current versus voltage curve for a Zener diode. Observe the nearly constant voltage in the breakdown region.

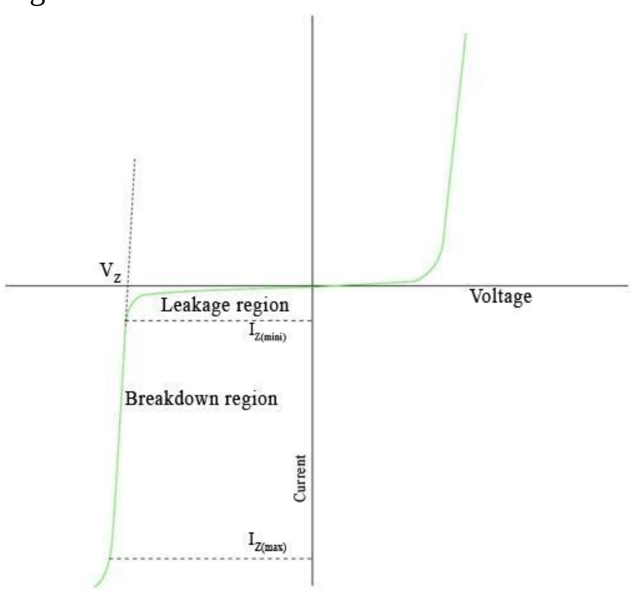


Fig 2: Zener diode characteristic curve

The forward bias region of a Zener diode is identical to that of a regular diode. The typical forward voltage at room temperature with a current of around 1 mA is around 0.6 volts. In the reverse bias condition the Zener diode is an open circuit and only a small leakage current is flowing as shown on the exaggerated plot. As the breakdown voltage is approached the current will begin to avalanche. The initial transition from leakage to breakdown is soft but then the current rapidly increases as shown on the plot. The voltage across the Zener diode in the breakdown region is very nearly constant with only a small increase in voltage with increasing current. At some high current level the power dissipation of the diode becomes excessive and the part is destroyed. There is a minimum Zener current, Iz(min), that places the operating point in the desired breakdown. There is a maximum Zener current, Iz(max), at which the power dissipation drives the junction temperature to the maximum allowed. Beyond that current the diode can be damaged.

Zener diodes are available from about 2.4 to 200 volts typically using the same sequence of values as used for the 5% resistor series –2.4, 2.7, 3.0 3.3, 3.6, 3.9, 4.3, 4.7, 5.1, 5.6, 6.2, 6.8, 7.5, 8.2, 9.1, 10, 11, 12, 13, 15, 16, 18, 20, 22, 24, etc. All Zener diodes have a power rating, PZ. From Watt's law the maximum current is $IZ_{(MAX)}$=PZ / VZ. Zener diodes are typically available with power ratings of 0.25, 0.4, 0.5, 1, 2, 3, and 5 watts although other values are available.

Zener Diode as Voltage Regulators

The function of a regulator is to provide a constant output voltage to a load connected in parallel with it in spite of the ripples in the supply voltage or the variation in the load current and the zener diode will continue to regulate the voltage until the diodes current falls below the minimum IZ(min) value in the reverse breakdown region. It permits current to flow in the forward direction as normal, but will also allow it to flow in the reverse direction when the voltage is above a certain value - the breakdown voltage known as the Zener voltage. The Zener diode specially made to have a reverse voltage breakdown at a specific voltage. Its characteristics are otherwise very similar to common diodes. In breakdown the voltage across the Zener diode is close to constant over a wide range of currents thus making it useful as a shunt voltage regulator.

The purpose of a voltage regulator is to maintain a constant voltage across a load regardless of variations in the applied input voltage and variations in the load current. A typical Zener diode shunt regulator is shown in Figure 3. The resistor is selected so that when the input voltage is at VIN(min) and the load current is at IL(max) that the current through the Zener diode is at least Iz(min). Then for all other combinations of input voltage and load current the Zener diode conducts the excess current thus maintaining a constant voltage across the load. The Zener conducts the least current when the load current is the highest and it conducts the most current when the load current is the lowest.

