PHYSICS 171

UNIVERSITY PHYSICS LAB II

Experiment 7

The PN Junction and Diodes

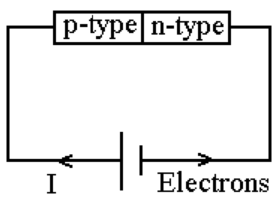
Equipment: Function Generator, Oscilloscope, Power Supply, VOM, DIgital Multimeter

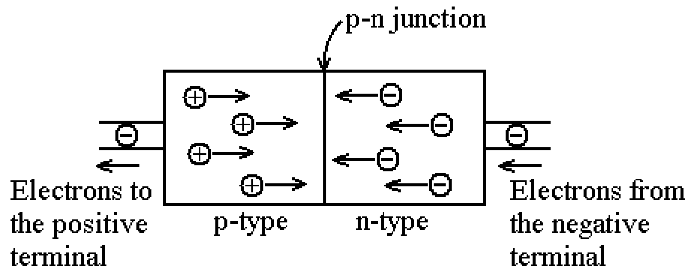
Supplies: 250 Ohm (5 Watt) resistor, Zener diode (1N5346), Rectifier Diode (5A4D/E4).

Perhaps no modern technology affects our daily lives quite as much as electronics. It is the basis for much of the mass communications media, for example: radio, television, and the telephone. The rapid growth of computers has also had an impact on society, and modern commerce would not be possible without the data processing provided by computer systems.

The development of modern electronics technology has occurred in three stages. The first occurred with the introduction of the vacuum tube, which is still used in a number of applications. The second state, which may be called solid-state electronics or semiconductors electronics, was initiated with the invention of the transistor in 1947. The development of circuit elements constructed from semiconductor crystals of germanium and silicon has produced a multi-billion-dollar industry. In many applications, solid-state devices have replaced vacuum tubes. In recent years advances in solid-state technology have enabled scientists and engineers to construct a variety of integrated circuits which combine many transistors and other circuit elements into a single miniature chip of semiconductor material. The development of inexpensive electronic calculators for the consumer electronics market is an outgrowth of integrated circuit technology. This third stage of development of electronics is still in its infancy, and many more applications may be expected.

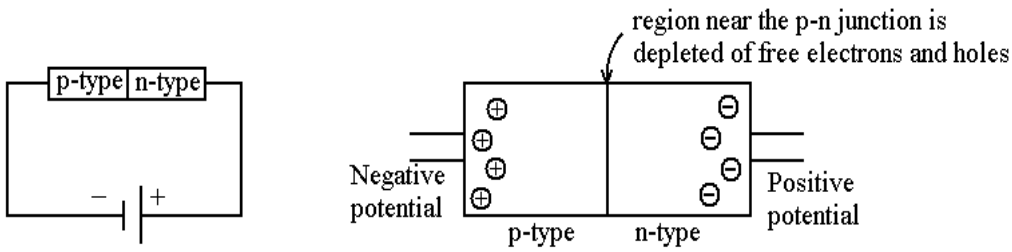
Although most electronic instruments appear to be very complex, it is possible to understand how they operate by considering a relatively small number of concepts and circuit elements. Our discussion here will be limited to semiconductor devices. The simplest solid-state device is the diode. The diode used in electronic circuits is usually a germanium or silicon crystal, which has been doped with impurities. Two types of impurities are used: n-type and p-type. Crystals doped with n-type impurities contain electrons that are free to move in the crystal. Those doped with p-type impurities contain a deficit of electrons called positive "holes." These holes are also free to move in the crystal.





The figure on the previous page shows a diode connected to a battery. Electrons from the negative terminal of the battery enter the n-type region through the lead connected at the point A. As the electrons enter the crystal, the Coulomb repulsive force causes free electrons in the n-type region to migrate towards the junction of the n- and p-type regions, and a current is thus produced. Similarly, bound electrons in the p-type region are withdrawn and flow out the lead at point B, creating holes (vacant electron energy states) in the p-type region. For each electron entering through lead A an electron must leave the diode through lead B. Newly created holes repel other holes in the p-type region, causing a migration of holes toward the junction. With a battery attached in this manner, the diode is said to be forward biased.

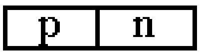
The figure below shows the same diode with the battery terminals reversed.



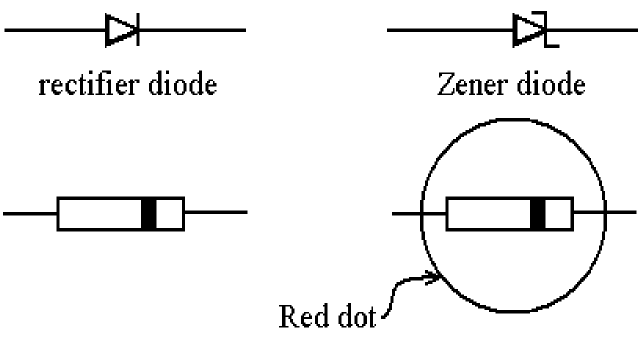
In this case the free electrons in the n-type region and the holes in the p-type region migrate away form the junction. Since there are few free electrons or holes near the junction, only a very small electric current flows and the diode is said to be reverse biased. Thus a semiconductor diode has the property that it conducts electric current in one direction and blocks the flow of current in the other direction.

