General Physics II Lab (PHYS-2021)
Experiment ELEC-4:
Resistivity

1 Equipment

Included:

1	Resistance Apparatus	EM-8812
1	Voltage Sensor	UI-5100
1	Patch cords (set of 5)	SE-9750
1	850 Universal Interface	UI-5000
1	PASCO Capstone	
1	Micrometer	SE-7337

2 Introduction

The resistivity of different metals is determined by finding the resistance of wires of a known diameter as a function of their length. It is also shown that the resistance of a wire of fixed length is inversely proportional to its cross-sectional area. This experiment requires a formal Lab Report as described in the “Lab Report Format” document.

3 Theory

If a current (I) is flowing through a wire, the voltage drop (V) across a certain length of wire with resistance *R* is given by Ohm's Law:

$$V = IR$$

or solving for R gives:

$$R = V/I \qquad (1)$$

In this experiment, you will measure V and I to determine R for various lengths of wire. You will then make a graph of R versus length (L).

The resistance of a wire depends on the length of the wire, the cross-sectional area (A), and the resistivity (ρ) of the material:

$$R = \rho\, L/A \qquad (2)$$

A plot of R vs. L will result in a straight line that has a slope equal to ρ/A.

Thus the resistivity is given by

$$\rho = (\text{slope})A = (\text{slope})\pi(d/2)^2 \qquad (3)$$

where d is the diameter of the wire.

4 Setup

Figure 1: Setup

1. Make the connections as shown in Figure 1. In PASCO Capstone Hardware Setup, click on Signal Generator #1 and select the Output Voltage Current Sensor. Set the sample rate of all the sensors to 100 Hz.
2. Open the Data Summary and click on the properties gear icon for the Voltage Sensor (UI-5100). Set the gain to 1000.
3. Select four brass wires of different diameter and measure* their diameters. Also select one each of the other wires (Nichrome, Steel, Aluminum, and Copper) and measure the diameters of each. Brass is yellow in color. The Aluminum, Steel, and Nichrome are all grey in color. The Aluminum is a lighter grey, and Nichrome is a uniform dark grey. The Steel is also dark grey, but not as uniform in color. Best way to tell is using a magnet. Of the five metals, only steel will be attracted to a magnet. Change the values in the Brass Wire table under the Data tab to match your values for Brass. Change the values in the Different Metals table under the Resistivity tab to match your values for the five different metals.

   *If you do not have a micrometer (or good digital calipers), use these values of diameter:

   0.127 cm

   0.101 cm (use this for the non-brass wires as well)

   0.082 cm

   0.051 cm

4. 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 the probe lifts up to allow installation of the sample wire. They will click into position.
5. Turn the two black handles counterclockwise to open the clamps to allow the sample wire to slide into position.
6. Install the copper wire in the apparatus. Slide from left or right using the white line-up hash marks. Figure 2 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 3. This prevents the wire from bowing as you tighten the clamps.
7. Tighten the clamps by turning the black handles clockwise.
8. Position the reference probe at the 0 cm mark and the slider probe at the 5 cm mark.