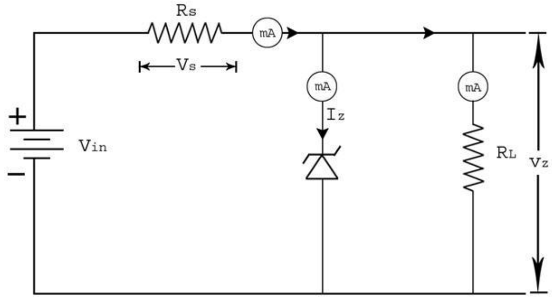


Fig 3: Zener diode shunt regulator

If there is no load resistance, shunt regulators can be used to dissipate total power through the series resistance and the Zener diode. Shunt regulators have an inherent current limiting advantage under load fault conditions because the series resistor limits excess current. A zener diode of break down voltage Vz is reverse connected to an input voltage source Vi across a load resistance RL and a series resistor RS. The voltage across the zener will remain steady at its break down voltage VZ for all the values of zener current IZ as long as the current remains in the break down region. Hence a regulated DC output voltage V0 = VZ is obtained across RL, whenever the input voltage remains within a minimum and maximum voltage.

Basically there are two type of regulations such as:

a) Line Regulation:

In this type of regulation, series resistance and load resistance are fixed, only input voltage is changing. Output voltage remains the same as long as the input voltage is maintained above a minimum value.

Percentage of line regulation can be calculated by = $\frac{\Delta Vout}{\Delta Vin} \times 100$

where V_0 is the output voltage and V_{IN} is the input voltage and ΔV_0 is the change in output voltage for a particular change in input voltage ΔV_{IN}.

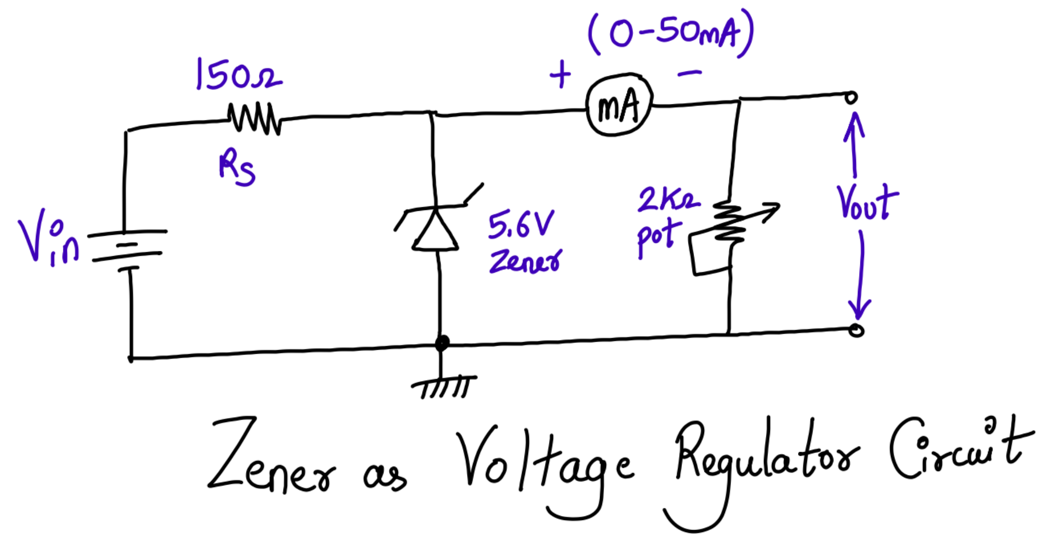
b) Load Regulation:

In this type of regulation, input voltage is fixed and the load resistance is varying. Output volt remains same, as long as the load resistance is maintained above a minimum value.

Percentage of load regulation = $\left[\frac{VNL-VFL}{VNL}\right] \times 100$

where VNL is the null load resistor voltage (ie. remove the load resistance and measure the voltage across the Zener Diode) and VFL is the full load resistor voltage

Circuit Diagram:



Stepwise-Procedure:

1. Design circuit and connect it as shown in the circuit diagram using Proteus simulator.
2. Keep V_{IN} around 4V and adjust Potentiometer R_L such that I_L= 5 mA. Vary V_{IN} and note V_{OUT} for finding line regulation.
3. Keep V_{IN} = 10 V and vary Potentiometer R_L such that I_L changed from 3mA to 15 mA and note V_{OUT} for finding load regulation.
4. Plot the graph V_{OUT} Vs V_{IN} for line regulation and V_{OUT} Vs I_L for load regulation.

