# Meters and Ohm's Law

**Purpose:** Familiarize yourself with electrical measurements, explore the nature of Ohm's Law, Resistivity, and practice interpreting data with graphs.

**Equipment:** Power supply producing an adjustable voltage from 0-30 V**,** two multimeters to measure voltage and current, some light bulbs, a resistor, and wires for making connections.

## Part I: Making a circuit (15 points)

Create a circuit with a battery, light bulb, and two wires. If you build your circuit correctly, the bulb will light up, showing you that current is flowing through the bulb, converting electrical energy to heat and light. If you disconnect any of the wires, current flow will stop. A working circuit requires that current goes in a complete loop (hence the name "circuit"). Try reversing the wires to the battery so that the wire that was going to the + end now goes to the – end, and vice versa. Does the light still light up?

Light the bulb just using the battery and one wire. When you are successful, show your TA to get your 5 points.

## Part II: Using multimeters to measure the voltage and current: Ohm's law

In this section, you will be given a resistor of unknown value. Using the adjustable power supply, you will vary the voltage between one side of the resistor and the other ("across the resistor"), and thus vary the current.

Although you may use the voltage and current meters on the power supply (left and right, respectively) as a guide, part of this lab is intended to provide an opportunity to learn how to use a voltmeter and an ammeter properly. So you will need to set up one of your hand-held multimeters as a voltmeter to measure the voltage difference **across** the resistor and the other as an ammeter to measure current **through** it.

## A. Measuring the voltage (10 points)

|  | Wire Color | Port |
|---|---|---|
| Multimeter #1 (Voltmeter) | Orange | VΩHz |
|  | Blue | COM |
| Multimeter #2 (Ammeter) | Yellow | 10A |
|  | Green | COM |
| Power Supply | Red | (+) |
|  | Black | (-) |

Use the different colored alligator-banana wires as indicated in the table above.

*Multimeter #1* will be used as a voltmeter.  To do this properly, the big dial on the multimeter must be set to the correct position. To measure volts, turn the dial pointer to the number 1000 in the area labeled "V" that is underscored with a solid line and a dashed line.  This means the meter will measure steady (DC) voltages up to a value of 1000 V.  The orange wire should be plugged into the "VΩHz" port, and the blue wire should be plugged into the "COM" port.

Before plugging in the Power Supply, turn the voltage knob on the power supply fully counterclockwise (OFF).  Plug a red and black alligator-banana wire into the power supply as indicated by the table above, and build the circuit below.  Connect your voltmeter to Points A & D.
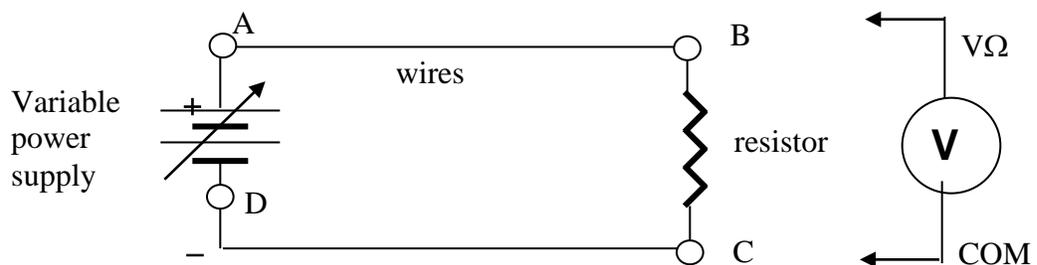


Fig. 2  Power supply and resistor.  The arrow through the power supply is supposed to indicate that the output voltage can be varied.  The movable voltmeter is shown at right.

After you made all of the connections, turn the voltage knob clockwise until the voltage on the meter on the power supply reads about 3.0 V.  Ask your TA if you have trouble.  You may, for example, need to turn up the current-limit knob on the power supply.

What does your hand-held voltmeter read?  Maybe zero, because the meter is set to 1000 V.  Turn the knob on the voltmeter counter-clockwise to 200, then to 20, and you'll see that the meter will give you a measurement with increasing numbers of digits.  Turn the knob to 2, and you'll see the meter displays "OL" or "1…." indicating it is overloaded  – the meter is set too low.  Always turn the meter to the setting that gives you the most numbers (for greatest accuracy).

Record the voltage reading from the voltmeter on the power supply and begin collecting voltage readings with your voltmeter as indicted on the Data Sheet. Note that the "VΩHz" jack of the voltmeter is the + end, and the "COM" jack is the – end. The voltmeter will read a positive value if the electric potential is higher at the "VΩ" jack than at the "COM" jack.

Turn the voltage knob all the way off, and turn off the power supply with the switch.

