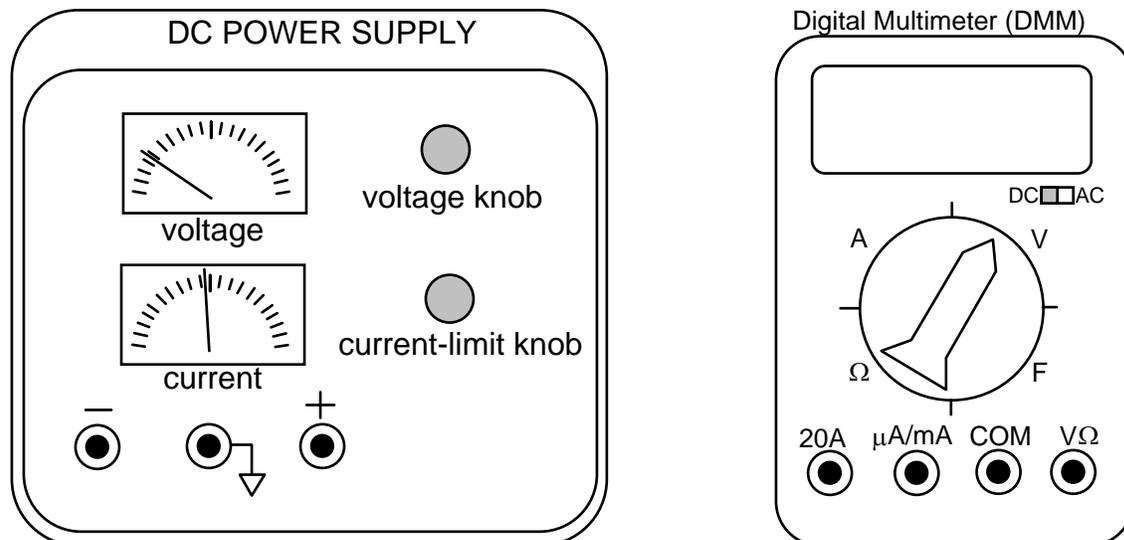


Lab E1: Introduction to Circuits

The purpose of this lab is to introduce you to some basic instrumentation used in electrical circuits. You will learn to use a DC power supply, a digital multimeter which can measure current, resistance and voltage, and an oscilloscope which can measure DC and AC voltages. DC means constant in time, and AC means time-varying, usually sinusoidal.

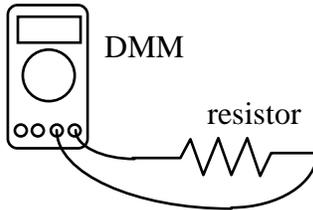
The DC power supply has three output terminals: plus (red), minus (black), and ground (green). The internal circuitry of the power supply holds the (+) terminal at some voltage higher than the (-) terminal, and this voltage difference can be adjusted with the voltage knob and read on the voltage meter. The ground terminal (green) is *always* at 0 volts. The internal circuitry does not know or care whether the (-) or (+) terminals are at zero volts; it only knows the difference between the (+) and (-) outputs. To make the (-) terminal output voltage be 0 volts, the ground terminal and the (-) terminal must be connected. In that case the (+) terminal is a positive voltage (>0). If the ground and (+) terminals are connected, then the (+) terminal is at zero volts and the (-) terminal becomes a negative voltage. When neither the (+) or (-) terminals are connected to ground, then the supply is said to be *floating*, and you cannot easily tell the absolute voltage of either.

Although the DC power supply used in this lab is a voltage source, it has both voltage and current adjust knobs. The current knob is used if you wish to limit the current to some maximum value (for safety or other reasons). The voltage knob adjusts the voltage, *unless* the voltage is so high that the current output exceeds the limit set by the current knob, in which case turning up the voltage knob further will have no effect. For this lab, you can leave the current-limit knob turned up fully (fully CW).