Observation Table:

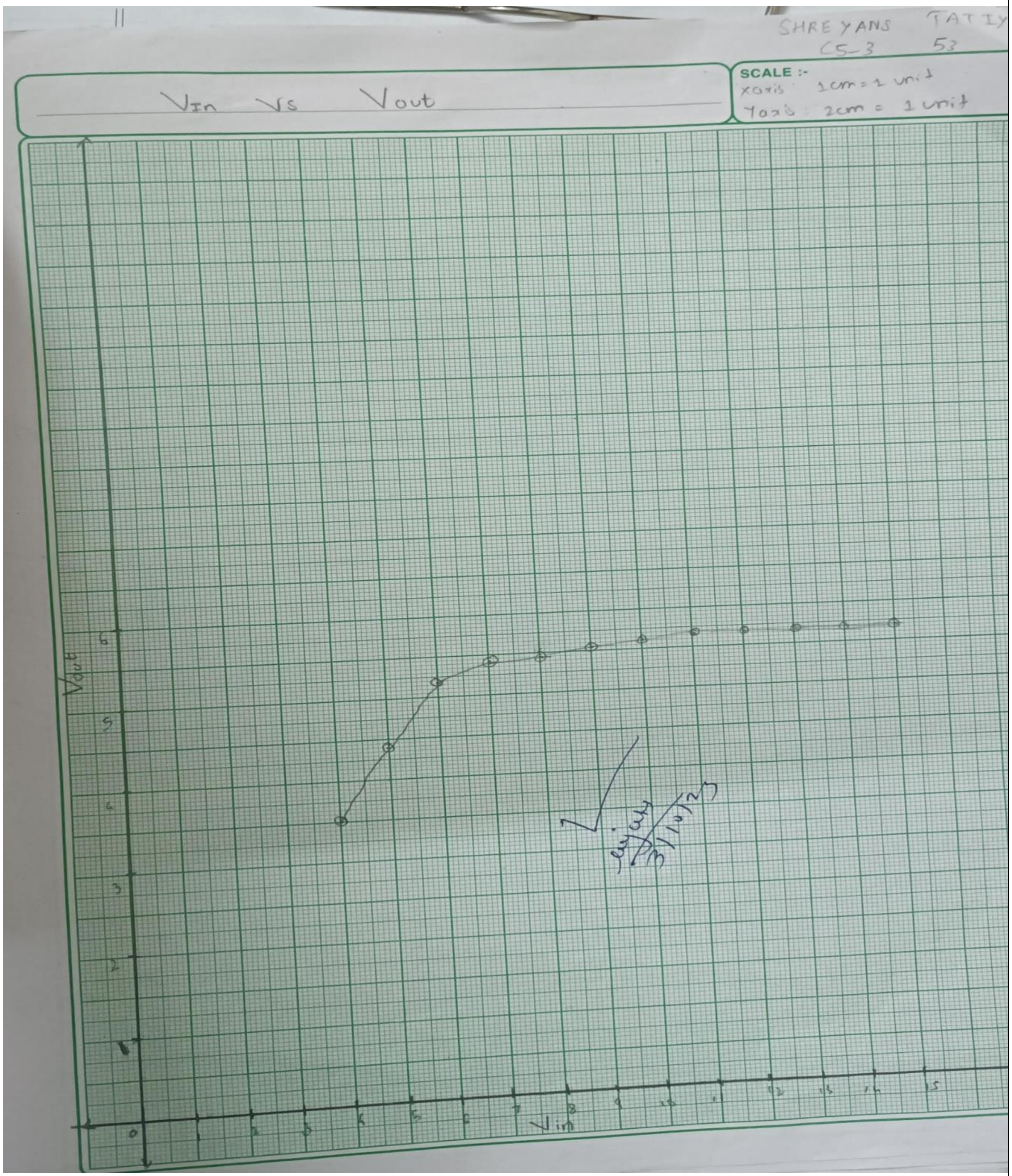
Line Regulation: (Keep I_L = 5mA constant)

Unregulated supply voltage (Vin)	Regulated output voltage (Vout)
4V	3.52
5V	4.41
6V	5.20
7V	5.45
8V	5.48
10V	5.54

12V	5.60
14V	5.65
16V	5.68

Load Regulation: (Keep Vin = 10V constant)

Line current I_L(mA)	Regulated output voltage (Vout)
3mA	5.50
4mA	5.49
5mA	5.49
7mA	5.48
9mA	5.48
10mA	5.47
12mA	5.47
14mA	5.46
No load value V_{NL}(Remove R_L & measure Vout)	5.50



