

Breadboards, 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, a light bulb in a socket, a resistor, a breadboard and wires for making connections.

Part I: Breadboard Layout (15 points)

Your TA will provide a ziplock bag with three jumper wires and three resistors. The bag, three jumper wires, and three resistors must be returned to your TA before you leave.

A breadboard is used for prototyping circuits without the need for solder. It has many holes that electrical components can be plugged into and connect with other components. The holes are configured in rows and/or columns, and certain holes are "wired" to each other by conductors under the holes. Using a multimeter as a continuity meter and two jumper wires, explore how the breadboard is wired. Plug a blue alligator-banana wire into the "COM" port of one of the multimeters. Plug an orange alligator-banana wire into the $V\Omega Hz \rightarrow |$ port and turn the large dial to the diode symbol $\rightarrow |$. The multimeter will emit a tone when there is "continuity" indicating a circuit is complete. Touch the two alligator clips together and make sure the multimeter emits a tone. Now, connect a jumper wire to each of the alligator clips, and probe the breadboard to determine which holes are connected, and which are not connected. Draw a sketch of the breadboard indicating how the holes are connected.

Note that the multimeters have an auto-off function. If the multimeter remains idle too long, it will automatically shut itself off. In order to reactivate the multimeter, the on/off button will need to be manually pressed so that it is in the off position, and then the multimeter can be turned back on.

After you have completed your sketch, remove the jumper wires from the alligator clips and return them to the ziplock bag. You will not need the jumper wires for the remainder of the lab.

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

In this section, you will use one of the resistors in the bag to create a circuit and practice taking readings with a voltmeter and ammeter. Using the adjustable power supply, you will vary the voltage between one end 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. Plus, the ammeter on the power supply does not have enough precision to read currents less than 400 mA. 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	mA hFE
	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 big dial to point 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.

Mount one of the resistors from the ziplock bag on the breadboard. Insert each end of the resistor into an appropriate hole of the breadboard such that the resistor will not be “shorted” by the conductors underneath the holes.

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.

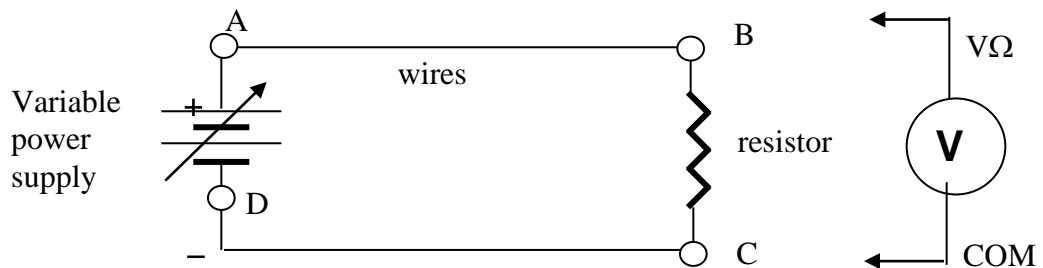


Fig. 2 Power supply and resistor. The arrow through the power supply is supposed to indicate that the output voltage can be varied. The movable voltmeter is shown at right.

After you have 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 will 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 indicated on the Data Sheet. Note that the "VΩHz→" port of the voltmeter is the (+) end, and the "COM" port is the (-) end. The voltmeter will read a positive value if the electric potential is higher at the "VΩHz→" port than at the "COM" port.

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 an ammeter **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.

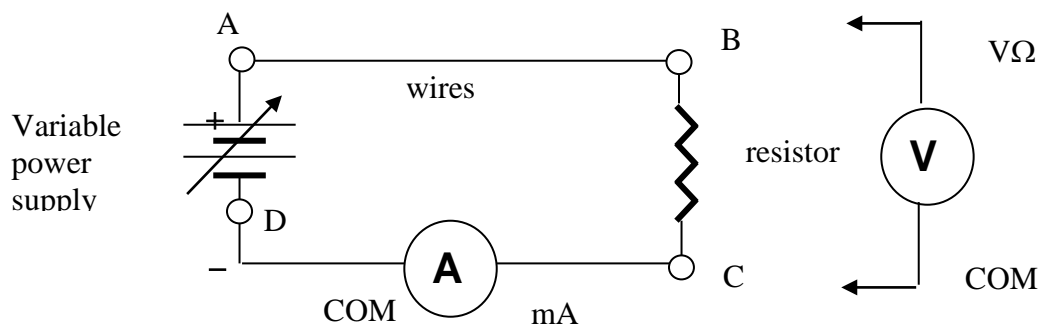


Fig. 3 Inserting an ammeter into the circuit to measure current.

