EE101 Laboratory 5 (FL03) Name ______________________________

Date ______________________ Partner's name ______________________________

Instructional Objectives (at the end of this lab you should be able to:)

- Be aware of basic electrical safety; know how to avoid electrical shock.
- Implement a circuit on your prototype board containing a diode and with the proper polarity.
- Use the oscilloscope to show the effect of a diode on a sinusoidal voltage signal.
- Describe the principles by which a diode affects a circuit.

Description and Background

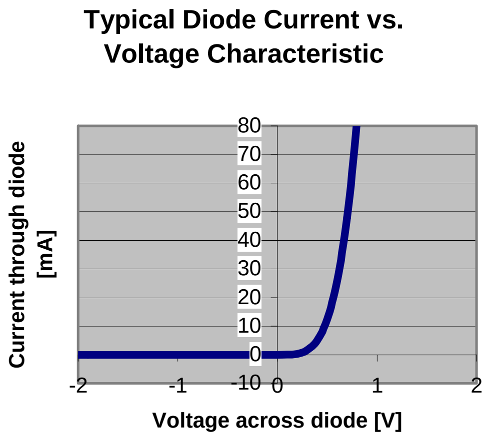
Electrical current flowing in a resistor circuit depends on the ratio of the voltage across the resistor and the resistance value: I = V/R (Ohm's Law). In other words, by measuring the resistance, and knowing the voltage, the electrical current can be found.

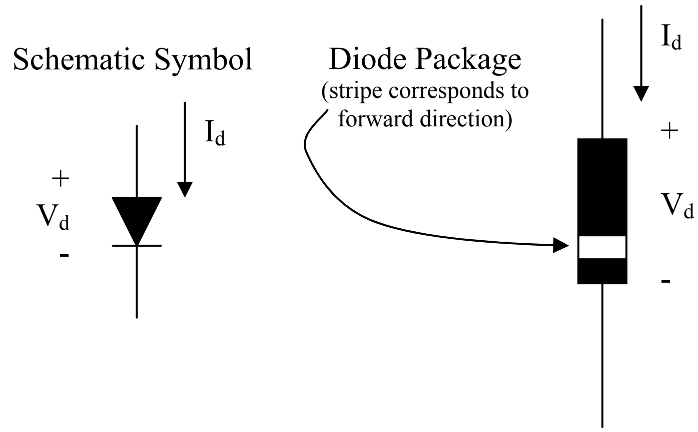
The human body has resistance to the flow of electrical current, so a voltage applied between two points on the human body will produce an electrical current through the body tissues. *Electrical shock* occurs when the human body reacts to the flow of current through its tissues. Extremely small electrical currents produce no detectable sensation, whereas somewhat higher electrical currents produce a "tingling" sensation. Muscle control can be affected if the current is sufficiently strong. Since muscle action is needed for breathing and heart beat, an electrical shock current can possibly disrupt the diaphragm as well as the heart muscle, quickly causing unconsciousness and potentially even death.

The voltage required to produce a dangerous level of electrical current in the human body can be estimated (no actual testing here!) by first measuring electrical resistance using very low voltages, then calculating the voltage necessary to produce a potentially lethal level of electrical current.

A *diode* is a circuit element that allows electrical current to pass in only one direction. In effect it functions as a "flow valve" – current is allowed to pass in one direction through the diode, but is prevented from passing through in the opposite direction. Diodes are marked to indicate in which direction electrical will flow through, so diodes have polarity; that is, they need to be placed in a circuit in the correct direction. This is unlike a resistor which does not have a polarity and so can be placed into a circuit in either direction with the same effect.

Although a diode allows current to flow through in one direction, it does this at the expense of a small voltage drop across the diode. Typically this *forward bias* voltage drop for a diode is about 0.5 V to 0.6 V (although some diodes exhibit a somewhat smaller voltage drop than this), and this voltage is relatively independent of the amount of electrical current flowing through the diode. An example of the current vs. voltage relationship for a diode is shown in the figure on the next page.





