

## Resistivity

### Equipment

Qty	Item	Parts Number
1	Voltage Source	850 Interface
1	Resistance Apparatus	EM-8812
1	Sample Wire Set	EM-8813
1	Voltage Sensor	UI-5100
2	Patch Cords	

### Purpose

The purpose of this activity is to examine how the resistance of a resistor is determined via geometry of the resistor, and the material which it is made of. Also, to further the student's understanding of the difference between resistance and resistivity.

### Theory

Ohm's Law describes the relationship between the resistance  $R$  of a wire, the voltage drop across it,  $V$ , and the current through the wire,  $I$ . This is formally given by the equation:

$$I = \frac{V}{R}$$

The resistance of the wire is a function of both the geometry of the wire and the material that the wire is composed of. This is formally given by the equation:

$$R = \rho \frac{L}{A}$$

Where here  $L$  is the length of the wire,  $A$  is the cross-sectional area of the wire (in this simple equation we are assuming the cross-sectional area is constant along the entire length of the wire), and  $\rho$  is the resistivity of the material the wire is composed of. The SI units of resistivity are Ohms·meters,  $\Omega \cdot m$ , and it is a quantification of how difficult it is to move a current through a length of the material. This equation shows us that resistance is a property of the object, while resistivity is a property of the material the object is made of. Due to this distinction it is really incorrect to say things like, "Copper has a low resistance.", because copper has a 'low' resistivity. If you take a copper wire and double its length, you double the resistance of that wire, but the value of the resistivity of the copper in that wire doesn't change.

Material	Color	Attracted to magnet?	Approximate Resistivity <sup>1</sup> ( $\mu\Omega \cdot cm$ )	Diameter(s) (inches)	Maximum <sup>2</sup> Constant Current (A)
Copper	Red	No	$1.8 \pm 0.1$	0.040	2
Aluminum	Light gray	No	$4.9 \pm 0.1$	0.040	2
Brass	Yellow	No	$7.0 \pm 0.5$	0.020, 0.032, 0.040, and 0.050	2
Nichrome	Dark gray	No	$105 \pm 5$	0.040	0.5
Stainless Steel	Dark gray	Yes	$79 \pm 1$	0.040	1

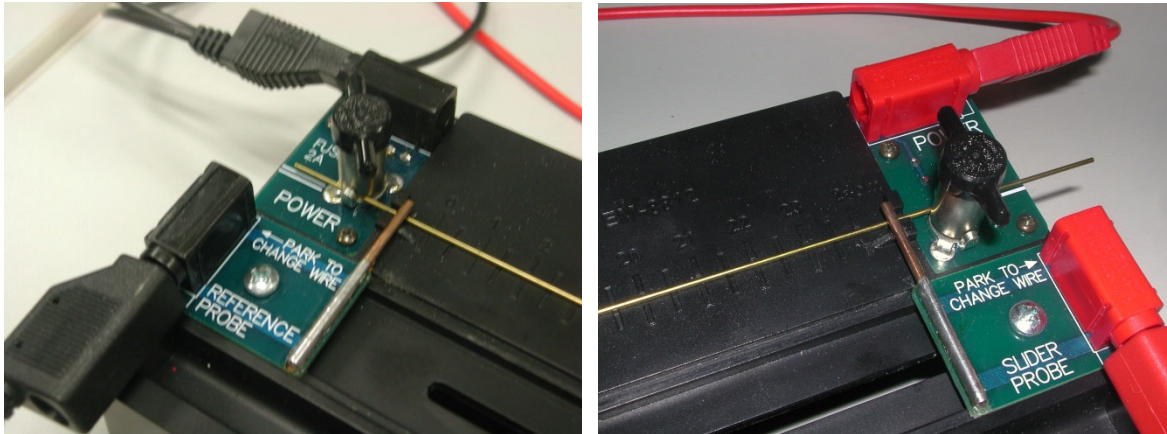
<sup>1</sup>All samples are alloys. The actual resistivity of a sample depends on its composition.

<sup>2</sup>Excess constant current will cause wires to heat up, changing their resistivities. Current up to 2 A can be applied briefly to all wires.

