Experiment 3

Recording the Current - Voltage Characteristics of a Diode

1- Objects of the Experiment

- Studying the characteristics of a diode.
- Determining the value of cut-in voltage.
- Determining the value of the reverse-bias saturation current
- Determining the value of the emission coefficient

2- Principles

The diode is a device formed from a junction of n-type and p-type semiconductor material. The lead connected to the p-type material is called the **anode** and the lead connected to the n-type material is the **cathode**. In general, the cathode of a diode is marked by a solid line on the diode (see Figure 1).

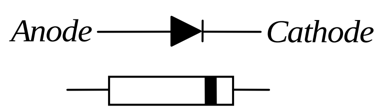

Figure 1. *The symbol for a diode compared to an actual diode package*

An ideal diode acts as a unilateral switch. It has a voltage-current characteristic as shown in the Figure 2. When forward biased the diode acts as a short circuit. When reverse biased, it acts as an open circuit. No power is dissipated in an ideal diode biased in either direction since either the voltage across it is zero (forward biased) or the current through it is zero (reverse biased).

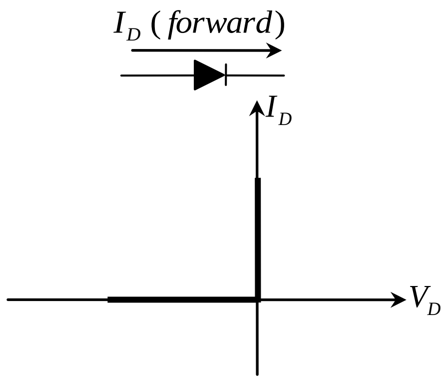

Figure 2. *Ideal diode*

A more realistic approximation to a real diode is a series circuit containing an ideal diode, a battery and a resistor (see Figure 3). This model is called as *piecewise linear model* or *small signal equivalent model*. The battery introduces a small cut-in voltage, V_γ, that must be exceeded before the diode begins conducting under forward bias conditions. The value of V_γ is determined by the type of semiconductor used in the p-n junction. The resistor approximates the semiconductor resistance under forward bias and determines the amount of dissipation in the diode.

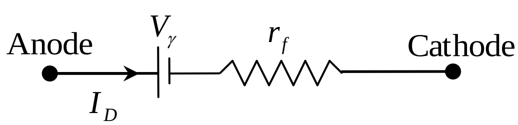

Figure 3. *Real diode in forward bias*

When a real diode is reverse biased a minuscule leakage current, I_S, flows through the device. This current can be effectively ignored as long as the reverse breakdown voltage of the diode is not exceeded (see Figure 4). At potentials greater than the reverse breakdown voltage, charge is pulled through the p-n junction by the strong electric fields in the device and a large reverse current flow. This usually destroys the device.

Real diodes have internal resistance called forward diode resistance, r_f, which can be found as follow (see Figure 4):