<u>Rectifier and Zener Diodes</u>

A junction diode consists of a PN junction where n-type and p-type semiconductor regions are adjacent, as shown below.



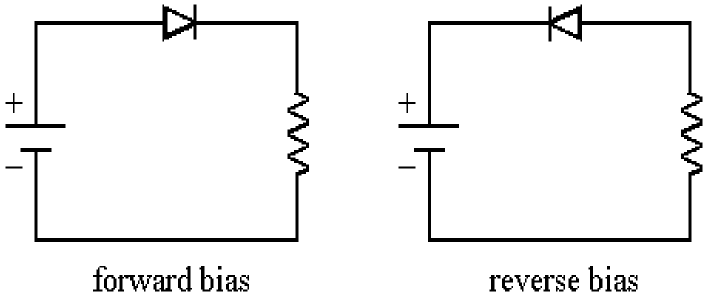
The p-side of the diode is called the anode; the n-side is called the cathode. The schematic symbols for two kinds of diodes that are of the PN junction type appear below.



The factor which determines whether a diode is a rectifier or a Zener is the relative concentration of impurity atoms.

The difference between Zener and rectifier diodes, as you will see in today's experiment, is dramatic. The rectifier diode offers virtually zero resistance when it is forward biased and infinite resistance when it is reverse biased. In comparison, the Zener diode provides nearly infinite resistance over a range of positive and negative potential differences. On either side of this range the voltage drop across the diode is nearly constant no matter what the current is.

When a diode is forward biased (p-side at a higher potential than n-side) the junction exhibits a very small resistance to current flow. A resistor is put in series with the diode, as shown below, to protect it from excessive current which would cause it to burn out. When a diode is reverse biased (p-side at a lower voltage then the n-side) the junction exhibits a larger resistance and very little current flows. This is the case until the reverse bias voltage reaches a certain breakdown value. The basic difference between a rectifier and a Zener is that the rectifier is destroyed if the reverse breakdown voltage is reached (called "avalanche breakdown") whereas the Zener is not destroyed (called "Zener breakdown"). In fact, the reserve breakdown voltage of a Zener diode is sufficiently repeatable so that it can be used as a voltage reference.

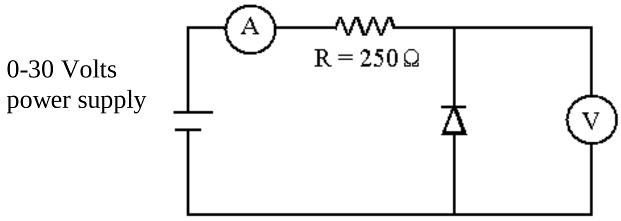


Procedure - Experiment 7

1. The Rectifier Diode

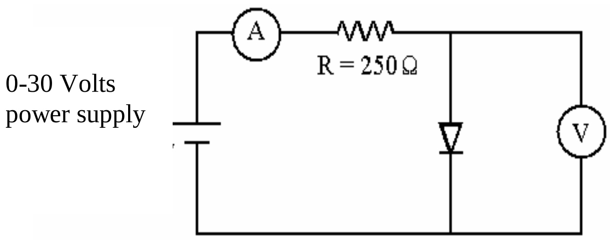
A. Reverse Bias

Set up the circuit shown below and attempt to measure the current in the circuit when the voltage drop across the diode is 5, 10, 20 and 30 Volts. Use the Simpson VOM as the ammeter and the digital meter as the voltmeter.



B. Forward Bias

Set up the circuit shown below and use the digital meter to measure the voltage drops across the resistor and then the diode when the flow of current in the circuit is 10μA, 50μA, 1 mA, 10 mA, 60 mA, and 100 mA. (When making the first two current measurements you will need to use the 50 microamp range on the VOM. Ask your instructor for assistance if you do not understand how to set the VOM to this range.) The circuit below shows you how to measure the voltage across the rectifier diode. To measure the voltage across the resistor, simply connect the voltmeter across the resistor.