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The Physical Effects of Electricity

Electrocution or electrical shock occurs when an electric current I passes through the body. The amount of current passing through the body is determined by Ohm's Law:

I = V/R

I = Current Through the Body
V = Voltage across the body
R = Resistance of the Body

Body resistance is an important variable when considering electrocution. There is a wide variation in body resistance between people therefore the same voltage level may result in different effects. The typical human body has a hand to hand resistance (R) somewhere between 1,000 and 2,000 ohms. Babies, Children and some other people have less resistance.

The current is the controlling factor for Electrocution and Electrical Shock. The threshold for perception is about 100 microamps (0.0001 Amps). Also See Microshock Electrocution Hazards for currents less than 100 microamps. The National Electrical Code (NEC) considers 5 milliamps (0.005 Amps) to be a safe upper limit for children and adults hence the 5 milliamps GFI circuit breaker requirement for wet locations. The normal nervous system reaction to any perceptible electrical shock may cause a person to injure themselves or others, therefore the so called safe limit does not assure freedom from injury.

The more serious electrocution and shock hazards occur above the "let go" limits.

99% of the female population have a "let go" limit above 6 milliamps, <u>with an average of 10.5 milliamps</u>.
99% of the male population have a "let go" limit above 9 milliamps, <u>with an average of 15.5 milliamps</u>.

Prolonged exposure to 60 Hz. currents greater than 18 milliamps across the chest causes the diaphragm to contract which prevents breathing and causes the victim to suffocate. No data is available for females or children but suffocation is presumed to occur at a lower current level.

The frequency of the electrical current is as important as magnitude when evaluating electrocution and electrical shock injuries. Humans and animals are most susceptible to frequencies at 50 to 60 hertz. The internal frequency of the nerve signals controlling the heart is approximately 60 hertz. Ventricular fibrillation occurs when 60 hertz current from the electric shock interferes with the natural rhythm of the heart. The heart loses its ability to pump and death quickly follows. Ventricular fibrillation can occur at current levels as low as 30 milliamps for a two year old child and 60 milliamps for adults. Most adults will go into ventricular fibrillation at hand to hand currents below 100 milliamps (0.1 Amp).

Humans are able to withstand 10 times more current at DC and at 1000 hertz than at 50 or 60 Hz.. Electro-surgical equipment operating above 100,000 Hertz pass high currents through the body with no effect on the heart or breathing of a patient. Do you think that Murphy's Law had anything to do with the American power line frequency being set at 60 hertz and the frequency for the rest of the world being 50 hertz? All of the current limits referred to in this article are based on power line frequencies of 50 or 60 hertz.

Electrocution may or may not leave physical evidence of the injury. The occurrence of burns or other skin damage is dependent upon the current density at the point where the current enters or leaves the body. Electrocutions occurring at 110 VAC seldom cause skin damage unless the point of contact is small or the victim has delicate skin. When higher voltages are involved, high currents pass through the body and there is greater likelihood that skin damage will occur. At higher voltages there are often, but not always entrance and exit wounds.

I am not a medical doctor, however, there are conflicting claims about electrocution causing a change in enzyme levels or other measurable physical changes in the victim.

Equipment

Your own circuit prototype board, your own lab kit containing resistors, capacitors, a diode (and other components), your own resistor color code chart, alligator clips from your lab kit, lab signal generator and oscilloscope, plus meter cables furnished in the lab for connecting to the signal generator.

Procedures

P1.
→ Using the lab multimeter, measure and record the electrical resistances required in the table below.

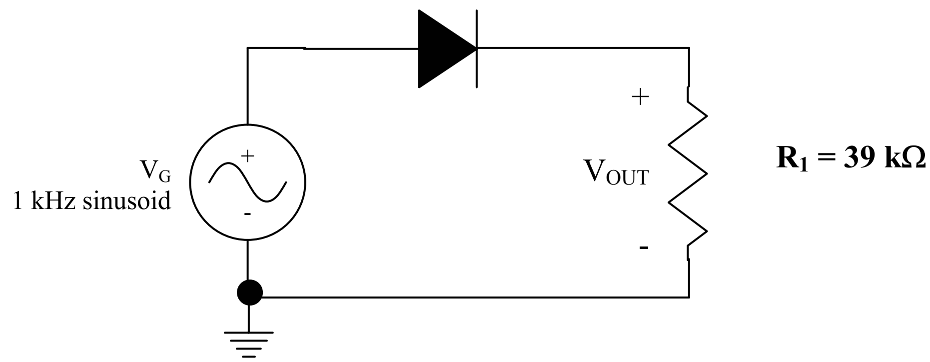
→ Complete the rest of the table by doing the necessary computations.