## B. Measuring the current (10 points)

To measure the current through a wire or resistor, the circuit must be "opened" to put the multimeter **between** two points, substituting it for a wire, as in Fig. 3. Contrast this with a voltmeter that you put "**across**" two points without removing a wire from the circuit.
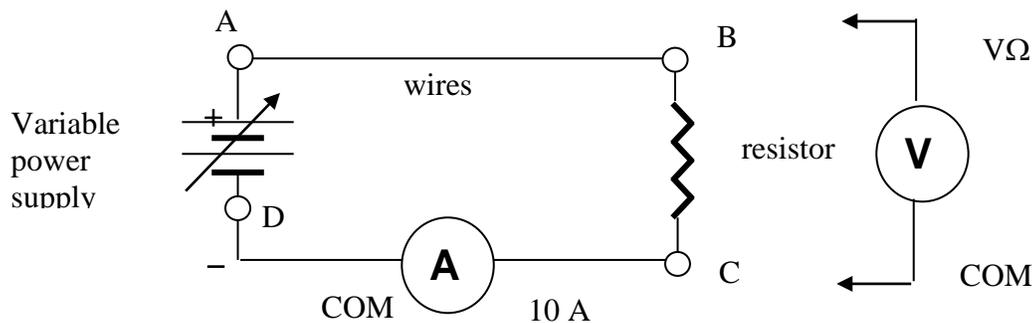


Fig. 3          Inserting an ammeter into the circuit to measure current.

To use *Multimeter #2* as an ammeter, turn the big dial of the multmeter to the lower left so that it points to the number 10 in the area labeled with a solid and dashed line in front of the "A". The yellow wire should be in the "10A" port and the green wire should be in the "COM" port.

Note that by using the "10 A" port of the multimeter, the multimeter is being used as an unfused ammeter. Since this may be the first time you are using an ammeter, this will allow you to make mistakes without blowing the internal fuse of the multimeter. However, for future labs, currents will need to be read with better accuracy, and the "200 mA" port will need to be used. In this case if a mistake is made in connecting the ammeter, you may blow the fuse. If an ammeter is connected across a resistor, the reading on the ammeter will definitely be ambiguous, and the fuse may blow.

Now the multimeter is set up as an "ammeter", and will measure current in amperes.

Put an ammeter between points "C" and D" in your circuit.

Turn on the power supply and turn the voltage to about 2.0 V

Record the current reading from the power supply, and from your ammeter on the data sheet, and answer the questions.

Turn down the knob on the power supply so that it reads 0 V.

## C. Ohm's Law with a Resistor (15 points)

**Collect and record measurements** of the voltage across the resistor and the current passing through the resistor by turning the knob on the power supply to obtain different output voltages. Collect at least 8 pairs of data for voltages between 0V and 4V. The voltages 0 V and 4 V should be included in your data.

Use **MS Excel** to create a plot of Voltage (y-axis) versus Current (x-axis). After your points have been plotted, **fit your data with a linear fit** and determine the **slope** of the line. Recall your basic line equation: $y = mx + b$, where $m$ is the slope of the line, and $b$ is the y-intercept.

From the information provided by your graph, determine the value of the **resistance** of the resistor in Ohms ($\Omega$ ).

## D. Ohm's Law with a Light Bulb (15 points)

We will now investigate the resistance of a light bulb. A light bulb consists of a length of tungsten wire inside a glass bulb usually filled with argon or krypton gas. The resistor in this circuit consists of the thin filament of tungsten wire.

**It is particularly important that you keep the voltage output of the power supply to 4 V or less. Otherwise, you'll burn out the bulb, and you'll be delayed in finishing the lab.**

Replace the resistor in your circuit of Fig. 3 with a flashlight bulb in a socket.

Measure the voltage across the light bulb and the current going through it as you vary the voltage between 0 V and 4 V using the voltage knob on the power supply. As the voltage is increased, carefully watch to make sure the current does not exceed 400mA. If the current approaches 400ma, stop collecting data and inform your TA. Begin collecting I and V data pairs including 0V and 4V as follows. Between 0V and 1.5V, change the voltage in increments of approximately 0.25V. After 1.5V, the voltage can be changed in increments of approximately 0.50V. **After you make your measurement at 4 V, turn down the voltage immediately.**

Plot your data on a scatter plot of V vs. I. First fit the data with a line and display the equation and the r-squared value on the plot. Second, fit the data using a polynomial of order 2 (quadratic), and display the equation and the r-squared value of this fit on the plot.

Although the tungsten within the bulb is a perfectly normal ohmic resistor, you will probably find that the data points do not lie on a straight line. Therefore, the resistance of the light bulb does not strictly follow Ohm's law R = V/I. Explain. (Hint: What is the resistivity of Tungsten?)