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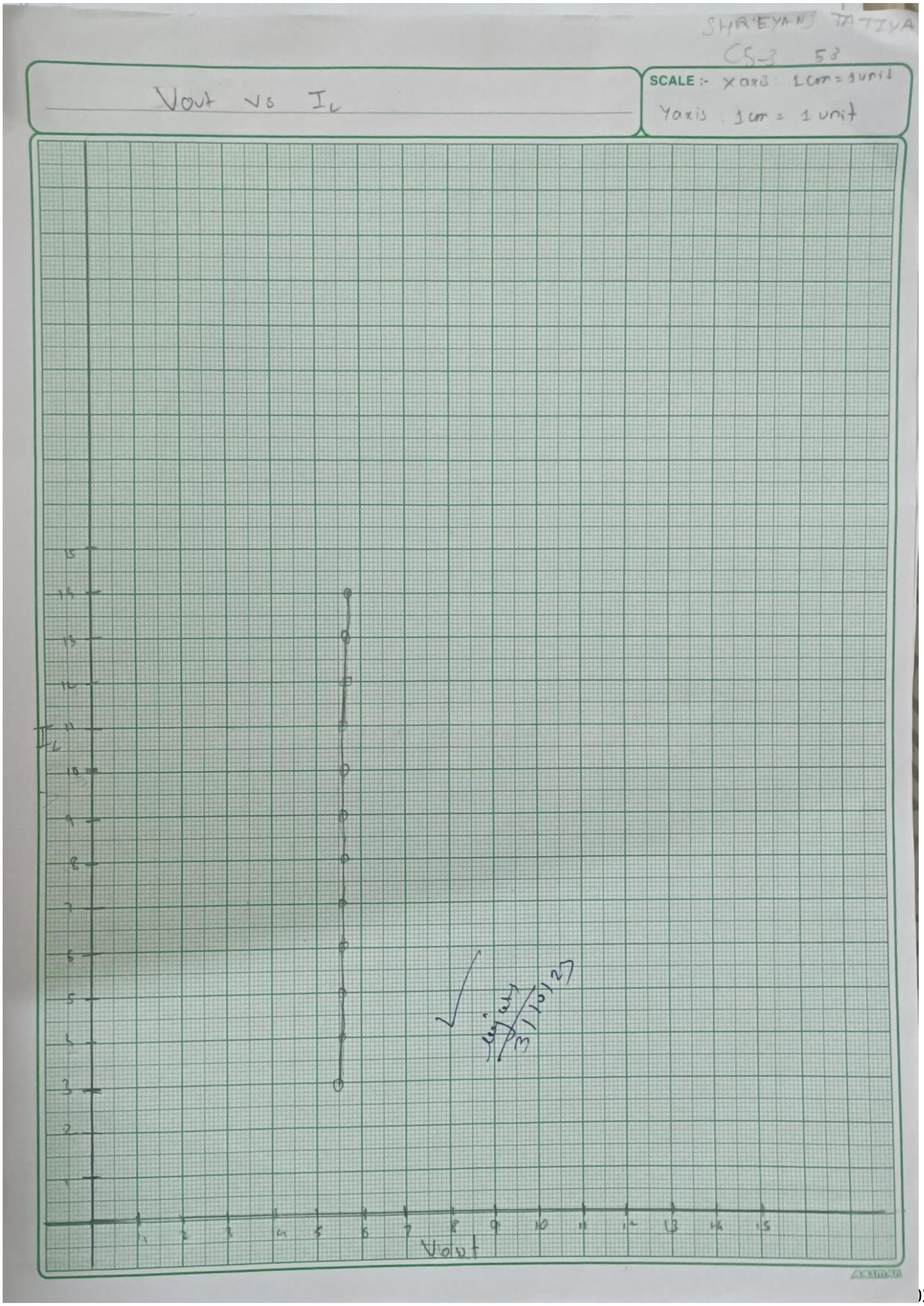
Vin vs Vout
SCALE :-
X axis : 1cm = 1 unit
Y axis : 2cm = 1 unit
Vout
Vin


SHREYANS TATIYA
CS-3 53
Vout vs IL
SCALE :- X axis 1cm = 1 unit
Y axis 1 cm = 1 unit
IL
Vout

Post Lab Subjective:

1. What is difference between PN junction diode and Zener diode?

The differences are as follows:

1. The PN junction diode allows the flow of electron in one direction only, whereas the Zener diode allows the flow of electron in both directions.
2. The voltage of the PN junction diode at which it starts working is comparatively higher, and the voltage of the Zener diode at which it starts working is lower, and it is known as Zener voltage.
3. The PN junction diode is not highly doped. On the other hand, the Zener diode has highly doped junctions.
4. On applying a large reverse bias voltage, the PN junction diode has chances of getting damaged, but the Zener diode is specialized for this case.
5. PN junction diode is used as voltage rectifiers, switchers, waveshapes, etc., whereas Zener diode is used as voltage stabilizers.

Conclusion:

By performing this experiment and by the graphs plotted we can conclude that when the diode is in the reverse breakdown region, the voltage across Zener diode remains almost constant irrespective of the current flowing through it.

Signature of faculty in-charge with Date: