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Lab 6: Resistivity

Name:

PES 216 Report

Lab Station:

Objective

The purpose of this lab was to determine the influence of material type (resistivity), length, and cross-sectional area have on the value of resistance. Through use of Ohm's Law and the mathematical relationship of resistance, we identified different wires' material composition.

Data and Calculations

We set up a simple circuit to measure the current though the circuit and the potential drop across the given length of wire. The circuit setup is shown in the figures below:

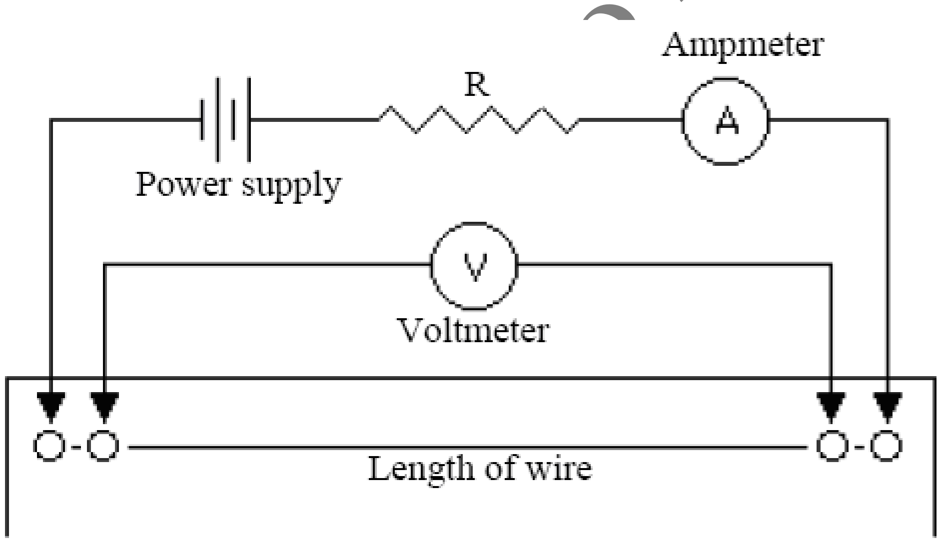


Figure 1: Experimental setup to determine the resistance of a given length of wire.

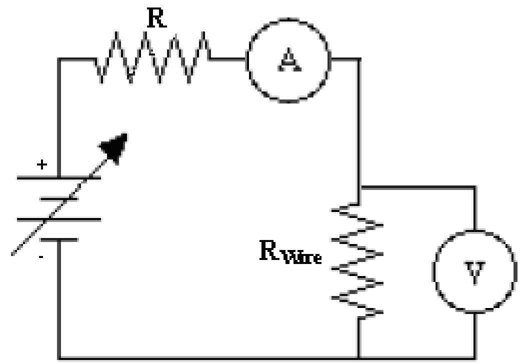


Figure 2: Circuit diagram of the experiment.

There were 4 materials (2 of which we each individually measured in class), labeled A though D. The gauge (cross-sectional area) of the wires was provided for each of the materials. We observed the color of each material to assist in the evaluation of the resistivity of the materials. We measured each of the five lengths of wire for each material type and then set up the circuit to obtain 500 mA of current passed though the circuit (as read from the Ampmeter). We then also measured the potential drop across each of the five lengths of wire (as read from the Voltmeter).

Material Name	Color of the Wire	Gauge [AWG]	Length of the Wire [m]	Current Through the Circuit [A]	Potential Drop Across the Length of Wire [V]
A	Brownish-Gold	40	0.2	0.500	0.343
A	Brownish-Gold	40	0.4	0.500	0.687
A	Brownish-Gold	40	0.6	0.500	1.03
A	Brownish-Gold	40	0.8	0.500	1.37
A	Brownish-Gold	40	1.0	0.500	1.72
B	Silver	38	0.2	0.500	0.354
B	Silver	38	0.4	0.500	0.708
B	Silver	38	0.6	0.500	1.06
B	Silver	38	0.8	0.500	1.42
B	Silver	38	1.0	0.500	1.77
C	Silver	22	0.2	0.500	0.337
C	Silver	22	0.4	0.500	0.675
C	Silver	22	0.6	0.500	1.01
C	Silver	22	0.8	0.500	1.35
C	Silver	22	1.0	0.500	1.69
D	Gold	34	0.2	0.500	0.328
D	Gold	34	0.4	0.500	0.657
D	Gold	34	0.6	0.500	0.985
D	Gold	34	0.8	0.500	1.31
D	Gold	34	1.0	0.500	1.64

We were given the conversion from Gauge to diameter. We used the diameter to calculate the cross-sectional area of the wire.

Gauge [AWG]	Diameter [mm]	Radius [mm]	Radius [m]	Area [m^2]
22	0.6440	0.3220	3.22×10^{-4}	3.26×10^{-7}
34	0.1600	0.0800	8.0×10^{-5}	2.01×10^{-8}
38	0.1010	0.0505	5.05×10^{-5}	7.97×10^{-9}
40	0.0799	0.03995	3.995×10^{-5}	5.01×10^{-9}

Next, we used Ohm's Law to find the resistance for each of the materials. These are given in the tables below. Ohm's Law is defined as:

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

Material A:

Length of the Wire [m]	Current Through the Circuit [A]	Potential Drop Across the Length of Wire [V]	Calculated Resistance [Ω]
0.2	0.500	0.343	0.686
0.4	0.500	0.687	1.374
0.6	0.500	1.03	2.06
0.8	0.500	1.37	2.74
1.0	0.500	1.72	3.44

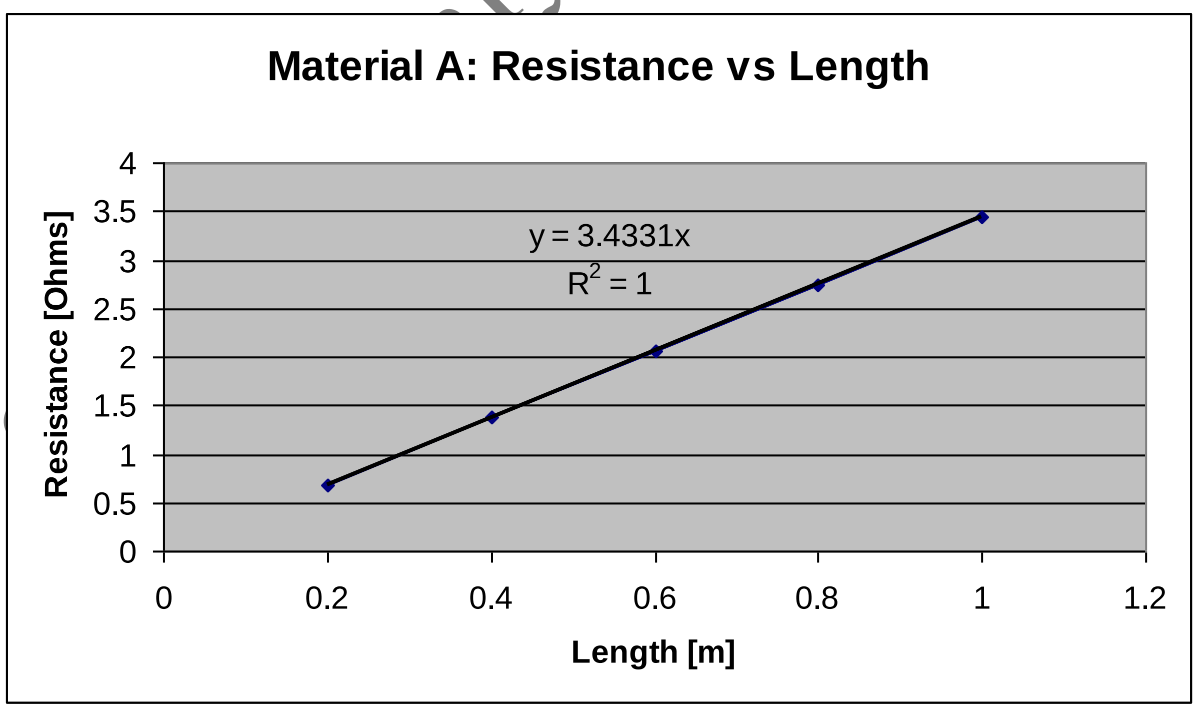
If we compare the equation for resistance to the equation of a straight line:

$$R = \left(\frac{\rho}{A}\right)L + 0$$

$$y = (m)x + b$$

We can see that we want to plot the resistance on the y-axis, plot the length on the x-axis, and the resulting best fit line will give the slope and the y-intercept.

The slope will obviously be the resistivity divided by the cross-sectional area (gauge), and the y-intercept will be zero.



Using the trendline feature in Excel, we got the following best fit line:

$$y = \left(3.4331\frac{\Omega}{m}\right)x + (0)$$

It is of particular interest to note the regression determined by Excel. This came out to be a value of 1.0. This means that the "linearity" of the data is extremely good.

Thus:

$$\frac{\rho}{A} = 3.4331\frac{\Omega}{m}$$

We then solved the above relationship for resistivity:

$$\rho = \left(3.4331\frac{\Omega}{m}\right)A$$

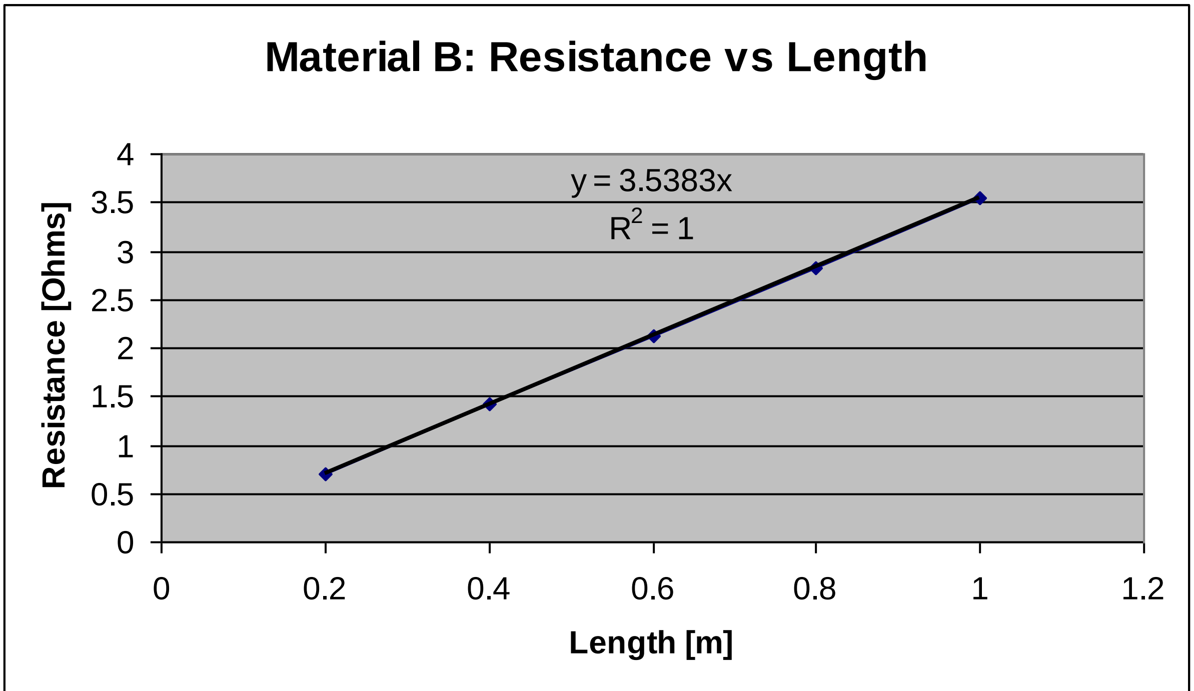
Material A was a 40 gauge wire. We found the cross-sectional area of this gauge above.

$$\rho = \left(3.4331\frac{\Omega}{m}\right)\left(5.01\times10^{-9}\ m^2\right) = 1.71998\times10^{-8}\ \Omega m$$

$$\boxed{\rho_{Material\ A} = 1.71998\times10^{-8}\ \Omega m}$$

Material B:

Length of the Wire [m]	Current Through the Circuit [A]	Potential Drop Across the Length of Wire [V]	Calculated Resistance [Ω]
0.2	0.500	0.354	0.708
0.4	0.500	0.708	1.416
0.6	0.500	1.06	2.12
0.8	0.500	1.42	2.84
1.0	0.500	1.77	3.54



Using the trendline feature in Excel, we got the following best fit line:

$$y = \left(3.5383\frac{\Omega}{m}\right)x + (0)$$

It is of particular interest to note the regression determined by Excel. This came out to be a value of 1.0. This means that the "linearity" of the data is extremely good.

