EXPERIMENT #1
DIODES

The purpose of this experiment is to allow you to become familiar with characteristics of typical diodes and some of the techniques for solution of circuits with diodes. There are several diodes in your lab kit. In this lab, you will spend some time generating the characteristic curves for three of your diodes. In other words, you will plot the current through the diode as a function of voltage across it. Then you will compare the predictions of several diode approximations with what actually happens in simple circuits.

It will be assumed in this laboratory that you have some understanding of diodes and of the approximation techniques used to solve circuits that include diodes. A brief overview is included here for reference. The most accurate diode approximation method makes use of the exponential diode equation. This equation takes into account such important effects as temperature and diode materials, and provides a fairly accurate model at low diode current. It is a non-linear equation, however, and can be difficult to apply, especially in complicated circuits.

Other methods assume that the diode can be represented by a characteristic curve made up of a series of straight lines. These are called “piecewise linear models” of the diode. The simplest version assumes only two lines, one that shows the diode to have no current when reverse biased, and one showing no voltage when forward biased. The most complicated version has a non-zero reverse bias current, a threshold voltage, and a non-zero internal resistance when the diode is on. All of these methods are easy to use once it is clear which part of the characteristic curve the diode is operating in. The difficulty lies in making this determination, i.e., whether the diode is on or off.

A method will be given with which you can generate a relatively accurate plot of diode current versus voltage. This will take a fair amount of time and is included only so that you can see for yourself what the diode really does, as opposed to the behavior indicated in the diode approximations given above.

Components Required

1N4001 (or similar) diodes

470 Ω resistor

1 kΩ resistor

2.2 kΩ resistor

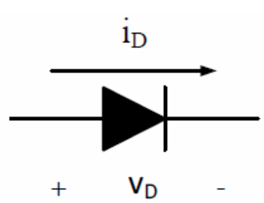
4.7 kΩ resistor

Pre-Lab

The ideal diode equation is as follows.

$$i_D = I_S\left(e^{\frac{v_D}{n v_T}} - 1\right)$$

where i_D and v_D are the diode current and voltage described in the figure below, IS is the reverse-bias saturation current, v_T is the thermal voltage (which is 0.026 V at room temperature), and *n* is the “ideality factor”. (The parameter *n* is a fudge factor used to bring actual diode current measurements into closer agreement with the ideal diode equation.)

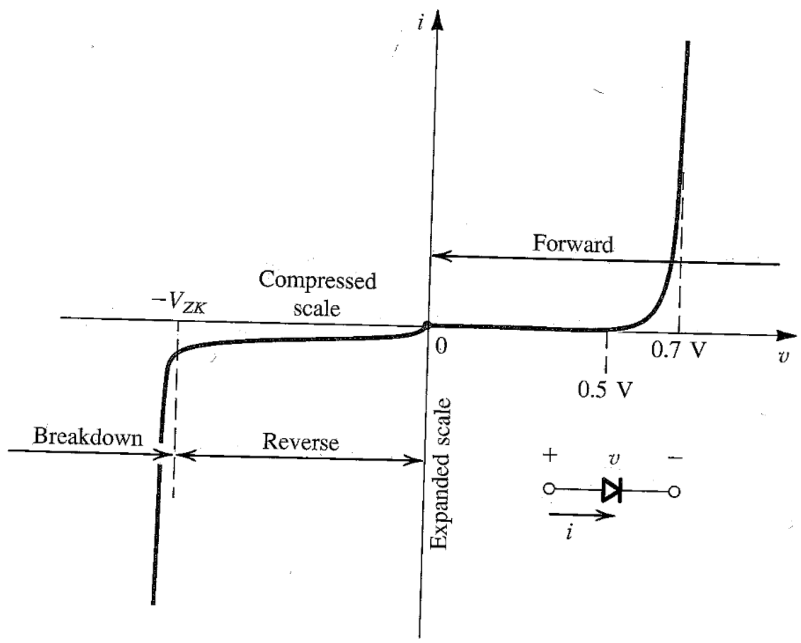


1. Using Excel or any mathematics package you like (or by hand), construct a plot of i_D vs. v_D for a diode with IS = 1 µA and n = 2.5. Your plot should cover the voltage range - 0.2 < v_D < 0.9 V.

