EXPERIMENT No. …….

Experiment Title: V-I Characteristics of a P-N Junction Diode in Forward and Reverse Bias

Aim:

To study the voltage-current (V-I) characteristics of a P-N junction diode under forward bias and reverse bias conditions and determine the knee voltage and reverse saturation current.

Practical Significance:

The V-I Characteristics of a P-N Junction Diode experiment provides students with a practical understanding of how a semiconductor diode behaves under forward and reverse bias conditions. It helps bridge the gap between theoretical concepts and real laboratory observations by allowing students to measure and analyse the relationship between voltage and current.

By performing this experiment, students learn to identify important diode parameters such as the cut-in (threshold) voltage, forward current, and reverse leakage current. They also gain hands-on experience in using electrical measuring instruments, plotting V-I characteristic curves, and interpreting experimental data.

The knowledge gained from this experiment forms the foundation for understanding the operation of many semiconductor devices and electronic circuits, including rectifiers, voltage regulators, LEDs, photodiodes, transistors, and power supplies.

Relevant program outcomes:

1. Engineering knowledge: Applies the fundamental principles of semiconductor physics and electronics to study the V-I characteristics of a P-N junction diode.

2. Problem analysis: Analyses the relationship between voltage and current in forward and reverse bias to interpret diode behaviour.

3. Modern Tool Usage: Uses laboratory instruments such as regulated DC power supply, voltmeter, ammeter/microammeter, and connecting circuits for accurate measurements.

4. Individual and team work: Performs the experiment individually or collaboratively while maintaining coordination and responsibility in the laboratory.

5. Communication: Presents experimental observations, graphs, calculations, and conclusions clearly through the laboratory record and discussions.

6. Life-long learning: Develops practical skills and conceptual understanding that form the basis for learning advanced semiconductor devices and electronic systems.

Relevant Course outcomes:

To examine the properties of a semiconductor diode by determining the forbidden energy gap and studying its characteristic curves.

Practical learning outcomes:

1. **Identify** the components and instruments required to study the V-I characteristics of a P-N junction diode.
2. **Set up** the experimental circuit correctly for both forward and reverse bias conditions.
3. **Measure** the voltage and current accurately using appropriate measuring instruments.
4. **Plot** the forward and reverse bias V-I characteristic curves from the recorded observations.
5. **Determine** the cut-in (threshold) voltage and observe the reverse leakage current of the diode.
6. **Differentiate** between the behavior of the diode under forward and reverse bias conditions.
7. **Develop** good laboratory practices by handling instruments safely, recording observations systematically, and drawing valid conclusions.

Practical skills:

By performing the **V-I Characteristics of a P-N Junction Diode** experiment, the following practical skills will be developed:

1. **Circuit Assembly Skills:** Ability to correctly connect the P-N junction diode and measuring instruments for forward and reverse bias circuits.
2. **Instrument Handling Skills:** Proficiency in using a regulated DC power supply, voltmeter, milliammeter, and microammeter accurately and safely.
3. **Measurement Skills:** Ability to measure voltage and current precisely while following proper experimental procedures.
4. **Observation and Recording Skills:** Systematic recording of experimental readings and maintaining an accurate observation table.
5. **Graph Plotting and Data Analysis Skills:** Ability to plot V-I characteristic curves and analyse diode behaviour under different biasing conditions.
6. **Interpretation Skills:** Ability to determine the cut-in (threshold) voltage, identify reverse leakage current, and compare practical results with theoretical concepts.
7. **Troubleshooting Skills:** Ability to identify and rectify common errors such as incorrect circuit connections, wrong polarity, or improper instrument settings.
8. **Laboratory Safety and Good Practices:** Development of safe handling techniques for electronic components and adherence to standard laboratory procedures.