To use **Multimeter #2** as an ammeter, turn the big dial of the multimeter to the lower left so that it points to the number 200m in the area labeled with a solid and dashed line in front of the "A". The yellow wire should be in the "mAHzFE" port and the green wire should be in the "COM" port.

When the "mAHzFE" port of the multimeter is used, the multimeter becomes a fused ammeter, and the display will read in milliamps (mA). If a current greater than 400 mA flows through the

multimeter while using this port, the fuse will blow and the fuse will need to be replaced. In general if an ammeter is connected across a resistor (in parallel with the resistor), the reading on the ammeter will be ambiguous, and the fuse may blow. You will be provided the luxury of blowing one fuse without a point deduction. However, if your group blows more than one fuse during this lab, point deductions will be taken as indicated on the Data Sheet. Also, remember that you do not need the jumper wires from the ziplock bag, and you may not use them.

Connect the 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 scatter plot of Voltage (y-axis) versus Current (x-axis). After your points have been plotted, **fit your data with an appropriate line** 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 (Ω).

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 a thin filament of tungsten wire.

It is very 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

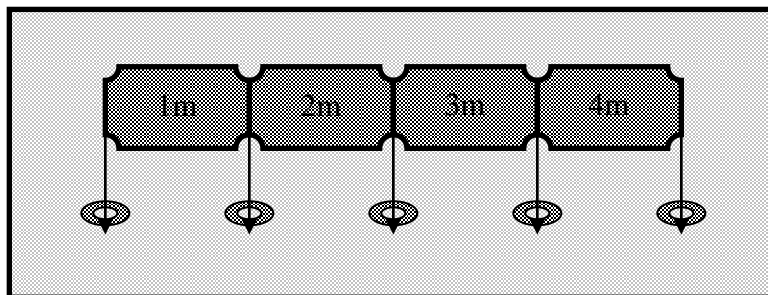
400ma, stop collecting data and inform your TA. Begin collecting I and V data pairs including 0V and 4V as follows. Between 0V and 1.5V, change the voltage in increments of approximately 0.25V. After 1.5V, the voltage can be changed in increments of approximately 0.50V. **After you make your measurement 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, 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 like the resistor. 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 4.1×10^{-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 that can be connected to the spools of wire. 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 expected value.

Name: _____

Banner ID: _____

Lab Group ID: _____

Number of Lab Partners: _____

Data Sheet

Breadboards, Meters and Ohm's Law Lab

Hints:

1. Voltmeters and Ammeters must be used in such a way as not to alter the circuit. When a meter is inserted in a circuit, the meter should not allow a significant amount of current to be diverted from the component(s) to which the meter was connected. Remember that current is lazy, and current will take the path of least resistance.
2. A voltmeter will typically have a resistance on the order of a $M\Omega$. Consider a $100\ \Omega$ resistor in parallel with a $1,000,000\ \Omega$ resistor. What percentage of the current will go through the $1,000,000\ \Omega$ resistor?
3. To read the voltage across a resistor with a voltmeter, connect the voltmeter in parallel with the resistor. This is true as long as the resistance of the resistor is much less than the resistance of the voltmeter.
4. An ammeter will typically have a resistance near zero ohms. What happens if you put a jumper wire across a resistor while it is in a circuit? Does the current want to flow through the resistor or the jumper wire?
5. To read the current through a resistor with an ammeter, connect the ammeter in series with the resistor.
6. Connecting an ammeter in parallel with a resistor will result in an ambiguous current reading, and the multimeter fuse may blow.

Part I. Breadboard Layout. (15 points total)

Provide a brief sketch using line segments to indicate how the breadboard is wired.

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 _____ (A) Current Reading from Ammeter _____ (mA)

Are both current readings reasonably close? _____

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

Your TA will circle the point deduction each time your group blows a fuse during this experiment. The total point deduction will be the sum of all the point deductions circled. The maximum loss of points could total 40 points.					
Blown Fuse #	1	2	3	4	5
Point Deduction	0 pts	5 pts	10 pts	10 pts	15 pts

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

Attach your plot to the Data Sheet.

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) _____

$$\text{Percent Difference} = \frac{|A - B|}{(A + B)/2} \times 100\% = \underline{\hspace{2cm}}$$

If your TA does not initial below indicating that you returned the ziplock bag containing the jumper wires and the white resistor, your group will receive a 10 point grade deduction. TA Initials: _____

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

Attach your plot to the Data Sheet.

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)

Attach your plot to the Data Sheet.

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 = $\frac{|A - B|}{B} \times 100\% =$ _____

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)