The hand-held digital multimeter is a wonderful little device which can be used to measure voltage and current (DC or AC), resistance, and capacitance. When making any measurement, there are always 2 wires to the DMM. One of the two wires always goes to the COM (common) terminal. To measure voltage or resistance, the second wire lead is attached to the V/Ω input. To measure current, the second wire is attached to one of the two current inputs. For currents up to 2 A, use the μA/mA input, for currents in the range 2 -

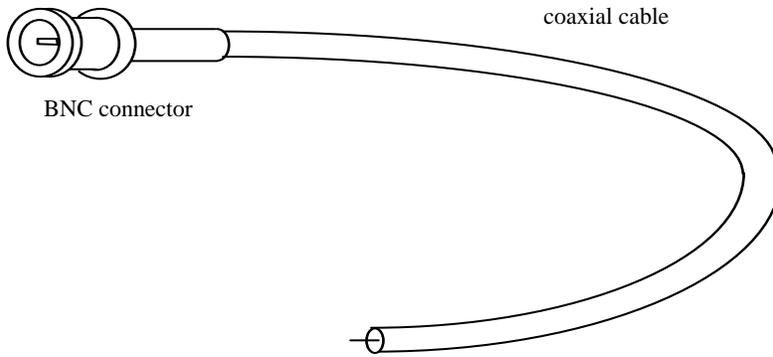
20A, use the 20A input. In this lab, all our measurements will be DC, so the DC/AC switch (upper right) should always be in the DC position. The DMM has an alarm; it sings if you have wires plugged into positions which conflict with the central knob's position. (For instance, if you have the wires in COM and $V\Omega$, but have the center knob in the amps quadrant.)



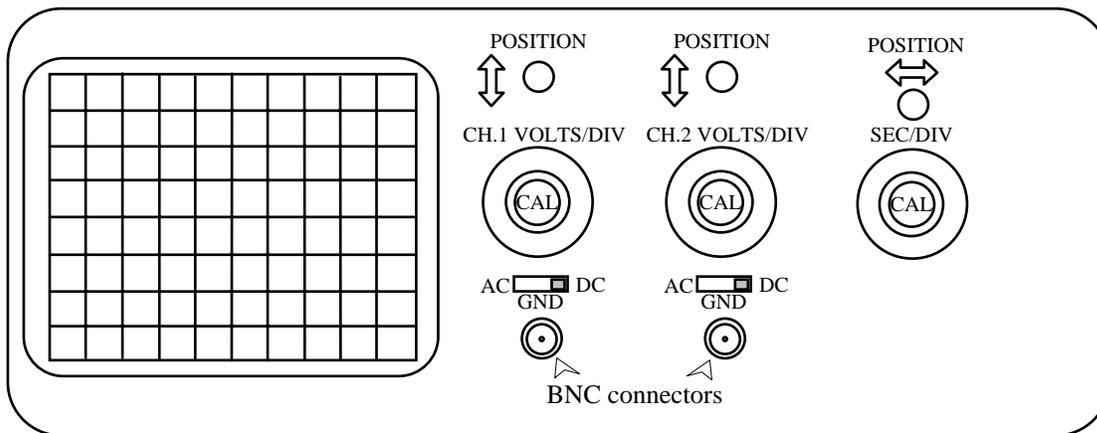
When measuring a resistance with a DMM, you must disconnect the source of the resistance (be it single resistor or some combination of resistors) from any other devices, such as power supplies. Never try to measure the resistance of a resistor while it is in a circuit.