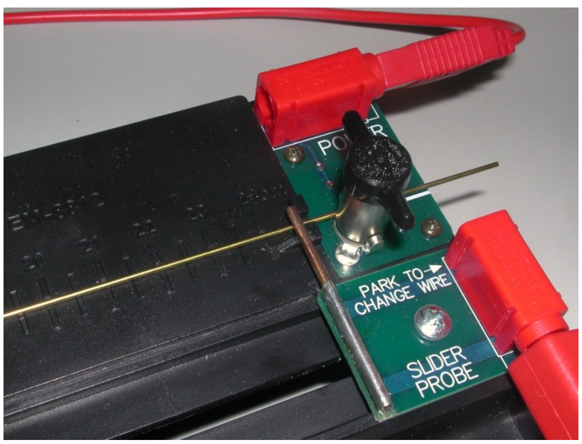


Figure 2: Right Hand Clamp

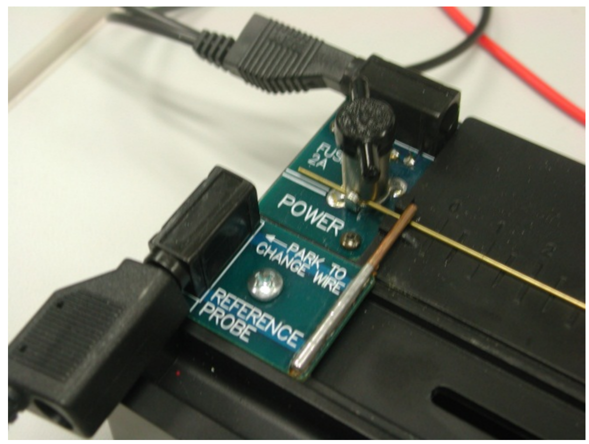


Figure 3: Left Hand Clamp

9. In PASCO Capstone, create a table with a user-entered data set called "Wire Length" with units of cm. Then, in the second column, create a user-entered data set called "Resistance" with units of mΩ.

Table: Different Lengths

	<No Data Selected>	<No Data Selected>
	Wire Length (cm)	Resistance (mΩ)
1		
2		
3		
4		
5		
6		
7		

Table II: Brass Wires

	Resistance. (mΩ)	diameter (mm)
1		
2		
3		
4		
5		
6		
7		
8		

10. Create another table with a user-entered data set called "Resistance." (Note the period) with units of mΩ. Then, in the second column, create a user-entered data set called "diameter" with units of mm.

11. Create a third table with five columns:

Table III: Different Metals

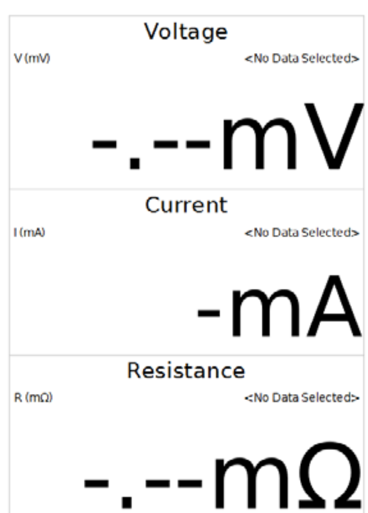
Metal	Wire Diameter (mm)	Slope (mΩ/cm)	ρ (μΩ cm)	Resistivity (μΩ cm)
Copper				
Aluminum				
Brass				
Steel				
Nichrome				

The first column has a user-entered data set called "Metal". The second column has a user-entered set called "Wire Diameter" with units of mm. The third column has a user-entered set called "Slope" with units of mΩ/cm. The fourth column has the calculation ρ as defined in the next step. The fifth column has a user-entered set called "Resistivity" with units of mΩ-cm. Enter the following manufacturer's values for the Resistivity: 1.8 ± 0.1; 4.9 ± 0.1; 7.0 ± 0.5; 79 ± 1; 105 ± 5.

12. Open the calculator and create the following calculations:

V = 1000*avg([Voltage, Ch A])	Units of mV
I = 1000*avg([Output Current, Ch O1])	Units of mA
R = 1000*[V]/[I]	Units of mΩ
Area = π*([diameter]/2)^2	Units of mm^2
ρ = (π*([Wire Diameter]/2)^2)*[R/L]*10	Units of μΩ-cm

13. Create three digits displays and choose the calculations: V(mV), I(mA), and R(mΩ).



14. Create a graph of Resistance vs. Length.

5 Procedure

1. Click open the Signal Generator (left side of screen). 850 Output 1 should be set for a DC voltage of 2.0 V. Click the On button to turn the Signal Generator on.
2. Move the Slider Probe on the Resistance Apparatus so the contact is at 5.0 cm.
3. *Read the rest of this page*, then click open the Data tab. The program will ask if you wish to turn off the Signal Generator, click Leave On.
4. Click RECORD at the bottom left of the screen. Wait a few seconds until the numbers stop changing and then click STOP.
5. The resistance in the lower box is calculated from R = V/I where the V and I values are averages that show in the upper two boxes. In the first row of the Table I, enter the Resistance and then the Wire Length (5.0 cm).
6. Repeat steps 5 & 6 for Slider Probe positions of 10.0 cm, 15.0 cm, 20.0 cm, & 24.0 cm.