# Part III:  Resistivity (20 points)

Your group will be provided a set of spooled wires. The wire is made of Nichrome, and the lengths (L) vary as demonstrated below. The diameter of the wire is $4.1 \times 10^{-4}$ m. Although using the provided multimeter as an ohmmeter is not the ideal piece of equipment to determine the actual resistivity of a material, the ohmmeter can be used to demonstrate that the resistance is related to a material's resistivity, length, and cross sectional area.
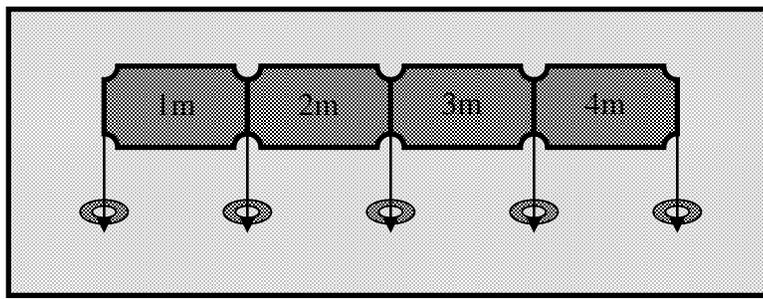


Use the multimeter that you were using as a voltmeter and convert it into an ohmmeter. Remove the orange and blue alligator-banana wires and replace them with red and black banana-banana leads. Select an appropriate setting within the section labeled "Ω" with the large dial. Now you can plug the other end of the leads into the jacks of spooled wire and collect resistance data. Collect data for 5, 6, 7, 9, and 10 meter lengths of wires. After you have collected the resistances of the various lengths of wire, create a plot of R (y axis) versus L (x axis). In addition to the points that you have collected, include the point 0 Ohms for 0 meters, (i.e. 0, 0) on your scatter plot. When you fit your data, do not force the y intercept to be zero. From your plot estimate the resistivity of Nichrome and compare it to the standard excepted value.

**Name:** _____     **Banner ID:** _____

**Lab Group ID:** _____     **Number of Lab Partners:** _____

# Data Sheet
# Meters and Ohm's Law Lab

**Part I. Light bulb circuit.**  (15 points total)

TA Confirmation that the group could light the light bulb (5 points) _____

Does the direction of the current through the light bulb determine whether it lights up or not? (5 points) _____

Draw a Circuit Diagram (Schematic) of your bulb circuit.   (5 points)

**Part II. Ohm's law**

**A. Voltmeter** (10 points)

Voltage reading from the voltmeter on the power supply: _____

Connect the red lead of the voltmeter to the first point indicated and the black lead to the second point.

1. Measure and record the voltage difference between A and D: _____

2. Measure and record the voltage difference between A and B: _____

3. Measure and record the voltage difference between B and C: _____

4. Measure and record the voltage difference between D and A: _____

Comment on the difference between the voltage readings of 1 and 4 above.

**B. Ammeter** (10 points)

Current reading from Power Supply _____     Current Reading from Ammeter _____

Are both current readings reasonably close? _____

What direction is the current flowing; from C to D, or D to C ?     _____

**C. Ohm's Law with a Resistor** (15 points)

What is the value you obtained for the resistance of the unknown resistor from your plot?   (A) _____

What was the actual value of the resistance using an Ohmmeter?  (B) _____

Percent Difference $= \dfrac{|A-B|}{(A+B)/2} \; x100\%$  = _____

**C. Ohm's Law with a Light Bulb** (15 points)

Was the plot of V vs I for the light bulb linear?  Would you expect it to be linear?  Explain:

**Part III. Resistivity** (20 points)

Does your plot appear to be linear?


Mathematically explain why your data should be linear.




What does the slope of the R vs L plot represent?




What is the value you obtained for the resistivity of Nichrome from your plot? (A) _____

What is the accepted value of resistivity of Nichrome? (B) _____

Percent Error $= \dfrac{|A - B|}{B} \, x100\%$ = _____

Remember that this was a very crude attempt to determine the resistivity of nichrome. Please make a list of three items that may be contributing to error and explain why each item may be contributing to an inaccurate value for the resistivity. (one hint: your lead wires are made of copper)

**Follow-up Exercise**  (15 Points)

The figure shows current through a resistor (on the vertical axis) plotted vs. the voltage across the resistor (on the horizontal axis).  Note the difference between this plot and how you plotted it in lab.

(a).   What is the resistance of this resistor?

(b).   Suppose the resistance of this resistor is doubled, perhaps by doubling its length.  Plot on this same graph the new line of I vs ΔV you would expect.