Ohm's Law and Resistivity

Objectives:

In this lab, you will:

- Test Ohm's law for brass with low applied voltages
- Measure the resistivity of various conductors
- Test if resistivity is independent of the cross section area and length of brass

WARNING: The wires bend easily, treat them delicately!

1: Warm Up Problem

You are a quality control engineer that oversees the procurement of supplies for large projects. A large spool of 12-gauge copper wire of total length 500 meters comes in. You measure a resistance of 3.37 ohms. Do you accept the shipment?

Checkpoint 1: Ask an instructor to check your work for credit. You may proceed while you wait to be checked off

2: Ohm's Law

(i) Theory

"**Ohm's law**" is that the voltage *(V)* difference between two points of a conductor is proportional to the current *(I)* through the conductor; the proportionality is the resistance *(R)* and is independent of I and V.

$$V=IR$$

(ii) Installing wires in the Resistivity Apparatus

(a) On the Resistivity apparatus, move the Reference Probe and the Slider Probe to the Park position. The probes should be as far left and right respectively as possible so that the probe lifts up to allow installation of the sample wire. They will click into position.

(b) Turn the two black handles counterclockwise to open the clamps to allow the sample wire to slide into position.

(c) To install a wire in the apparatus, slide from left or right using the white line-up hash marks. Figure 1 shows the right hand side as the wire slides in. Note that on the right hand side, the wire is on the far side of the silver clamp (with black handle), but on the left hand side the wire will be on the near side of the clamp as shown in Figure 2. This prevents the wire from bowing as you tighten the clamps.

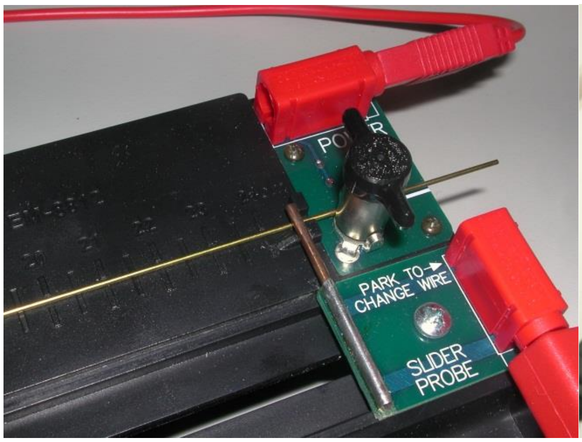

Figure 1: Right Hand Clamp

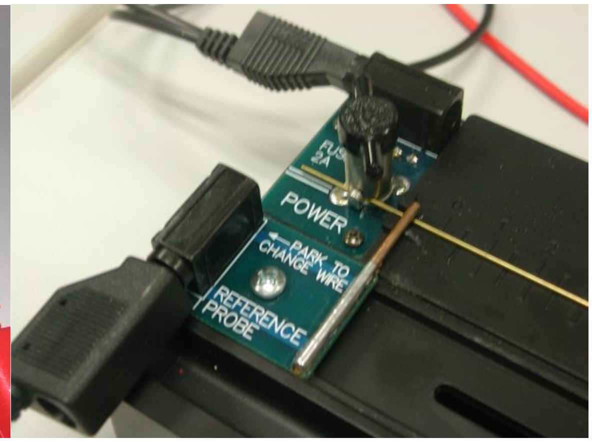

Figure 2: Left Hand Clamp

(d) Tighten the clamps by turning the black handles clockwise.

(e) To remove the wire, first park the probes, then loosen the clamps, and slide the wire out.

(iii) Experimental Procedure

(a) Using a voltage sensor, connect Channel B of the power supply to the Reference probe and Slider probe of the PASCO Resistance Apparatus. Then connect output 1 of the power supply to the power supply terminals of the PASCO resistance apparatus (see Figure 3). This is known as a "four terminal" connection. (The key reason four-terminal measurements are useful is that the reference/slider probes do not themselves carry the large current coming out of output 1. Thus they only pickup the small voltage across the conductor and not the larger voltage drop caused by the resistance of all the connections used to bring the output current to the conductor. probe used to drive the current through the conductor.)

