Name ______________________

Date ______________________

Instructor ______________________

EXPERIMENT

2

Diode Characteristics

OBJECTIVE

To calculate, compare, draw, and measure the characteristics of a silicon and a germanium diode.

EQUIPMENT REQUIRED

Instruments

DMM

Components

Resistors

(1) 1-kΩ
(1) 1-MΩ

Diodes

(1) Silicon
(1) Germanium

Supplies

DC power supply

Miscellaneous

Demonstration: 1 heat gun

EQUIPMENT ISSUED

Item	*Laboratory serial no.*
DMM	
DC power supply	

RÉSUMÉ OF THEORY

Most modern-day digital multimeters can be used to determine the operating condition of a diode. They have a scale denoted by a diode symbol that will indicate the condition of a diode in the forward and reverse-bias regions. If connected to establish a forward-bias condition the meter will display the forward voltage across the diode at a current level typically in the neighborhood of 2 mA. If connected to establish a reverse-bias condition an "OL" should appear on the display to support the open-circuit approximation frequently applied to this region. If the meter does not have the diode-checking capability the condition of the diode can also be checked by obtaining some measure of the resistance level in the forward and reverse-bias regions. Both techniques for checking a diode will be introduced in the first part of the experiment.

The current–volt characteristics of a silicon or germanium diode have the general shape shown in Fig. 2.1. Note the change in scale for both the vertical and horizontal axes. In the reverse-biased region the reverse saturation currents are fairly constant from 0 V to the Zener potential. In the forward-bias region the current increases quite rapidly with increasing diode voltage. Note that the curve is rising almost vertically at a forward-biased voltage of less than 1 V. The forward-biased diode current will be limited solely by the network in which the diode is connected or by the maximum current or power rating of the diode.

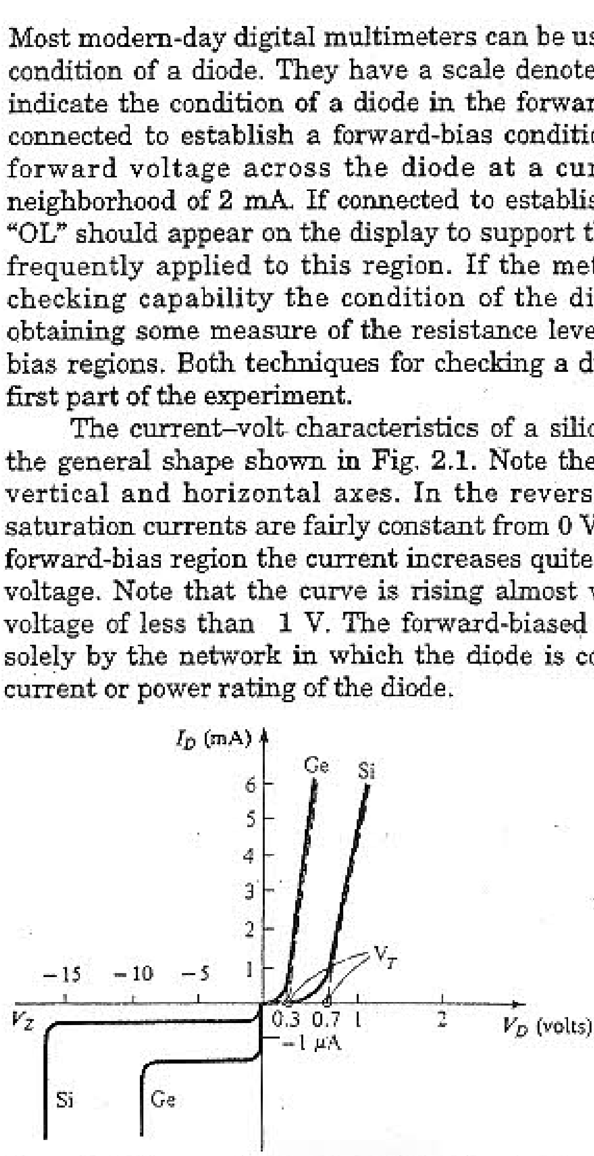

Figure 2-1 Silicon and germanium diode characteristics.

The "firing potential" or threshold voltage is determined by extending a straight line (dashed lines of Fig. 2.1) tangent to the curves until it hits the horizontal axis. The intersection with the V_D axis will determine the threshold voltage V_T at which the current begins to rise rapidly.