The oscilloscope is a device which displays a graph of voltage vs. time (voltage on the vertical axis, time on the horizontal axis). If the voltage is DC, that is, constant in time, then the oscilloscope display is a horizontal line, whose vertical position indicates the voltage. Your TA will introduce you to the use of the oscilloscope. The oscilloscope screen has 1 cm divisions on both axes. There is a volts per division (volts/div) knob, which sets the vertical (volts) scale and a seconds per division (sec/div) knob which sets the horizontal (time) scale. There are knobs for setting the vertical and horizontal position of the display. Under the volts/div knob is a 3-position switch which reads (AC - ground - DC). In the ground position, the input to the oscilloscope is grounded (set to 0 volts), and the display becomes a horizontal line whose position (which can be adjusted with the vertical position knob) is the zero volts position. For instance, one could set the middle line of the screen to be 0 volts. Then positions above the middle would be positive voltages, and positions below the middle would be negative voltages. When the switch is in the DC position, the signal is input to the oscilloscope unaltered. When the switch is in the AC position, an internal capacitor is in series with the input to the oscilloscope, and the DC component of the signal is removed. There is small knob in the center of both the volts/div and time/div knobs, called the CAL or calibration knob. This should always be in the fully CW position in order for the volt/div and sec/div scale settings to be correct.

Electrical connections to the oscilloscope are made through a special kind of connector called a BNC connector. The BNC connector is used with coaxial cables (coax, for short). Coax cables have a central wire carrying the signal voltage and an outer cylindrical conductor which is usually grounded (0 volts). The outer conductor on the BNC connector on an oscilloscope is always grounded, and it is important to remember that the outer wire of a coax cable is always at zero volts when it is connected to an oscilloscope. There are special adapter connectors for attaching coax cables to banana-plug type connectors. The ground side of a double banana plug always has a little plastic tab, indicating which banana plug is at ground.

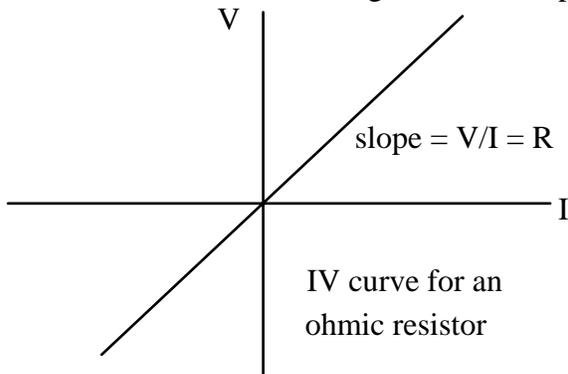


Oscilloscope Front Panel



Part I. IV characteristic of a light bulb.

We will measure voltage vs. current of a light bulb filament, and use these data to compute the resistance of the filament. The relation between voltage, current, and resistance is Ohm's Law: $V = IR$. Ohm's Law can always be used to compute the resistance $R = \frac{V}{I}$; but only in the special case of an *ohmic* resistor is voltage proportional to the current so that the resistance is independent of current or voltage. A plot of V vs. I for a ohmic resistor is a straight line which passes through the origin and whose slope is R .