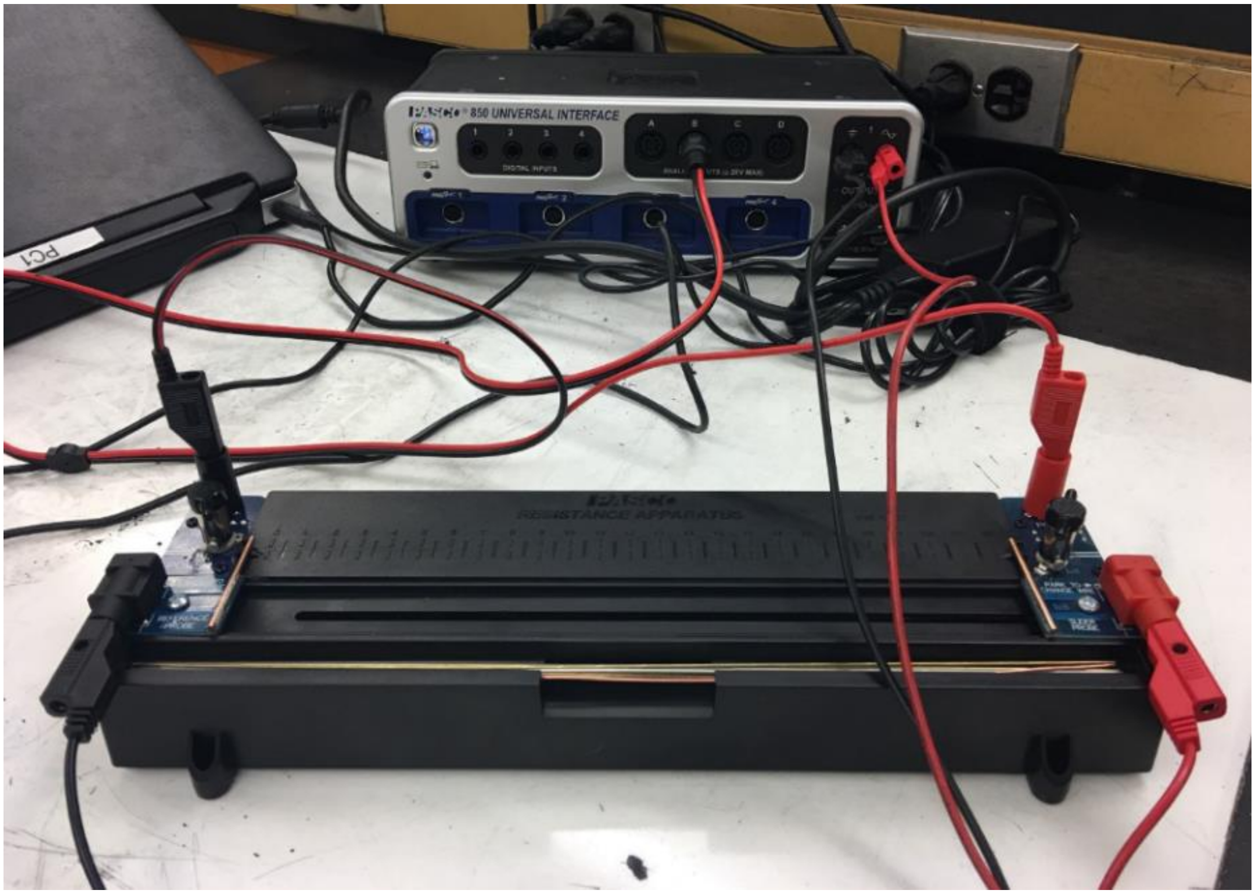

Figure 3: Measurement Setup

(b) Install the thickest brass wire into apparatus. (Brass is yellow in color). Follow the procedure as described in section (ii).

(c) Position the reference probe at the 0 cm mark and the slider probe at the 24 cm mark. This is the maximum length of the wire.

(d) Download and open the capstone file “ Lab 8” on blackboard learn.

(e) Click on the Signal Generator menu option on the left-hand side of your Capstone workbook.

(f) Under 850 Output 1, set the DC voltage to 0.1 V and Voltage limit to 0.8 V.

(g) Click On.

(h) Click the Signal Generator button again to close the Signal Generator menu.

(i) Click Record and record the voltage and current measurements from the ‘Data collection’ tab into ‘V vs I’ tab.

(j) Click Stop and turn off the output voltage in the Signal Generator menu.