Path of Current	**Measured Resistance** (use the multimeter)	**Calculated voltage necessary to induce a current equal to average "let go" threshold** (note: the average "let go" current is different for males and females: see handout notes)	**Calculated lethal voltage estimate** (based on assumption that 18 mA is lethal passing through the chest)
Finger-to-finger, same hand Person 1			
Finger-to-finger, same hand Person 2			
Left-to-right hand Person 1			
Left-to-right hand Person 2			
Left-to-right hand Person 1 Contact points on hands wet			
Left-to-right hand Person 2 Contact points on hands wet			

P2.
→ (a) Discuss the risk associated with coming in contact with typical voltages used in this laboratory class, and support your answer with your results from the table above.

→ (b) Discuss the risk associated with coming in contact with voltages that are used in modern house wiring – 110 volts and 220 volts – and support your answer with your table of results.

P3. Construct the circuit shown below on your prototype board. Use the lab signal generator to provide the input voltage, which is a sinusoidal signal.



Set the input voltage amplitude to 2 V peak-to-peak and set the frequency to 1 kHz. Observe V_G on one channel of the oscilloscope and V_{OUT} on the other channel. Both channels should be set for DC Coupling in order to give proper readings.

→ Record all of the measurements required in the table below along with correct units labels. Note that some of the required measurements are *maximum* and *minimum* voltages with respect to ground, not peak-to-peak values.

V_G voltage, peak-to-peak volts	**V_{OUT} voltage, peak-to-peak volts**	**V_{OUT} maximum, volts**	**V_{OUT} minimum, volts**

P4.
→ Sketch the shape of the voltage waveform V_{OUT} for the diode circuit and be sure to include labeling the maximum and minimum voltages on your sketch.

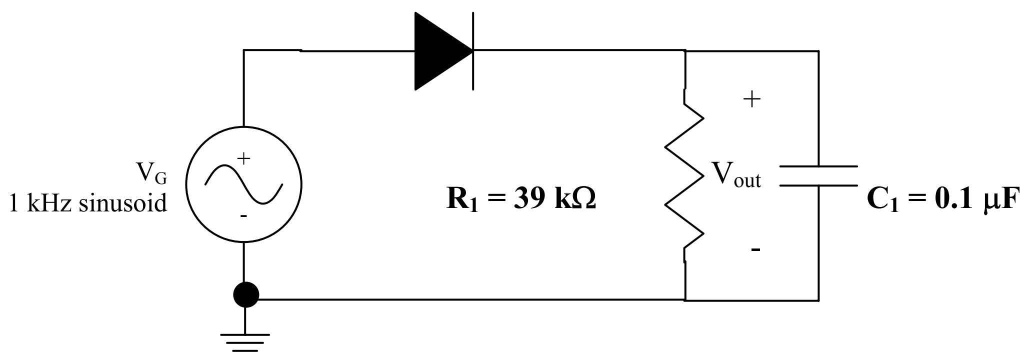
→ Explain how the waveform shape for V_{OUT} compares with that for the input voltage V_G .

P5.

→ Now change the polarity of the diode (*reverse* it) and obtain the following measurements.

Change polarity of diode	**V_G voltage, peak-to-peak volts**	**V_{OUT} voltage, peak-to-peak volts**	**V_{OUT} maximum, volts**	**V_{OUT} minimum, volts**

P6. Assemble the circuit shown below: this is the same as the circuit of P3, but with a 0.1 μF capacitor added in parallel with the resistor. This is a simple AC-to-DC *rectifier* circuit.



→ Sketch (and LABEL) the waveform of the voltage across the resistor/capacitor combination, and indicate the maximum and minimum voltages that you measure.

→ Compare the maximum and minimum voltages for this modified circuit with the maximum and minimum voltages for P4. What is the difference between these two sets of voltages?