Thus:

$$\frac{\rho}{A} = 3.5383\frac{\Omega}{m}$$

We then solved the above relationship for resistivity:

$$\rho = \left(3.5383\frac{\Omega}{m}\right)A$$

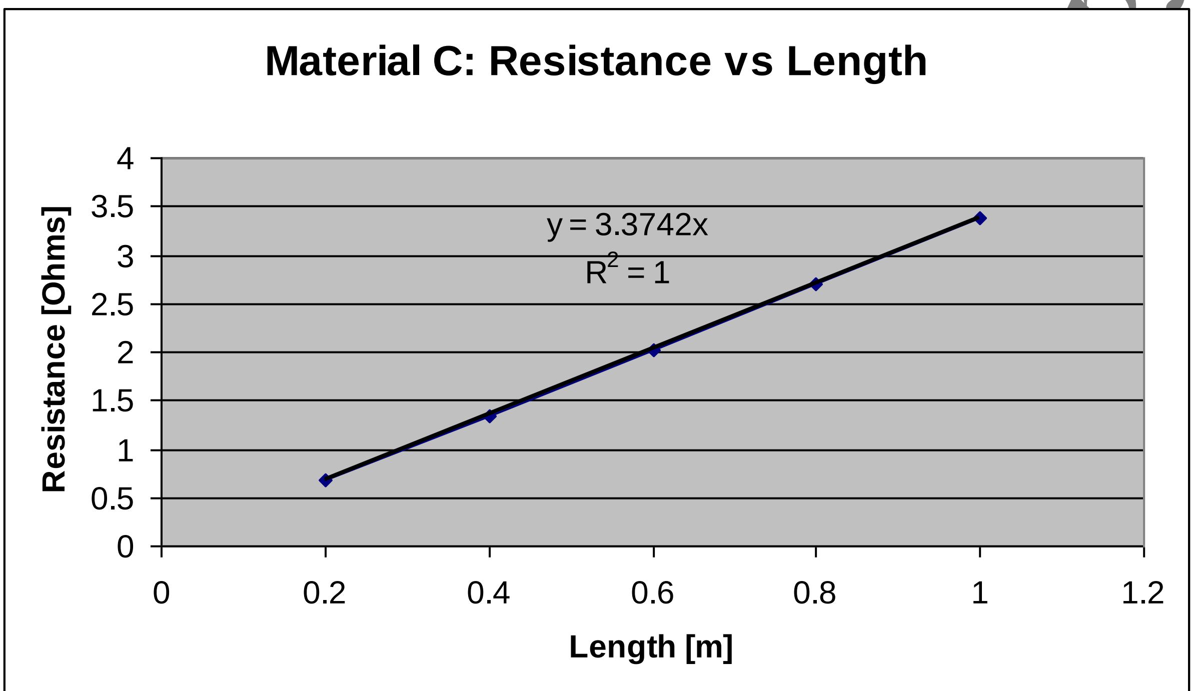
Material B was a 38 gauge wire. We found the cross-sectional area of this gauge above.

$$\rho = \left(3.5383\frac{\Omega}{m}\right)\left(7.97\times10^{-9}\ m^2\right) = 2.8200251\times10^{-8}\ \Omega m$$

$$\boxed{\rho_{Material\ B} = 2.8200251\times10^{-8}\ \Omega m}$$

Material C:

Length of the Wire [m]	Current Through the Circuit [A]	Potential Drop Across the Length of Wire [V]	Calculated Resistance [Ω]
0.2	0.500	0.337	0.674
0.4	0.500	0.675	1.35
0.6	0.500	1.01	2.02
0.8	0.500	1.35	2.70
1.0	0.500	1.69	3.38



Using the trendline feature in Excel, we got the following best fit line:

$$y = \left(3.3742\frac{\Omega}{m}\right)x + (0)$$

It is of particular interest to note the regression determined by Excel. This came out to be a value of 1.0. This means that the "linearity" of the data is extremely good.