(k) Repeat steps (e) through (j) to take measurements for output voltages from 0.2 V to 0.8 V in increments of 0.1 V.

(l) From the graph of V(millivolts) versus I(milliamperes), read off the resistance of the brass wire (24 cm length) in ohms.

(m) **Compare the Output voltage to the Voltage across the wire. If there is a difference, explain why.**

(n) **Does Ohm's law hold for Brass wire at the applied Current/Voltages? Justify your answer empirically.**

(o) It is actually very important to use the voltage between the reference and slider probe instead of the output voltage. Roughly estimate how far you would be off if you had used the output voltage.

(p) It is also important to understand that higher currents may heat the wire which may change the wire's resistance. This is why we limited the applied voltage to 0.8V.

Checkpoint 2: Ask an instructor to check your work for credit. You may proceed while you wait to be checked off

3: Measuring resistivity of brass

(i) Theory

In this checkpoint, you will make several resistance measurements for various lengths of a wire of known cross-sectional area. You will then plot a graph of R versus length *(l)*.

The resistance of a wire is directly proportional to its length (l) and inversely proportional to its cross-sectional area *(A)*. This constant of proportionality is called the resistivity (ρ) of the material:

$$R = \rho l/A$$

Thus, the slope of the *R* versus *l* graph is equal to ρ/A.

(ii) Experimental procedure

(a) With the thickest brass wire installed in the apparatus, position the reference probe at the 0 cm mark and the slider probe at the 24 cm mark. This is the first value of l.

(b) Click on the Signal Generator menu option on the left-hand side of your Capstone workbook.

(c) Under 850 Output 1, fix the DC voltage to 0.5 V. This ensures that the current is always less than 1 Ampere.

(d) Click On.

(e) Click the Signal Generator button again to close the Signal Generator menu.

(f) Hit the Record button on the bottom of the workbook.
(g) On the PASCO Capstone workbook, you will read off the resistance values for different lengths of wire from the 'Data collection' tab and record the same values in the 'R vs L' tab. Make sure to use the correct units of R (ohms) and L (meters).
(h) Decrease the length of the wire in steps of 2 cm starting from 24 cm until 2 cm. You must hit the Record/Stop button each time you change the length to restart the internal averaging of capstone.
(i) For each value of length, read off and record the resistance value as described in step (g).
(j) From the graph of R versus L, calculate ρ.

Calculate the resistivity of the 0.0013 m diameter brass wire:

Checkpoint 3: Ask an instructor to check your work for credit. You may proceed while you wait to be checked off

4: Measuring the resistivity for brass with different cross-sectional areas

In this checkpoint, you will measure the resistivity of different sized brass wires and compare your calculated value to the accepted value for brass.

Repeat all the steps of the procedure in section 3 for the other three diameters of the brass wire and fill in the table below:

Diameter (m)	c/s area (m^2)	Resistivity (Ω. m)
0.0013		
0.001		
0.00081		
0.00051		

How do the values of ρ for the four brass wires compare to each other?

The accepted value of resistivity for brass falls between 6e-8 to 9e-8 Ω. m. How does the average value of ρ compare to the accepted value?

What can you conclude from the above measurements?

Checkpoint 4: Ask an instructor to check your work for credit. You may proceed while you wait to be checked off

5: Measuring the resistivity of unknown conductors

In this checkpoint, you will measure the resistivity of different unknown materials, compare their calculated values to the accepted values and determine what they are made of.

Calculate the resistivity of the four other wires given to you and record them in the table below.

Note: All the above wires have a diameter of 0.10 cm. Keep the output DC voltage fixed at $0.5V$.

Wires	**Measured Resistivity (Ω. m)**
1	
2	
3	
4	

Given below is a table of resistivity of several conductors. From your measurements, determine what the wires are made up of.

Material	**Published Resistivity (Ω. m)**
Copper	1.68e-8
Aluminum	2.65e-8
Tungsten	5.6e-8
Iron	9.71e-8
Lead	22e-8
Stainless steel	6.9e-7
Nichrome	1.1e-6

Checkpoint 5: Ask an instructor to check your work for credit. You may proceed while you wait to be checked off

6: Final Problem

You have a copper wire and a wire of unknown material but of equal length. The copper wire has 21% higher resistance, but half the cross-sectional area. What is the unknown wire made of?

Checkpoint 6: Ask an instructor to check your work for credit.