Lab 1

The first lab will continue with the basic **battery-resistor-LED** circuit demonstrated during the first lecture. We will attempt to understand all important aspects of how it works so you can create your very own LED circuit.

Components
9V battery with snap
Various Resistors
LED

Part I

The first component we learned about (besides the battery) was the resistor. We use a resistor to limit the amount of current that flows in a circuit. If we place a resistor across a battery, we can then determine the current that we expect to be flowing through the resistor. It's very important to remember that putting a **voltage across** a resistor causes a **current to flow through** the resistor. This is shown in Fig. 1 below.

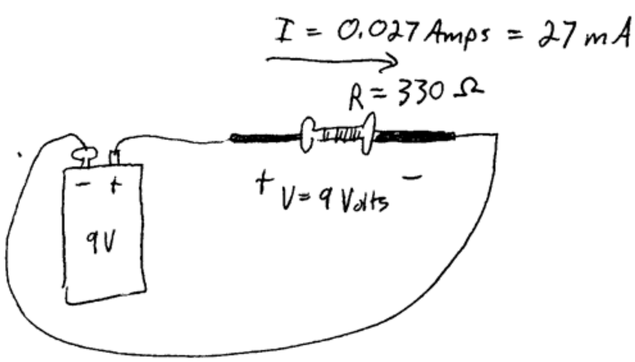

Fig. 1

If we look at Fig. 1 more closely we can begin to see how the circuit is predictable. Remember that Ohm's Law says that **V = I*R**, which can be rewritten to give **R = V / I**, or **I = V / R**. Let's suppose that we don't know how much current is flowing through the resistor, but we do know that the 9V battery indeed is putting out 9V exactly and the resistance of the resistor is exactly 330 Ohms. (Note: Ohms = **Ω**) We can then calculate the exact current flowing through the resistor. We do this by plugging in the values of the resistance and voltage into Ohm's Law **I = V / R** equation like so:

9 Volts / 330 Ohms = 0.027Amps = 27 mA

So if we were to measure the current in the circuit using our multimeter, it should be very close to 0.027 Amps or 27 mA. Doing this exercise again with a different value of resistor would give us a different current in the circuit. Let's suppose that a 470 Ohm resistor was used instead. We should expect the current to be less since we increased the resistance. Our Ohm's Law equation would the give:

9 Volts / 470 Ohms = 0.019 Amps = 19 mA

When a voltage is present across a component like we can see across the resistor in Fig. 1, we say there is a "voltage drop." This implies that the voltage is somehow lowered by the component from the positive side to the negative side. This will be clearer if we use an example with two resistors instead of just one.

Using the same type of circuit as in Fig. 1 but with two resistors instead of one, we can see that there will be two voltage drops, two separate voltages across the resistors. An important property of voltage is that in a closed loop circuit like below the voltage of the battery must be the sum of all the voltage drops. Because we have two identical resistors in our circuit, the voltage drop will be equal, which means they will both be half of the 9V coming from the battery. We can then use the same calculations as above to determine the current flow through each resistor.

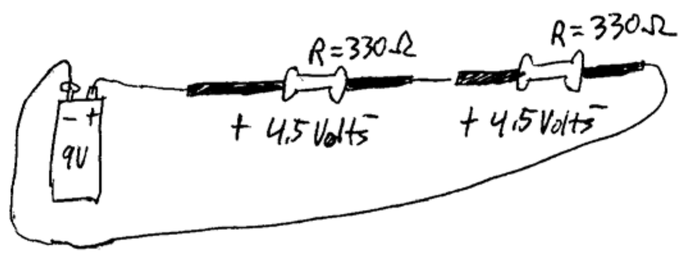

Fig. 2

The second component we briefly learned about was the LED. The LED is a semiconductor device which means it doesn't follow such a simple equation as the resistor does. Like most electronics components, the way it behaves in a circuit can be characterized by a few generalized rules. The resistor behaves according to Ohm's Law as shown above, but the LED (a diode), behaves very differently. In the case of an LED, the direction you put it in the circuit is very important. As shown in the first lecture, the long wire, or lead, of the LED is placed towards the positive terminal while the short lead is placed toward the negative terminal of a battery.

Associated with every diode, including LEDs, is a threshold voltage. This voltage value is the voltage that has to be present across the LED for it to "turn on." Turning on means it allows current to flow through it. When it is placed correctly in the circuit, we can describe its behavior using these rules.

1) Current will only begin to flow in the LED when the voltage from the battery is higher than the threshold voltage.
2) Once current begins to flow through the LED, the voltage remains at the threshold voltage, regardless of how much current flows through the LED.