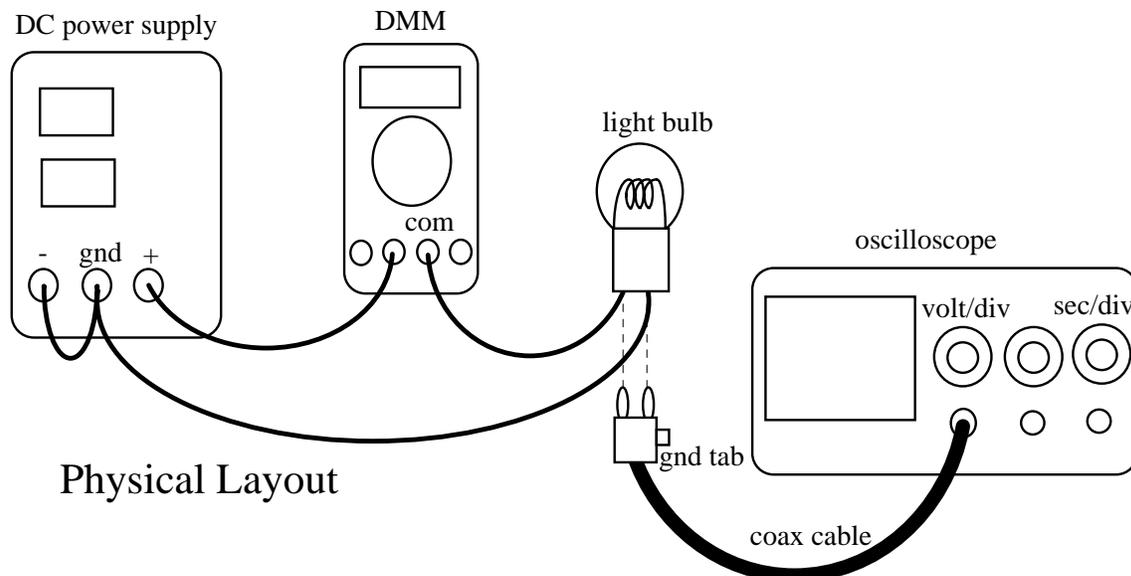
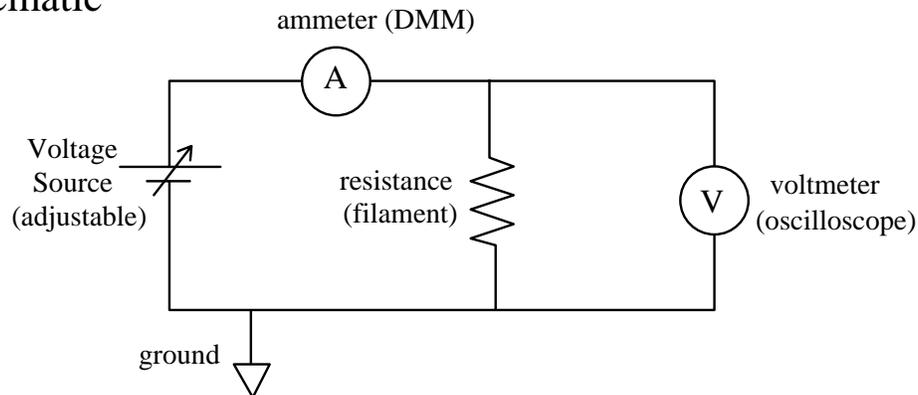


The curve of V vs. I is called an IV characteristic.

A light bulb filament is not ohmic; its V vs. I curve is not a straight line. As the filament current increases, the filament gets hot and as it gets hotter, its resistance increases, resulting in a very non-linear IV characteristic.

Begin by hooking up the power supply, the light bulb, the digital multimeter (DMM) and the oscilloscope as shown below. We will use the oscilloscope to read the voltage drop across the filament and the DMM to read the current through the filament. Note that the ammeter is in series with the filament, while the voltmeter is in parallel with the filament. An ideal ammeter has zero resistance so that it does not impede the flow of the measured current. An ideal voltmeter has infinite resistance so that it does not draw any current from the circuit it is probing. Our oscilloscope has an input resistance of $1\text{M}\Omega$, high enough not to affect most circuits.

Schematic



Double check your wiring before turning on the DC power supply. Start with the voltage knob turned all the way down (fully CCW) and the current limit knob turned up (fully CW). Then adjust the current with the voltage knob. Slowly turn up the voltage while watching the current rise until the light bulb begins to glow. Play with the circuit a while until you are comfortable with everything. Then take measurements of current and voltage for several voltages. Take at least 20 data points, covering the whole range. (You can take data quickly by setting the voltage to some easy-to-read round number on the

oscilloscope screen and then read the current from the DMM.) At the very high currents, when the light bulb is very bright, take the data as quickly as possible to preserve the light bulbs. They burn out quickly at the maximum current. For the high current data points, turn up the current, quickly note the current and voltage, and then immediately turn the current back down, until you are ready for the next point.