Relevant affective domain related outcomes:

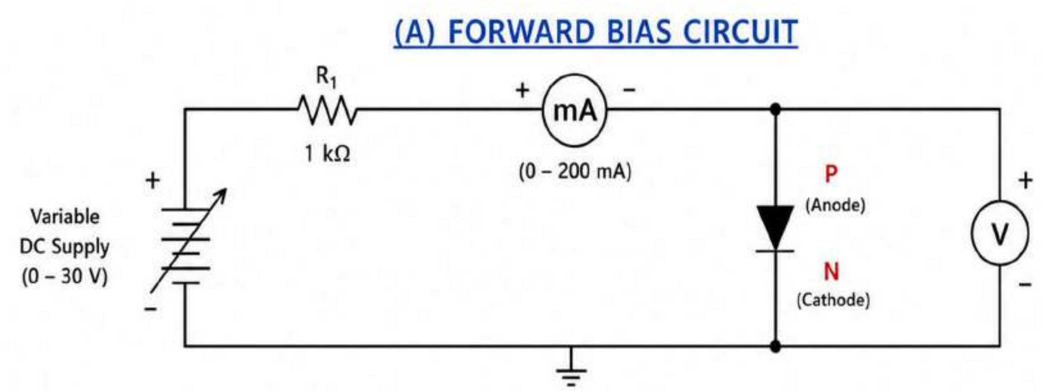
1. **Receiving (Attending): Demonstrate awareness** of laboratory safety rules, proper handling of semiconductor devices, and standard experimental procedures.
2. **Responding: Actively participate** in setting up the experimental circuit, taking measurements, and discussing the observed V-I characteristics.
3. **Valuing: Appreciate** the importance of accurate measurements, systematic observations, and the role of P-N junction diodes in modern electronic systems.
4. **Organization: Integrate** scientific attitude, safety practices, and ethical behavior while conducting experiments and reporting results.
5. **Characterization by Value: Consistently demonstrate** responsibility, honesty, precision, and professionalism during laboratory work and experimental documentation.

Theoretical Background:

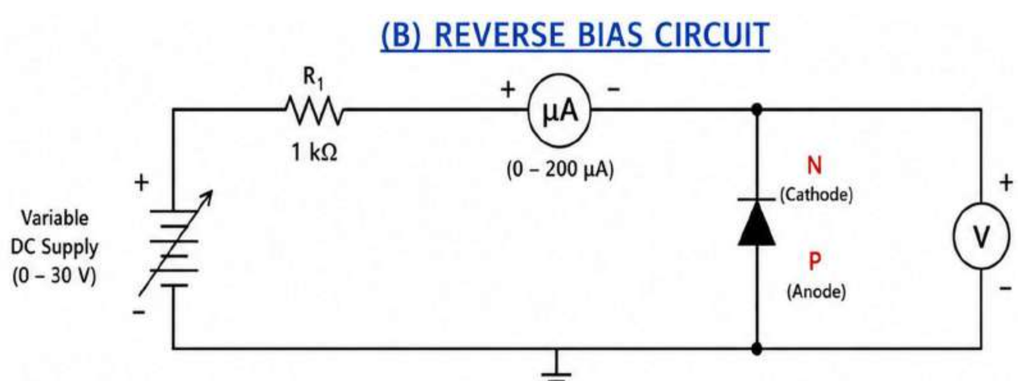
A **P-N junction diode** is a two-terminal semiconductor device formed by joining P-type and N-type semiconductor materials. It allows electric current to flow easily in one direction while offering high resistance in the opposite direction.

When p-type and n-type semiconductors are joined, majority charge carriers diffuse across the junction and recombine, leaving behind a narrow region depleted of free carriers — the depletion region. This region sets up an internal electric field, which appears as a barrier potential (about 0.7V for silicon and 0.3V for germanium).

Forward bias: When the p-side is connected to the positive terminal and the n-side to the negative terminal, the applied voltage opposes the barrier potential. Once the applied voltage exceeds the barrier potential — this threshold is called the cut-in voltage or knee voltage — the depletion region collapses and current rises sharply, almost exponentially, for a small increase in voltage.