The LED circuit demonstrated during the first lecture is shown below in Fig. 3. The typical threshold voltage for a red LED is 1.7 V. Remember that an important characteristic about voltage is that with a simple loop, like the one below, the voltage across all the components must add up to the voltage the battery puts out. Using the rules above, the additive voltage property, and our circuit analysis from the circuits in Fig. 1 and Fig. 2, we can begin to understand the LED circuit.

We have a battery that is supplying our circuit with 9V of electricity. We know that LED Rule 1 says that since our battery is higher than the red LED's threshold voltage of 1.7V, current will be flowing through our circuit. We also know from LED Rule 2 that because we have current flowing through our circuit (hence, also through the LED), the voltage across the LED will be constant and exactly the threshold voltage, 1.7 V. Finally, we know that because of our new voltage addition rule, the voltage drop across the resistor and across the LED must add up to 9 V. This means the voltage across the resistor is going to be 9 V – 1.7 V = 7.3 V.

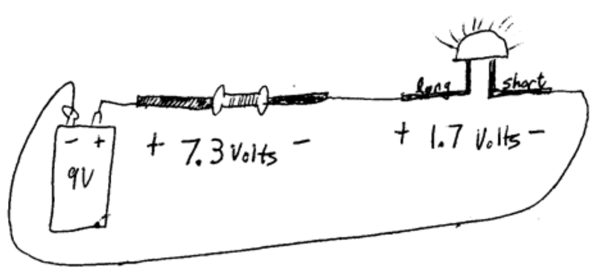

Fig. 3

Task 1 – Measuring using a multimeter

1. Resistors often have resistances slightly different that what is shown on the package, within a certain tolerance (+/- 5%). Using the R or Ω position on the multimeter, measure and record the resistance of at least two resistors using the multimeter and record both the ideal value (number on package) and the actual value (number on multimeter).

Ideal	Actual
____________	____________
____________	____________

2. Like we saw in the first lecture, the voltage on a battery will also not be exactly what the battery says it is. Measure the voltage on the 9 V battery using the multimeter and record the ideal value and its actual value. Do this at both the beginning of the lab and at the end of the lab and compare your two measurements.

	Ideal	Actual
Beginning	____________	____________
End	____________	____________

3. Connect the circuit shown in Fig. 1 on your breadboard. Measure and record the voltage across the resistor. Use the measured voltage of that resistor and the ideal resistance of the resistor to predict (calculate) what you expect the current to be.

   Measured Voltage ___________
   Calculated Current ___________

4. Connect the circuit shown in Fig. 2 on your breadboard. Measure and record the voltage across each of the two resistors. Add the two measured values together to predict the total voltage across both resistors together.

   Resistor 1 Voltage ___________
   Resistor 2 Voltage ___________
   Predicted Total Voltage ___________

   Now measure and record the total voltage across both resistors. This should be the same as measuring the voltage across the terminals of your battery, but this time the battery is in a circuit when you measure it.

   Measured Total Voltage ___________

   How does the measured voltage here compare to the voltage you measured across the battery when it was not in the circuit?

Task II – Designing your own LED circuit

1. Refer to the discussion about Fig. 3. It is important to note that the voltage across the resistor was determined without any knowledge about the resistance. This means that there will always be 7.3 V across any resistor placed in that circuit. Because of this constant voltage, we can calculate the current in the circuit for any value of resistor.

Suppose that we choose a 330 Ohm resistor like in Fig. 4, calculate the current flowing through the resistor. See Fig. 4.

I = _________

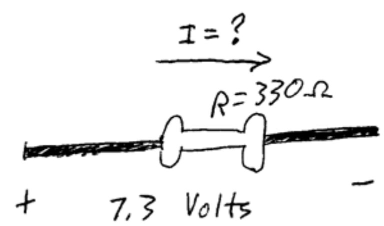

Fig. 4

Now let's suppose that we want the current to be a certain value, I = 15.5mA. (Hint: 15.5mA = 0.015A.)
Calculate the value of resistor that we would need to put in the circuit to have that current.

R = ___________

2. Now design your own LED circuit using the same circuit as in Fig. 3. You can assume that if you are using a red LED that the threshold voltage will still be 1.7 V, but if you are using a green LED, the threshold voltage will be 2.1 V.

*If you use a red LED, design your circuit so that only 7.3 mA of current flows through the LED.
*If you use a green LED, design your circuit so that 6.9 mA of current flows through the LED.

a) Draw and label your circuit as was done in the previous figures.
b) Calculate all values, showing all calculations.
c) Connect the circuit together on a breadboard
d) Measure the voltage across the resistor and the LED to verify they are correct.
e) Repeat a-d if the voltages don't reasonably match

Task III – Soldering

1. Transfer your LED circuit from Task II to a perforated circuit board and solder all connections into place. Verify the same way as in Task II.