The *DC* or *Static resistance* of a diode at any point on the characteristics is determined by the ratio of the diode voltage at that point, divided by the diode current. That is,

$$R_{DC} = \frac{V_D}{I_D} \quad \text{ohms} \tag{2.1}$$

The *AC resistance* at a particular diode current or voltage can be determined using a tangent line drawn as shown in Fig. 2.2. The resulting voltage (ΔV) and current (ΔI) deviations can then be measured and the following equation applied.

$$r_d = \frac{\Delta V}{\Delta I} \quad \text{ohms} \tag{2.2}$$

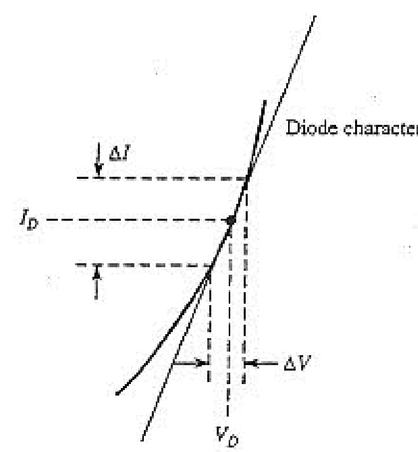

Figure 2-2

It can be shown through the application of differential calculus that the AC resistance of a diode in the vertical-rise section of the characteristics is given by

$$r_d = \frac{26 \text{ mV}}{I_D} \quad \text{ohms} \tag{2.3}$$

For levels of current at and below the knee of the curve the AC resistance of a silicon diode is better approximated by

$$r_d = 2\left(\frac{26 \text{ mV}}{I_D}\right) \quad \text{ohms} \tag{2.4}$$

PROCEDURE

Part 1. Diode Test

Diode Testing Scale

The diode-testing scale of a DMM can be used to determine the operating condition of a diode. With one polarity, the DMM should provide the "firing potential" of the diode, while the reverse connection should result in an "OL" response to support the open-circuit approximation.

Using the connection in Fig. 2.2, the constant-current source of about 2 mA internal to the meter will forward bias the junction, and a voltage of about 0.7 V (700 mV) will be obtained for silicon and 0.3 V (300 mV) for germanium. If the leads are reversed, an OL indication will be obtained.

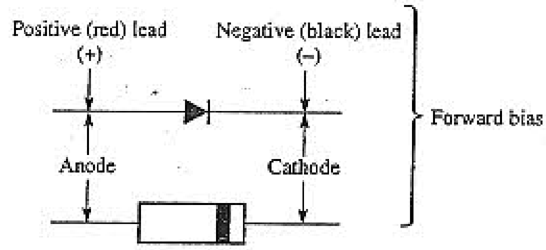

Figure 2-3 Diode testing.

If a low reading (less than 1 V) is obtained in both directions, the junction is shorted internally. If an OL indication is obtained in both directions, the junction is open.

Perform the tests of Table 2.1 for the silicon and germanium diodes.

TABLE 2.1

Test	*Si*	*Ge*
Forward		
Reverse		

Based on the results of Table 2.1, are both diodes in good condition?

Resistance Scales

As indicated in the Résumé of Theory section of this experiment, the condition of a diode can also be checked using the resistance scales of a volt-ohm-meter (VOM) or digital meter. Using the appropriate scales of the VOM or DMM, determine the resistance levels of the forward- and reverse-bias regions of the Si and Ge diodes. Enter the results in Table 2.2.

TABLE 2.2

Test	*Si*	*Ge*	Meter
Forward			VOM
Reverse			DMM

Although the firing potential is not revealed using the resistance scales, a "good" diode will result in a lower resistance level in the forward bias state and a much higher resistance level when reverse-biased.

Based on the results of Table 2.2, are both diodes in good condition?

Part 2. Forward-bias Diode Characteristics

In this part of the experiment we will obtain sufficient data to plot the forward-bias characteristics of the silicon and germanium diodes on Fig. 2.5.

a. Construct the network of Fig. 2.4 with the supply (E) set at 0 V. Record the measured value of the resistor.

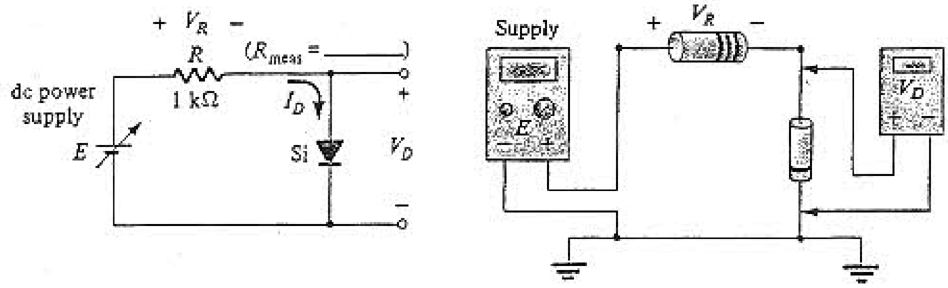

Figure 2-4

b. Increase the supply voltage until V_R (not E) reads 0.1 V. Then measure V_D and insert its voltage in Table 2.3. Calculate the value of the corresponding current I_D using the equation shown in Table 2.3.