Reverse bias: When the polarity is reversed, the depletion region widens further, and only a small reverse saturation current (in the microampere range) flows due to minority carriers. These current stays nearly constant with increasing reverse voltage — until the diode reaches its breakdown voltage, beyond which current increases sharply again, this time destructively unless limited by a resistor.



The current through a diode is given by

$$I = I_S\left(e^{\frac{qV}{\eta kT}} - 1\right)$$

where

- I= diode current
- I_S= reverse saturation current
- V= applied voltage
- q= electronic charge
- k= Boltzmann constant
- T= absolute temperature
- η= ideality factor

Experimental set-up:

Resources required:

S. No.	Name of equipment	Specifications	Quantity	Remark
1	P-N Junction Diode	Silicon	2	
2	Regulated DC Power Supply	-	1	
3	Milliammeter	0–100 mA	1	
4	Microammeter	(0–200 µA	1	
5	Voltmeter	-	1	
6	Breadboard/Trainer Kit	-	1	
7	Connecting Wires	-	5 to 6	

Precautions

1. Verify all circuit connections before switching ON the supply.
2. Observe correct polarity of the diode.
3. Increase the supply voltage gradually.
4. Never exceed the rated current of the diode.
5. Do not exceed the reverse breakdown voltage.
6. Use properly calibrated meters.
7. Take readings carefully without parallax error.
8. Switch OFF the power supply after completing the experiment.

Procedure:

Part A – Forward Bias

1. Connect the circuit as per the forward bias diagram.
2. Ensure correct polarity of the diode.
3. Keep the supply voltage at zero initially.
4. Switch ON the power supply.
5. Increase the voltage gradually.
6. Record the corresponding current for each voltage.
7. Plot the graph between voltage and current.

Part B – Reverse Bias

1. Reverse the diode connections.
2. Connect the microammeter in series.
3. Keep the supply voltage at zero.
4. Increase the reverse voltage gradually.
5. Record the reverse current.
6. Do not exceed the breakdown voltage.
7. Plot the reverse V-I graph.

Observation Table:

