EXPERIMENT No. …….

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.

Apparatus required:

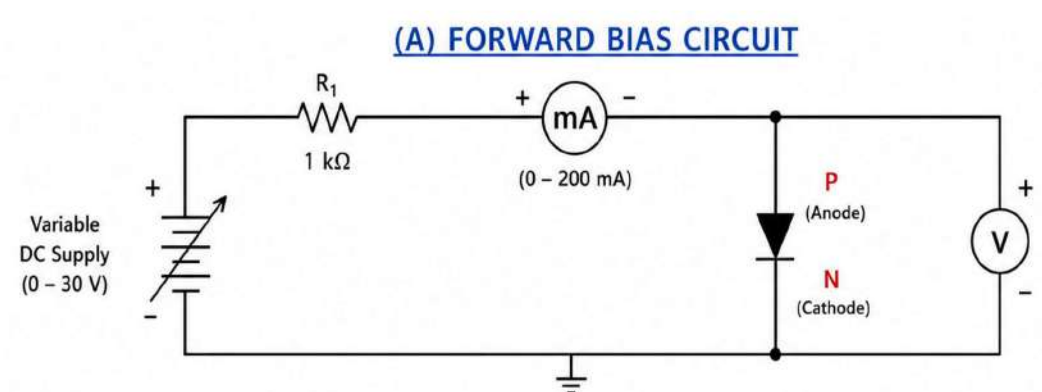
S. No.	Name of equipment	Specifications	Quantity	Remark
1	P-N Junction Diode	Silicon	2	
2	Regulated DC Power Supply	-	1	
3	Milliammeter	0–100 mA	1	
4	Microammeter	(0–200 µA	1	
5	Voltmeter	-	1	
6	Breadboard/Trainer Kit	-	1	
7	Connecting Wires	-	5 to 6	

Theory:

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.

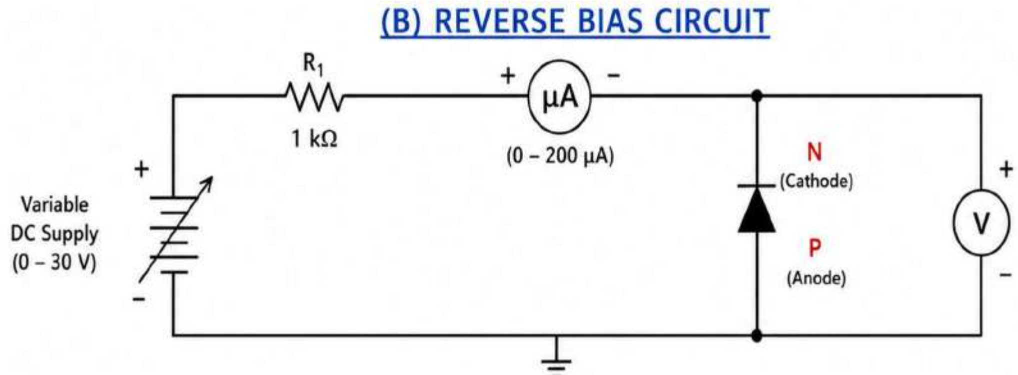
When p-type and n-type semiconductors are joined, majority charge carriers diffuse across the junction and recombine, leaving behind a narrow region depleted of free carriers — the depletion region. This region sets up an internal electric field, which appears as a barrier potential (about 0.7V for silicon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

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:

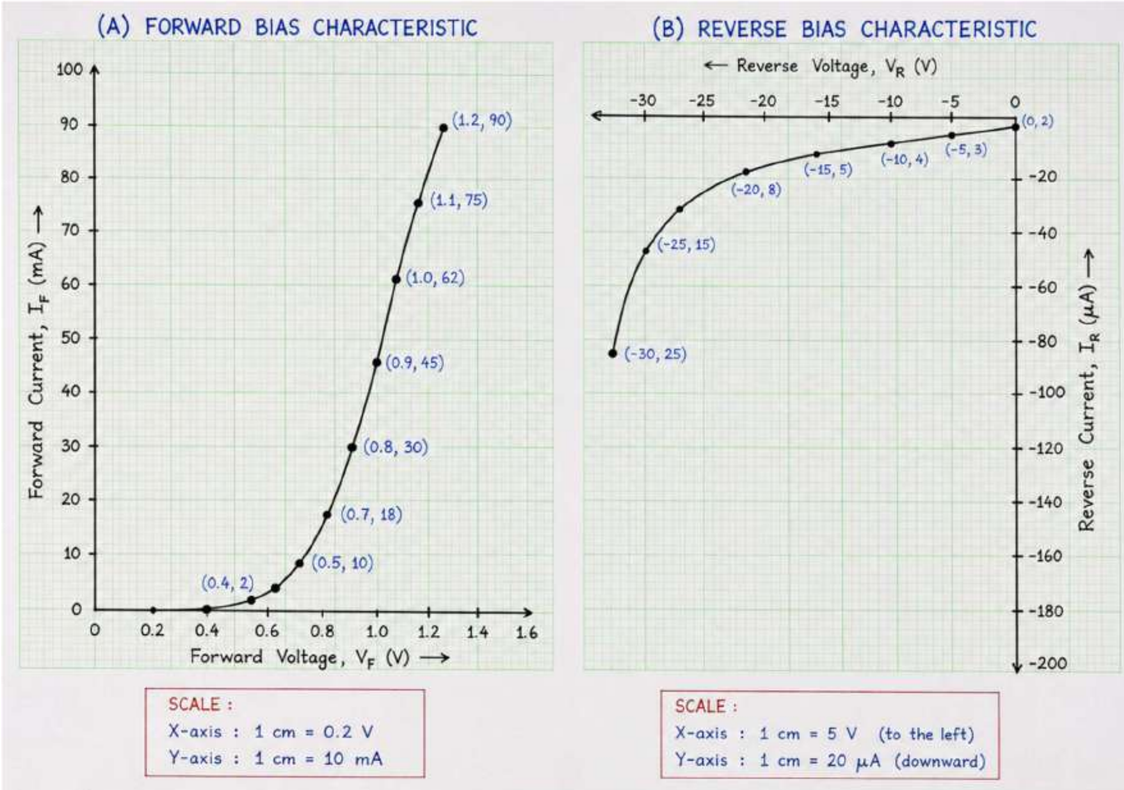
1. For Forward Bias-

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.

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.