Quick Review:

- **VOLTAGE (VOLTS)** is a measure of the electrical force (per unit charge) present in a circuit that causes the charge carriers to move producing **CURRENT (AMPS)**. You should think of the charged particles of the current as analogous to marbles moving through garden hose. They can’t bunch up anywhere or they would burst the hose thus at any junction of a circuit, the total current coming in equals the total current out. In the following picture, the sum of currents $I_A$, $I_B$ and $I_C$ equal $I_{Total}$.

- Any **RESISTANCE (OHMS)** in the circuit will dissipate electrical energy as heat or mechanical work.
- The resistance comes from **COMPONENTS** you choose.
- If your resistive component is **OHMIC**, then it satisfies **OHM’S LAW**: $V=IR$.
- These three concepts are the same for **DIRECT CURRENT** (constant voltage source) and **ALTERNATING CURRENT** (oscillating source voltage).
- For alternating currents, there are two additional kinds of standard components:
  - **CAPACITORS** are conductive plates that resist current from a slowly varying alternating current (a high-pass filter).
  - **SOLENOIDS** (also called **INDUCTORS**) are coils of wire that resist rapid changes in voltage (a low-pass filter).

**The Energy-Circuit Diagram – Conservation of Energy**

- Think about a circuit with constant voltage as a sort of “energy-circuit diagram”. The $y$-axis represents voltage (potential energy per unit positive charge) while the $x$-axis represents the position of the circuit components.:

This diagram is an attempt to convey that the battery lifts a unit of positive charge to 1.5 Joules of electrical potential energy and that this unit of charge loses all this energy when flowing through the light bulb. Another way to say this is that the battery provide 1.5 volts of electrical potential to the circuit and that all this electrical potential is lost across the light bulb.
Note also that the wires are drawn nearly parallel to the x-axis. This is because wires are highly conductive (very low resistance) and so there is no appreciable drop in electrical potential along a wire.

- Now imagine adding another identical light bulb in series with the first. If the resistances are the same, the bulbs will each consume half of the voltage created by the battery.

![Circuit Diagram]

- The big idea here is that all the voltage created by the battery is lost when you traverse the circuit: a charge carrier starts at zero voltage and ends at zero voltage.
- An oscillating source voltage can be thought of as a battery turning upside down repeatedly in the energy-circuit diagram.

**Instructions:**

- **Digital Multimeter (DMM)**
  - Use the digital multimeter to measure the DC voltage of a battery (or constant voltage power supply).
  - Set up a simple circuit to have a DC voltage discharge through a resistor. Then use your DMM to measure the voltage drop across the resistor. It should look something like:

![Circuit Diagram]

- Note that your DMM can also measure the resistance of a resistor (in Ohms), but you should always make this measurement when the resistor is not hooked up in a circuit:
The Oscilloscope

- The DMM can measure constant voltage across any component in a circuit, but most every electronic device operates using changing voltages. The o-scope can show you these changing voltages as a picture on its screen.
- Use the function generator to create a sine wave with 1,000 Hz frequency. Use the oscilloscope on channel one to see the voltage on the screen (get help from mentors).

Now use your function generator to send an oscillating voltage through a resistor (hook this up first). Then view the oscillating voltage across the resistor on your oscilloscope:

The o-scope has two channels so that you can measure two signals at once. Unfortunately, both black (ground) leads of these channels are connected internally so that if you want to measure any two components, you must place the black channel lead in the middle of the components:

Now wire the circuit shown above and use the oscilloscope to measure the voltage across each resistor simultaneously on both channels by setting up a “middle ground”.

Now wire the circuit shown above and use the oscilloscope to measure the voltage across each resistor...
**O-scope Features**

- The following picture shows the digital oscilloscope and labels its most common features.

Set up an RLC circuit with a sinusoidal source voltage with the values $f_{\text{drive}} = 3,500$ Hz, $R = 1 \, \text{k}\Omega$, $C = 0.1 \, \mu\text{F}$, and $L = 50 \, \text{mH}$ (no o-scope involved):

![RLC Circuit Diagram]
- Use a middle ground configuration to examine the voltage of the source and the voltage across the resistor simultaneously on your o-scope.
- Use the **autoset** button to quickly get your signal on the screen so you can adjust your function generator DC offset correctly. Be sure that your channel is on “1x probe” and that your trigger is set to the correct source. **Do this now.**
- Use the measurement feature set to measure the mean voltage of channel one.
- Use the measurement feature set to measure the period of the wave on channel two.
- Use the measurement feature set to measure the peak-to-peak voltage of both channels.
- Use a two cursor measurement **of time** and get the oscilloscope to tell you on its screen how much time the sine wave spends being positive.
- Now use a two-cursor measurement **in voltage** and get the oscilloscope to tell you on its screen the voltage drop of the wave from its maximum positive value to zero.
- Now change the display to x-y mode to see the channel one voltage become the x-axis and the channel two voltage become the y-axis. Judging from the shape this makes, determine if the two signals are in phase (a straight line) or 90° out of phase (a perfect ellipse or circle).
- Adjust the frequency to see how this phase relationship changes.

- **A Simple Radio:**
  - The eerie process of Faraday’s Law states that a changing magnetic field can create a voltage in a loop of wire. This is often used to make a simple radio antennae because the radio waves in the air are made of oscillating electromagnetic waves.
  - Take a large solenoid from the corner of the room and hook it to channel one (an nothing to channel two). You should see some small oscillating voltages caused by the electromagnetic waves in the air.
  - Use the math feature of FFT to discover the frequencies of the electromagnetic waves in the air.