2. Based on your plot, estimate the “threshold voltage”. How did you determine this value?

Procedure

1. Plot the forward and reverse characteristics of diode. Use the circuit shown in Figure 1. For the voltage source V_{SS} shown in the figure, use the DC power supply in the lab station. Vary this source over the range $-20V < V_{SS} < 20V$. This will mean switching the power supply connection between positive and negative ranges. In order to obtain a 0 (zero) V, you might need to short V_{SS} to ground, but with the source completely removed, in order to obtain a zero point. Connect your measured points with a smooth curve. It is also convenient to use different vertical scales for positive and negative diode current; see the figure below for an example.



While changing V_{SS}, monitor the voltage across the diode and the current through it. It is probably easiest to use the multimeter in the lab as a voltmeter, and to measure the voltages across the diode and the 1[k□] resistor. The current can then be obtained by dividing the resistor voltage by the resistance. Figure 1 illustrates measurement of the diode voltage using the voltmeter. If you wanted especially accurate measurements you would compensate for the resistance of your meter. This will not be required, except as noted in the questions at the end of the experiment.

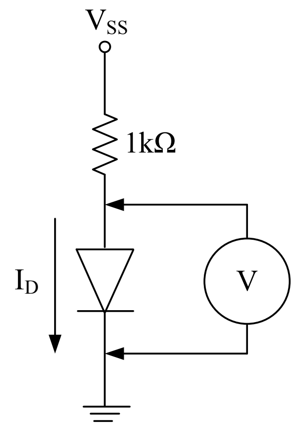


Figure 1 Circuit for plotting diode characteristic curves.

2. Build the circuit in Figure 2. Measure the current i_D with an ammeter. Then calculate the current you would expect from this configuration using your plots from step 1. This can be done most easily by drawing a load line ($V_D = V_{SS} - I_D R_D$) on your plot of the characteristic curves. A load line is simply a plot of the straight line resulting from application of Kirchhoff's voltage law to the loop including the diode, the resistor, and the source. Record your results in Table 1 and compute the percentage errors.

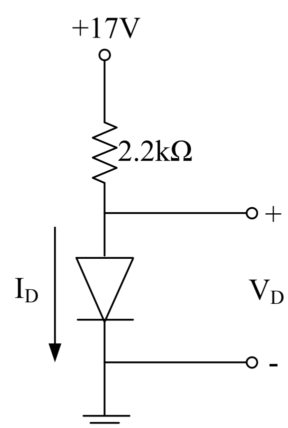


Figure 2 Circuit for testing diodes.

Next, calculate the current you would predict for these diodes using a piecewise linear model with a threshold voltage V_f of 0.7 V and with a threshold voltage of 0V. Assume in both cases an "on" resistance of zero. Enter your results in Table 2, and again compute the percentage errors.

Table 1: Currents measured and calculated for Figure 2: graphical calculations.

Diode	i_D *measured*	i_D *from graph*	% error
Diode "A"			

Table 2: Currents measured and calculated for Figure 2: linear diode approximations.

Diode	i_D *measured*	i_D *(Vf=0) (calculated)*	% error	i_D *(Vf =0.7V) (calculated)*	% error
Diode “A”					
Diode “B”					

We wish to get some idea of the ‘reproducibility’ of the diodes, that is, we wish to ask, “How closely do the properties of two ‘identical’ diodes match?” To address this question, take a second diode (labeled “B”), repeat your measurement of *iD*, and enter the result into Table 2.

NOTE: If you need you can use the graph papers given below.