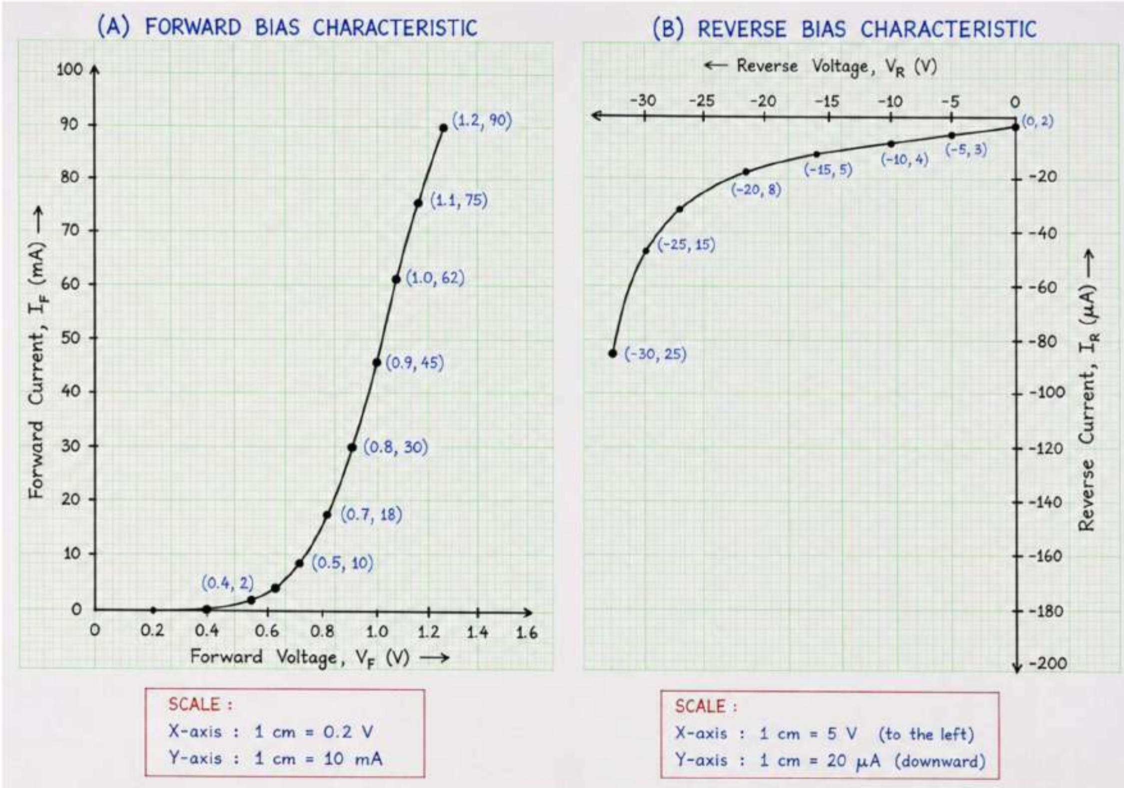
1. For Forward Bias-

S. NO.	Forward Voltage V_F (V)	Forward Current I_F (mA)
1		
2		
3		
4		
5		
6		
7		

2. Reverse Bias

S. NO.	Reverse Voltage V_0 (V)	Reverse Current I_R (μA)
1		
2		
3		
4		
5		
6		
7		

Graph: Two graphs are drawn.



Identify the cut-in voltage from the graph and calculate static and dynamic resistance from the slope.

Calculations:

1. **Determination of Cut-in (Threshold or knee) Voltage:**

Definition

The cut-in voltage is the minimum forward voltage at which the diode starts conducting a significant amount of current. On the forward characteristic curve, it is the point where the current begins to increase rapidly.

Method from the Graph

1. Plot the forward V-I characteristic.
2. Identify the knee (bend) of the curve, where it changes from almost horizontal to a steep rise.
3. Draw a tangent to the steep portion of the curve.
4. Extend the tangent backward until it intersects the voltage (X) axis.
5. The voltage at this intersection is the cut-in voltage.

2. **Static (DC) Resistance: -** Static resistance is the ratio of voltage to current at any operating point.

$$R_{DC} = \frac{V}{I}$$

Where, V= Voltage at the chosen operating point, I= Current at the same point

3. **Dynamic (AC) Resistance: -**
   Dynamic resistance is obtained from the **slope of the V-I curve**. Instead of taking one point, take **two nearby points** on the straight (steep) portion of the graph.
   Formula

$$r_d = \frac{\Delta V}{\Delta I}$$

Where,

$$\Delta V = V_2 - V_1$$
$$\Delta I = I_2 - I_1$$

4. **Reverse saturation current (I_S): -** It is the small current that flows through a P-N junction diode under reverse bias due to minority charge carriers. It remains nearly constant with increasing reverse voltage until the breakdown voltage is reached.
   From the Reverse Bias Graph: -
   - Look at the reverse characteristic graph.
   - Locate the nearly **horizontal portion** of the reverse-bias curve (before breakdown). The corresponding current value is taken as the **reverse saturation current**.

Results:

The V-I characteristics of the P-N junction diode were studied successfully under forward and reverse bias conditions. The knee voltage was found to be _____ V, and the reverse saturation current was _____ µA, thereby verifying the expected characteristics of a P-N junction diode.

Conclusion and recommendations:

Conclusion: -

The V-I characteristics of the P-N junction diode were successfully studied under forward and reverse bias conditions. The knee (cut-in) voltage and reverse saturation current were determined from the V-I characteristics. The experiment verified that the diode conducts current easily in forward bias and blocks current in reverse bias before breakdown.

Recommendations: -

- Ensure correct forward and reverse bias connections before switching on the power supply.
- Increase the applied voltage gradually and do not exceed the diode's rated values.
- Record observations carefully and use proper graph scaling for accurate results.
- Handle the diode and measuring instruments carefully to avoid damage and measurement errors.