Thus:

$$\frac{\rho}{A} = 3.3742\frac{\Omega}{m}$$

We then solved the above relationship for resistivity:

$$\rho = \left(3.3742 \frac{\Omega}{m}\right) A$$

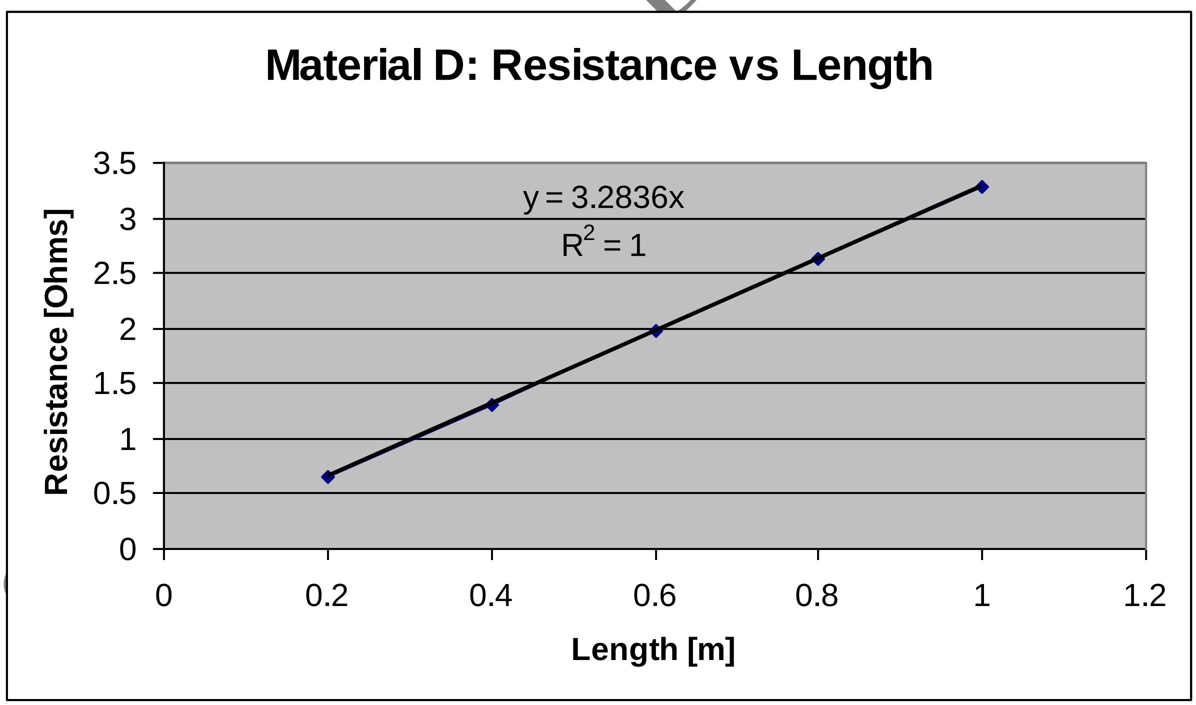
Material C was a 22 gauge wire. We found the cross-sectional area of this gauge above.

$$\rho = \left(3.3742 \frac{\Omega}{m}\right)\left(3.26 \times 10^{-7}\ m^2\right) = 1.0999892 \times 10^{-6}\ \Omega m$$

$$\boxed{\rho_{Material\,C} = 1.0999892 \times 10^{-6}\ \Omega m = 109.99892 \times 10^{-8}\ \Omega m}$$

Material D:

Length of the Wire [m]	Current Through the Circuit [A]	Potential Drop Across the Length of Wire [V]	Calculated Resistance [Ω]
0.2	0.500	0.328	0.656
0.4	0.500	0.657	1.314
0.6	0.500	0.985	1.97
0.8	0.500	1.31	2.62
1.0	0.500	1.64	3.28



Using the trendline feature in Excel, we got the following best fit line:

$$y = \left(3.2836 \frac{\Omega}{m}\right) x + (0)$$

It is of particular interest to note the regression determined by Excel. This came out to be a value of 1.0. This means that the "linearity" of the data is extremely good.