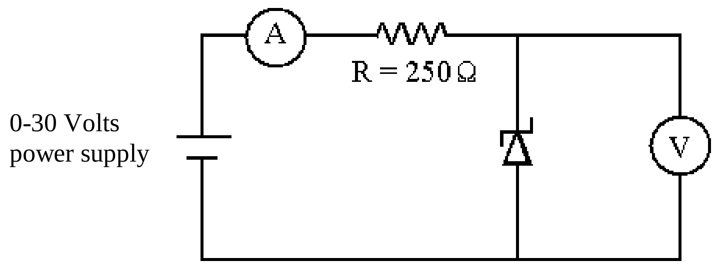
C. Conclusion

Examine the results you found in the first two parts of this experiment. What do they conclusively show you about the effect of a rectifier diode?

2. The Zener Diode

A. Reverse Bias

Set up the circuit shown and measure the current versus voltage for the reverse biased Zener diode. For some current measurements the VOM will be used on the 50 microamp range. Take measurements for currents as low as 10 microamps and as high as 100 milliamps.

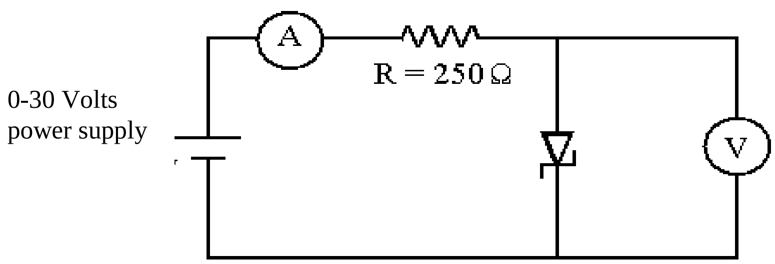


The maximum power rating of the 1N5346 is 1 watt and its Zener voltage is about 9 volts. Do not exceed the corresponding maximum current rating of (1 watt)/(9 volts) = 100 mA.

Question: Does the 250 ohm resistor have an adequate power rating. To answer this calculate the largest amount of power dissipated in the resistor in the measurements made above.

B. Forward Bias

Set up the circuit shown and measure the current versus voltage for the forward biased Zener diode. Take measurements for currents as low as 10 microamps and as high as 100 milliamps.

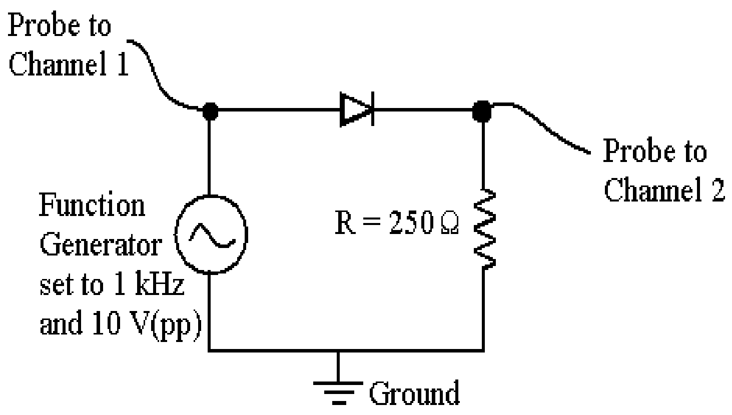


C. Graphs of I versus V

Use the data for both reverse and forward biased diode and plot a curve of I versus V. Both sets of data should be plotted on the same graph (reverse bias data is represented with negative values of I and V).

3. Half-Wave Rectifier

Using the scope, set the function generator to give a 10 V(pp) sine wave of frequency 1 kHz. Set up the circuit shown below. Use the dual trace feature of the oscilloscope to look at both V_{in} (Channel 1)and V_{out} (Channel 2). Make sure the scope probes are grounded.



Sketch the input and output voltages.

Data Sheet - Experiment 7

Section # ______

1. The Rectifier Diode

A. Reverse Bias

Voltage across rectifier	Current through rectifier
5 Volts	
10 Volts	
20 Volts	
25 Volts	
30 Volts	

B. Forward Bias

Current through rectifier	Voltage across the resistor	Voltage across rectifier
10 μA		
50 μA		
1 mA		
10 mA		
50 mA		
100 mA		

C. Conclusion

What does this data above show you conclusively about the effect of a rectifier diode?

2. The Zener Diode

A. Reverse Bias

Current through Zener	Voltage across Zener
100 mA	
80 mA	
60 mA	
40 mA	
20 mA	
10 mA	
5 mA	
1 mA	
0.5 mA	
50 μA	
40 μA	
30 μA	
20 μA	
10 μA	

B. Forward Bias

Current through Zener	Voltage across Zener
100 mA	
80 mA	
60 mA	
40 mA	
20 mA	
10 mA	
5 mA	
1 mA	
0.5 mA	
50 μA	
40 μA	
30 μA	
20 μA	
10 μA	

C. 1. Using a linear scale, plot a graph showing I versus V for both reverse and forward bias. Remember that reverse bias is represented with negative values of I and V.

3. Half-Wave Rectifier

Sketch below the input signal (use a dashed line) and the output signal (use a solid line). Please put the correct scale on the axes.