## Setup

1. Open the Capstone software. On the left side of the main screen is the Tool Bar. Click on the Hardware Setup icon. This will open the Setup window.
  - Click on Analog Channel A of the picture of the 850 Universal Interface in the Setup window, and then scroll down, and add the 'Voltage Sensor'.
  - Click on Output Channel 1 of the picture of the 850 Universal Interface in the Setup window, and then scroll down and add the 'Output Voltage-Current Sensor'.
2. On the bottom center left of the main screen the Sample Rate Tab should now say 'Common Rate'.
  - Set the Sample Rate to 1 Hz.
3. To the right of the Sample Rate is the Recording Conditions icon, click on it. This should open up the Recording conditions window.
  - Click on 'Stop condition'.
  - Set Condition type to 'Time Based'.
  - Set Record Time to 1.00 seconds.
  - Click on 'ok'.
4. In the Tool Bar, now click on the Signal Generator Icon. This will open the Signal Generator window.
5. In the Signal Generator window, click on the tab "850 output 1" tab. This will open up the options window for the output generator 1.
6. Set the Waveform to a "DC".
7. Set the DC Voltage to 2 volts.
8. Set the Voltage Limit to 2 volts.
9. Set the Current Limit to 1.10 A.
10. Set the Generator to "Auto" so that it will start and stop automatically when you start and stop collecting data.
11. Close the Tool Bar.
12. In the main window, click on the "Two Displays" option. (Bottom left option). A two-display window should appear.
13. In the Display Bar, on the right side of the main screen, click and hold down the 'digits' icon, then drag it out to the top display, and then release. Repeat for the bottom display as well.
14. For the top digits display click on 'select measurement' and select 'Voltage Ch A (V)'
15. For the bottom digits display click on 'select measurement' and select 'Output Current, Ch 1 (A)'.
16. **Putting a wire in the Resistance Apparatus.**
  - Move the Reference Probe, and the Slider Probe to their "parked" positions.
  - Twist the two black handles counterclockwise to open the clamps to allow the wire to slide into position.
  - Slide the 0.050-inch diameter Brass wire into position such that each end passes underneath both a probe and one of the clamps.

- Tighten the clamps to hold the wire in place, but don't tighten too much. As soon as you get a little resistance, stop tightening.



17. Plug in the Voltage sensor to Analog Ch A, then plug the two ends of the voltage sensor into the two slots on the probes of the apparatus. Black into black, and red into red.
18. Plug two patch cords into Output Ch 1, (top right of the 850 Universal Interface). Then plug one patch cord into each of the power slots on the apparatus. Again, black into black, and red into red.
19. On the main window select the 'Two Large Digits' template.
  - Click on the top 'Select Measurement' tab, and select Voltage, Ch A(V).
  - Click on the bottom 'Select Measurement' tab, and select Output Current, Ch 01(A).



## Procedure

1. Move the Reference Probe to the 0.0 cm position, and move the Slider Probe to the 5.0 cm Position.
2. Click on Record at the bottom left of the main screen.
  - The Record tab should now be a Stop tab.
  - Record the values for Voltage, and current in Table "Brass, 0.050 inch"
3. Then repeat step two for the Slider Probe in positions 10.0 cm, 15.0 cm, and 20.0 cm.
4. Return both the Reference Probe and the Slider Probe to their parked positions.
5. Then untighten the two black handles, and remove the brass wire.
6. Now repeat for the following wires: Brass 0.040 in, 0.032 in, 0.020 in.



**Brass 0.040 inch Diameter**

Cross-Sectional Area \_\_\_\_\_

<b>L(cm)</b>	<b>L/A(cm<sup>-1</sup>)</b>	<b>V(V)</b>	<b>I(A)</b>	<b>V/I=R(Ω)</b>	<b>R(μΩ)</b>

3. Complete the chart. Show work. (10 points)

4. In Excel, plot Resistance (μΩ) vs Length/Area, and show the trendline on the graph. What are the units of the slope of this graph, and what physical quantity does it represent? (8 points)

**Brass 0.032 inch Diameter**

Cross-Sectional Area \_\_\_\_\_

<b>L(cm)</b>	<b>L/A(cm<sup>-1</sup>)</b>	<b>V(V)</b>	<b>I(A)</b>	<b>V/I=R(Ω)</b>	<b>R(μΩ)</b>

5. Complete the chart. Show work. (10 points)

6. In Excel, plot Resistance (μΩ) vs Length/Area, and show the trendline on the graph. What are the units of the slope of this graph, and what physical quantity does it represent? (8 points)

Brass 0.020 inch Diameter

Cross-Sectional Area \_\_\_\_\_

L(cm)	L/A(cm <sup>-1</sup> )	V(V)	I(A)	V/I=R(Ω)	R(μΩ)

7. Complete the chart. Show work. (10 points)
8. In Excel plot Resistance (μΩ) vs Length/Area, and show the trendline on the graph. What are the units of the slope of this graph, and what physical quantity does it represent? (8 points)
9. Calculate the average value of your slopes, then calculate the % error between it and the accepted value. (8 points)
10. State at least two possible 'physics' sources of our percent error (*do not include rounding errors, calculation errors, human errors or equipment malfunction*). (10 points)
11. Did our experiment confirm the theory? Explain your answer. (10 points)