   If you use the same positions for each run, you will only need to enter them for the Copper runs.
7. The Data summary should show five runs. Double click on the last run (probably Run #5) and re-label it Copper. Delete all the other runs using the white triangle by the Delete Last Run icon at the bottom of the page.
8. Replace the Copper wire with the Aluminum wire. The Aluminum wire is lighter in color and weighs less. Repeat steps 5 thru 8 except label the last run Aluminum. Delete all the other runs except for Copper.
9. Repeat for the Steel and Nichrome wires except do step 2 again and change the Gain to 10x.
10. Repeat for the 1.0 mm (second largest) brass wire except do step 2 and change the Gain to 100x. When you do the 24 cm run, enter the Table I as before, but also enter it in the Table II in the 1 mm row.
11. Repeat for the other three brass wires, except only do the 24 cm position and enter the data in the Table II. Label the runs Brass 127, Brass 82, Brass 51.

6 Analysis

1. The graph shows the resistances you measured versus the length of wire you used. From the graph toolbar, click the Run Select black triangle and select the Copper run.
2. Click the Scale-to-fit icon at the top left of the toolbar.
3. Click the black triangle by the Curve Fit icon on the toolbar and select Linear. Right click in the Linear box and click on Show Uncertainty if it is not already showing.
4. Record the slope, m, of the R versus L graph in the Slope column of the Table III. Note that in most cases the uncertainty in the slope is less than 1%.
5. Repeat for each of the different metals.

7 Conclusions

1. How well does the data fit straight lines? What does this show?
2. Click open the Calculator at the left of the page and verify that line 5 calculating ρ is in agreement with Equation 3 from Theory. The factor of 10 arises from converting from $mm^2(m\Omega)/cm$ to μΩ-cm. Click the Calculator closed.
3. The value calculated for ρ is given in column 3. Except for Nichrome, the major source of uncertainty is the measurement of the diameter. If you measured this with a micrometer or digital calipers that read to 0.01 mm, the uncertainty in ρ is about 1%. Nichrome may have had a larger uncertainty in Slope due to spread in the data.
4. Column 4, labeled Resistivity, contains the manufacturer's values. The uncertainty arises because the metal wires are actually alloys and the actual resistivity depends on the exact composition.
5. Discuss how well you data agrees with the given values. What does this show about Equation 3?

Material	Color	Attracted to magnet?	Approximate Resistivity[1] (μΩ·cm)	Diameter(s) (inches)	Maximum[2] Constant Current (A)
Copper	Red	No	1.8 ± 0.1	0.040	2
Aluminum	Light gray	No	4.9 ± 0.1	0.040	2
Brass	Yellow	No	7.0 ± 0.5	0.020, 0.032, 0.040, and 0.050	2
Nichrome	Dark gray	No	105 ± 5	0.040	0.5
Stainless Steel	Dark gray	Yes	79 ± 1	0.040	1

[1]All samples are alloys. The actual resistivity of a sample depends on its composition.
[2]Excess constant current will cause wires to heat up, changing their resistivities. Current up to 2 A can be applied briefly to all wires.

8 Area Dependence

1. Create a graph of the resistances you measured (Resistance.) versus the cross-sectional area for the four brass wires.
2. On the Area axis, click on the measurement and select the quick-calc y^{-1}.
3. Click on the Curve Fit black triangle and turn on Linear.
4. How well does your data fit a straight line? What does this show about Equation 2 from Theory? What is the physical meaning of the slope?