For each data point, adjust the scales on the DMM and the oscilloscope to give maximum precision in your reading. For instance, in using the oscilloscope, use the gnd switch to set the zero volts level at the bottom line on the screen. Then adjust the volts/div knob to make the signal cover as much of the height of the screen as possible.

For each of your measured IV points, compute resistance $R = V/I$ and power $P = IV$. [Don't do this by hand! Use Mathcad to compute all the points at once. You know.... after entering your values for V_i and I_i , then define $R_i := V_i / I_i$, etc.] Make plots of V vs. I, R vs. I, and P vs. I. Make two versions of the P vs. I plot: an ordinary plot with both scales linear and a semi-log plot with a log scale on the P axis. In Mathcad, use the X-Y PLOT, FORMAT menu to set the y-axis to a log scale. From your data, determine the resistance of the light bulb filament when it is cold and when it is very hot. What is the maximum power dissipated in the light bulb?

Also, measure the resistance of the cold light bulb filament directly with DMM. Is the DMM measurement consistent with your other data?

Part 2. Measurement of the frequency of an periodic signal

At each lab position there is a photodiode attached to a BNC connector. A photodiode produces a small voltage when exposed to light. You will also be given a device that produces a periodic light signal with some frequency f . Point the photodiode at this device. You should see a periodic signal on the oscilloscope screen. Play with the volts/div knob and the sec/div knob to see how these knobs change the display. Also, observe what happens as you cover the photodiode with your hand. Measure the period T of the signal (period = time for one complete cycle of a periodic signal). The best way to do this is to adjust the sec/div knob to get several complete cycles on the screen. Measure the time for the several cycles and divide by the number of cycles to get the period. From the period, compute the frequency f ($f=1/T$).

Line voltage, which is the voltage coming out of a wall socket, is an AC voltage with a frequency of 60 Hz, and an amplitude of 120V rms. How does the frequency of the device compare 60Hz? Can you explain why?

Part 3: Construction of a circuit.

In week 2 of this lab, you will be given a circuit to build and an experimental goal.

Prelab Questions:

1. The resistance of all metals increases with temperature. At low temperatures (room temperature and below), the resistance is nearly independent of temperature. But at higher temperatures, the resistance R is roughly proportional to the temperature, $R \propto T$, where T is the temperature *in Kelvin*. A light bulb filament is made of tungsten metal. Knowing these things, make a qualitative sketch of the resistance of a light bulb filament as a function of current. On the same graph, plot R vs. I for an *ohmic* resistor. (Qualitative sketch only; no numbers!)
2. Describe a coaxial cable with a picture. Which conductor on a coaxial cable is usually the ground (0 volts)?
3. How would you hook up a DC power supply to produce a negative voltage output? Draw a picture to make your answer clear.
4. Make a simple sketch showing how you would hook wires between an ohmmeter and two resistors R_1 and R_2 in order to measure the resistance of the two resistors in series.
5. What are the formulas for the total resistance of two resistors R_1 and R_2 in series and in parallel? (Look up the answer in your physics text, if you do not know.) Consider two resistors with resistances $R_1 = 100\Omega$ and $R_2 = 200\Omega$. Compute the resistance of these two resistors in series and in parallel. Show your work!
6. Suppose you connected two resistors in parallel to a DC power supply so that there is a voltage across the two resistors R_1 and R_2 . Now suppose you wish to measure the current coming out of the power supply, using the DMM. Make a sketch showing how you would connect the power supply, the two resistors, and the DMM to make the desired measurement.
7. Suppose that you have the same circuit as in problem 6, except that now you wish to use the DMM to measure the voltage across the two resistors, rather than the current. Make a sketch showing how you would connect the DMM to the circuit to make the desired measurement.
8. True or False: It is perfectly safe to stick your tongue into a light bulb socket that is plugged into the wall.
9. True or False: the resistance of an ohmic resistor depends on the current in the resistor during the measurement.
10. True or False: the voltage in the wall sockets in your home is 240 Volts, DC.