$$Slope\ of\ tangent\ line = \frac{1}{r_f} \qquad \text{(Equation 2)}$$

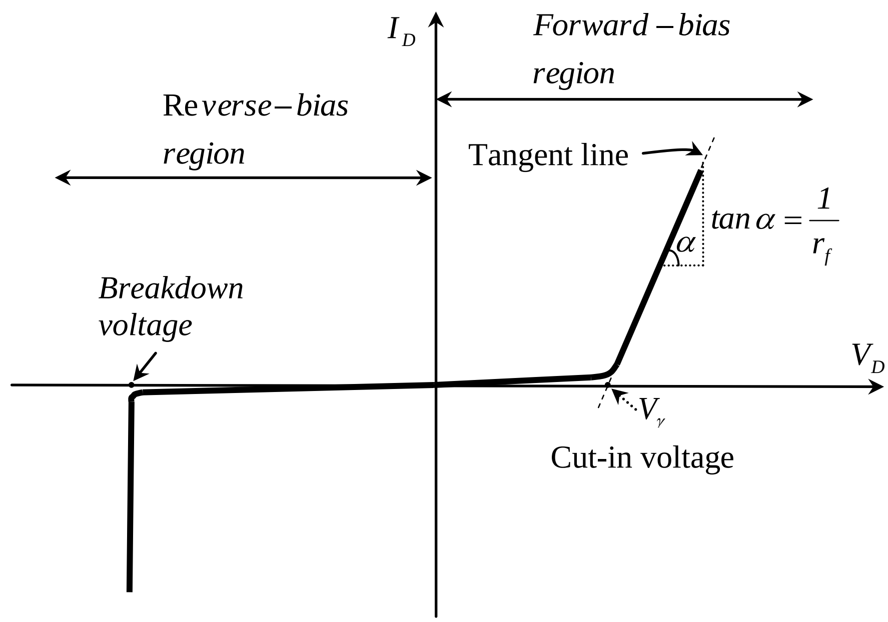

Figure 4. *Real diode characteristics*

The voltage current relationship of semiconductor diode is expressed as

$$I_D = I_S e^{\left(\frac{V_D}{nV_T} - 1\right)} \cong I_S e^{\left(\frac{V_D}{nV_T}\right)} \qquad \text{(Equation 2)}$$

$$where \quad \begin{cases} I_S : reverse\text{-}bias\ saturation\ current \\ V_T : thermal\ voltage, V_T\ (at\ 300K) = 0.026V \\ n : emission\ coefficient\ or\ ideality\ \ factor \end{cases}$$

The relationship given in this equation is valid for both forward and reverse bias; however, it fails to be valid when the reverse bias voltage reaches a value that causes breakdown. The parameters I_S and n can be found experimentally. For this purpose the straight line portion of I - V curve on a semi logarithmic plot is extrapolated to intercept the current axis at $V_D = 0$ (see Figure 5). I_S is read from the graph and n is calculated from the slope.

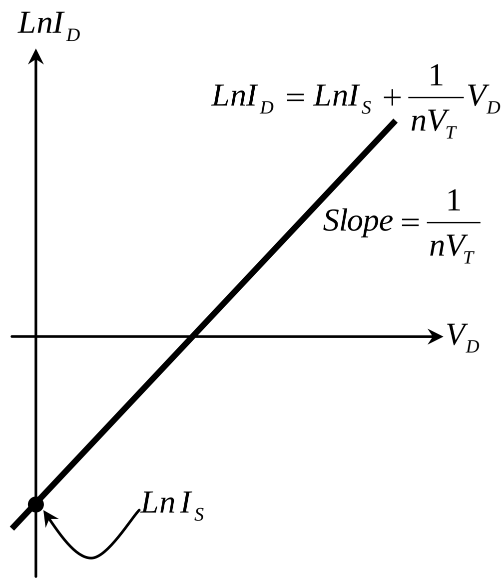

Figure 5. *Determination of reverse-bias saturation current (I_S) and emission coefficient (n) of Si-diode*

3- Equipments

1 Plug-in board 297 X 300	726 50
1 STE Resistor 100 Ω, 2 W	577 32
1 STE Si-Diode 1N4007	578 51
1 AC/DC stabilizer (-15 V)...(+15 V) / 1 A	726 88
2 Digital Multimeters	
Connecting Leads 100 cm	500 441
1 Potentiometer 220 Ω, 3W	577 90