TABLE 2.3
V_D versus I_D for the silicon diode

V_R (V)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
V_D (V)								
$I_D = \frac{V_R}{R_{meas}}$ (mA)								

V_R (V)	0.9	1	2	3	4	5	6	7	8	9	10
V_D (V)											
$I_D = \frac{V_R}{R_{meas}}$ (mA)											

c. Repeat step b for the remaining settings of V_R, using the equation in Table 2.3.

d. Replace the silicon diode by a germanium diode and complete Table 2.4.

TABLE 2.4
V_D versus I_D for the germanium diode

V_R (V)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
V_D (V)								
$I_D = \frac{V_R}{R_{meas}}$ (mA)								

V_R (V)	0.9	1	2	3	4	5	6	7	8	9	10
V_D (V)											
$I_D = \frac{V_R}{R_{meas}}$ (mA)											

e. On Fig. 2.5, plot I_D versus V_D for the silicon and germanium diodes. Complete the curves by extending the lower region of each curve to the intersection of the axis at $I_D = 0$ mA and $V_D = 0$ V. Label each curve and clearly indicate data points. Be neat!

f. How do the two curves differ? What are their similarities?

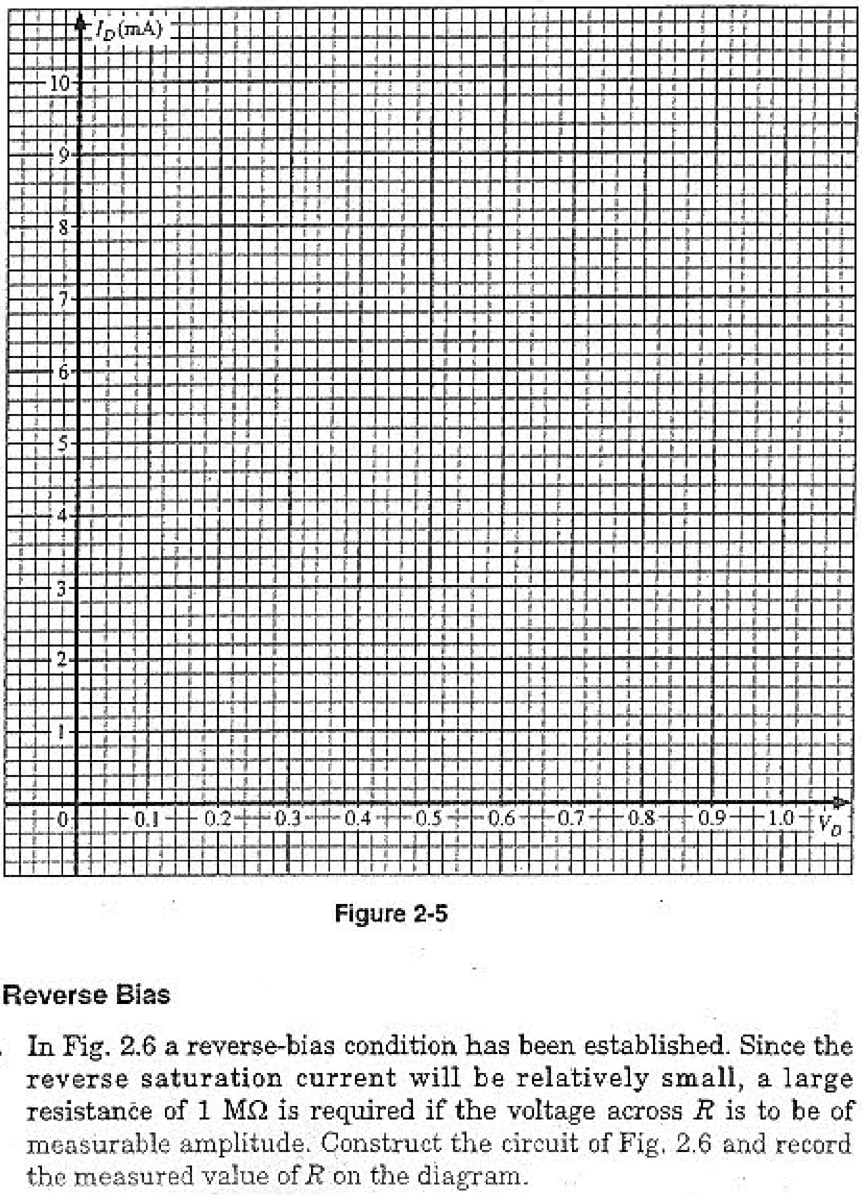

Figure 2-5

Part 3. Reverse Bias

a. In Fig. 2.6 a reverse-bias condition has been established. Since the reverse saturation current will be relatively small, a large resistance of 1 MΩ is required if the voltage across R is to be of measurable amplitude. Construct the circuit of Fig. 2.6 and record the measured value of R on the diagram.