4- Setup

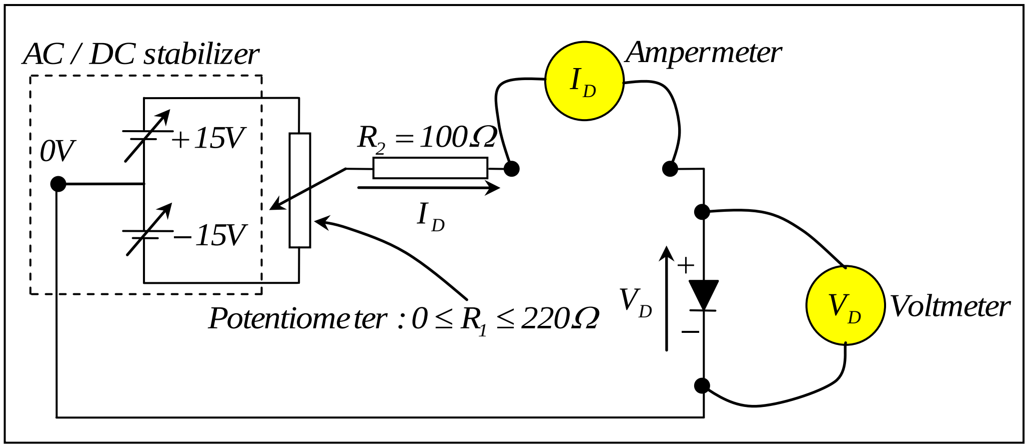

Figure 6. *Setup for determining I_D-V_D characteristics.*

5- Carrying out the experiment

5-1- I-V characteristic of a Silicon (Si) diode

- - Turn the potentiometer's button at the maximum position.

- - Turn the AC/DC stabilizer's button at zero position.

- Set up the experiment as shown in the Figure 6. Plug in the Si-Diode, so that the tip of the triangle points from plus to minus (in the direction of the current, "forward direction"). Pay attention to the measuring range and polarity of the multimeters.

- Turn the button of the AC/DC stabilizer until you reach a value close to 30mA in the ampermeter. The current I_D should not exceed 30 mA. After this operation, don't touch the button.

- Turn the potentiometer's button to position 0

- Carefully increase resistance R_1 of the potentiometer and observe current I_D.

- For different pairs of voltage V_D and current I_D fill table 1.

Table 1. *I-V characteristics of a Si-diode*

V_D (V)	$I_D(mA) \le 30mA$
-3	
-1	

0	
0.1	
0.16	
0.18	
0.23	
0.26	
0.28	
0.32	
0.35	
0.38	
0.43	
0.57	
0.67	

- Fill the first two columns of Table 2 with different pairs of voltage V_D and current I_D from Table 1 such that $10 < I_D(mA) \leq 30mA$

Table 2. *Si-Diode in conducting-state (forward) direction*

V_D (V)	$10 < I_D(mA) \leq 30mA$	$Ln(I_D)$	$Ln(I_D).V_D$	V_D^2
$\overline{V_D} =$	$\bar{I}_D =$	$\overline{Ln(I_D)} =$	$\overline{V_D.Ln(I_D)} =$	$\overline{V_D^2} =$

Part 1

1) Prepare a sheet of graph paper for plotting I_D versus V_D (Table 1). You should make I_D the vertical axis and V_D the horizontal axis. Each axis should be labeled and appropriate units indicated. The graph should have a title.

2) Plot your data on the graph.

3) Trace a smooth curve joining the different points.

4) Determine the value of cut-in voltage V_γ (see Figure 4)

5) Determine the value of r_f by using Equation 1.

Part 2

1) Prepare a sheet of graph paper for plotting $Ln(I_D)$ versus V_D (Table 2). You should make $Ln(I_D)$ the vertical axis and V_D the horizontal axis. Each axis should be labeled and appropriate units indicated. The graph should have a title.

2) Plot your data on the graph.

3) Draw a best fit line to the points on your graph by using the method of least square (See Apendix).

The equation of the best fit line is: $Ln(I_D) = mV_D + b$

4) Determine the slope ***m*** of your best fit line, and the y-intercept ***b***.

5) Find the relationship between m and I_S (see equation in Figure 5).

6) Find the relationship between b and n (see equation in Figure 5).

7) Determine the values of I_S *and* n.

6- Conclusion

Make a general conclusion about the experiments and the results obtained.