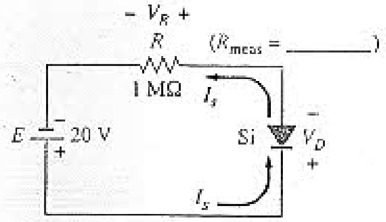

Figure 2-6

b. Measure the voltage V_R. Calculate the reverse saturation current from $I_s = V_R/(R_{meas} \| R_m)$. The internal resistance (R_m) of the DMM is included because of the large magnitude of the resistance R. Your instructor will provide the internal resistance of the DMM for your calculations. If unavailable, use a typical value of 10 MΩ.

R_m = ________

V_R (measured) = ________

I_s (calculated) = ________

c. Repeat step 3(b) for the germanium diode.

V_R (measured) = ________

I_s (calculated) = ________

d. How do the resulting levels of I_s for silicon and germanium compare?

e. Determine the DC resistance levels for the silicon and germanium diodes using the equation

$$R_{DC} = \frac{V_D}{I_D} = \frac{V_D}{I_s} = \frac{E - V_R}{I_s}$$

R_{DC} (calculated) (Si) = ________

R_{DC} (calculated) (Ge) = ________

Are the resistance levels sufficiently high to be considered open-circuit equivalents if appearing in series with resistors in the low kilohm range?

Part 4. DC Resistance

a. Using the Si curve of Fig. 2.5 (page 18) determine the diode voltage at diode current levels indicated in Table 2.5. Then determine the DC resistance at each current level. Show all calculations.

TABLE 2.5

$I_D(mA)$	V_D	R_{DC}
0.2		
1		
5		
10		

b. Repeat Part 4(**a**) for germanium and complete Table 2.6 (Table 2.6 is the same as Table 2.5).

TABLE 2.6

$I_D(mA)$	V_D	R_{DC}
0.2		
1		
5		
10		

c. Does the resistance (for Si and Ge) change as the diode current increases and we move up the vertical-rise section of the characteristics?

Part 5. AC Resistance

a. Using the equation $r_d = \Delta V/\Delta I$ (Eq. 2.2), determine the AC resistance of the silicon diode at $I_D = 9$ mA using the curve of Fig. 2.5. Show all work.

r_d (calculated) = ________

b. Determine the AC resistance at I_D = 9 mA using the equation r_d = 26 mV/I_D (mA) for the silicon diode. Show all work.

r_d (calculated) = ____________

How do the results of Parts 5(a) and 5(**b**) compare?

c. Repeat step 5(**a**) for I_D = 2 mA for the silicon diode.

r_d (calculated) = ____________

d. Repeat step 5(**b**) for I_D = 2 mA for the silicon diode. Use Eq. 2.4.

r_d (calculated) = ____________

How do the results of Parts 5(**c**) and 5(**d**) compare?

Part 6. Firing Potential

Graphically determine the firing potential (threshold voltage) of each diode from its characteristics as defined in the Résumé of Theory. Show the straight-line approximations on Fig. 2.5.

V_T (silicon) = ____________

V_T (germanium) = ____________

Part 7. Temperature Effects (Demonstration)

Reconstruct the circuit of Fig. 2.4 using the silicon diode. Establish a current of about 1 mA by setting V_R to 1 V.

a. Place the DMM across the diode. Select the suitable volt scale. Note the reading as the instructor heats the diode with the heat gun. Record the effect on V_D of heating the diode.

b. Let the diode cool down and then measure the voltage across the resistor R. Note the effect on V_R of heating the diode. Since $I_D = V_R/R$ what effect on the diode current of the network results from heating the diode?

c. Since $R_{diode} = V_D/I_D$ what is the effect of increasing temperature on the resistance of the diode?

d. Does a semiconductor diode have a positive or negative temperature coefficient? Explain.

Questions

1. Compare the characteristics of silicon and germanium in the forward- and reverse-bias regions. In particular, which diode is closer to the short-circuit approximation in the forward-bias region and which is closer to the open-circuit approximation in the reverse-bias region? How are they similar and what are their most noticeable differences?

2. Research the effect of heat on the terminal resistance of semiconductor materials and briefly review why the terminal resistance will decrease with the application of heat.