Thus:

$$\frac{\rho}{A} = 3.2836\frac{\Omega}{m}$$

We then solved the above relationship for resistivity:

$$\rho = \left(3.2836\frac{\Omega}{m}\right)A$$

Material D was a 34 gauge wire. We found the cross-sectional area of this gauge above.

$$\rho = \left(3.2836\frac{\Omega}{m}\right)\left(2.01\times10^{-8}\ m^2\right) = 6.600036\times10^{-8}\ \Omega m$$

$$\boxed{\rho_{Material\ D} = 6.600036\times10^{-8}\ \Omega m}$$

Additional Questions

Material	Resistivity (x 10^{-8} Ω· m)		Material	Resistivity (x 10^{-8} Ω· m)
Aluminum	2.82		Nichrome	100
Brass	7.00		Osmium	9.5
Carbon	3500		Platinum	10.6
Copper	1.72		Plutonium	141.4
Germanium	46,000,000		Rubber	$1x10^{17}$
Glass	$1x10^{18}$		Silicon	64,000,000,000
Gold	2.44		Silver	1.59
Iron	10.0		Tungsten	5.6
Lead	22		Uranium	30.0

From the prelab, we know the following are typical metals used for wires:

☑ Copper (Brownish metal):

$$\rho_{Cu} = 1.76\times10^{-8}\ \Omega m$$

☑ Aluminum (Silvery metal):

$$\rho_{Al} = 2.82\times10^{-8}\ \Omega m$$

☑ Gold (Gold metal):

$$\rho_{Au} = 2.44\times10^{-8}\ \Omega m$$

☑ Tungsten (Silvery metal – used in light bulbs – glows when a current sent through it):

$$\rho_W = 5.5 \times 10^{-8} \;\Omega m$$

☑ Nichrome (Silvery alloy of Nickel and Chromium):

$$\rho_{Ni+Cr} = 110 \times 10^{-8} \;\Omega m = 1.1 \times 10^{-6} \;\Omega m$$

☑ Brass (Brownish alloy of Copper and Zinc):

$$\rho_{Cu+Zn} = 6.33 \times 10^{-8} \;\Omega m$$

(For brass, the value may be anywhere in the range from 6.0 x 10^{-8} [Ω m] to 7.0 x 10^{-8} [Ω m]. This is due to the fact that brass my have different amounts of copper and zinc in the wire at different places.)

Using the color we recorded for the different material types and the calculated resistivites, we can determine the material composition of the 4 unknown wires.

Material A:

We determined that Material A was a "Brownish-Gold" color. From the graph of Resistance versus Length, we also obtained the following resistivity, since we knew the cross-sectional area of the wire, as well.

$$\rho_{Material\ A} = 1.71998 \times 10^{-8} \;\Omega m$$

It is obvious that the *only* choice for this material is **Copper** (since the given and calculated resistivities and color types match up perfectly). If we perform a percent difference:

$$\%\ difference = \frac{|\rho_{Theory}| - |\rho_{Measured}|}{|\rho_{Theory}|} x100\%$$

$$\%\ difference = \frac{(1.71998 \times 10^{8} \;\Omega m) - (1.76 \times 10^{8} \;\Omega m)}{(1.76 \times 10^{8} \;\Omega m)} x100\%$$

$$\boxed{\%\ difference = 2.27\%}$$

Material B:

We determined that Material B was a "Silver" color. From the graph of Resistance versus Length, we also obtained the following resistivity, since we knew the cross-sectional area of the wire, as well.

$$\rho_{Material\ B} = 2.8200251 \times 10^{-8} \;\Omega m$$

There are two potential choices for this material: Gold and Aluminum; however, using the color (silver) we know that **Aluminum** is the only possible choice. If we perform a percent difference:

$$\% \ difference = \frac{\left(2.8200251 \times 10^{8} \ \Omega m\right) - \left(2.82 \times 10^{8} \ \Omega m\right)}{\left(2.82 \times 10^{8} \ \Omega m\right)} x100\%$$

$$\boxed{\% \ difference = 0.0\%}$$

Material C:

We determined that Material C was a "Silver" color. From the graph of Resistance versus Length, we also obtained the following resistivity, since we knew the cross-sectional area of the wire, as well.

$$\rho_{Material\,C} = 1.0999892 \times 10^{-6} \ \Omega m = 109.99892 \times 10^{-8} \ \Omega m$$

It is obvious that the *only* choice for this material is **Nichrome** (since the given and calculated resistivities and color types match up perfectly). If we perform a percent difference:

$$\% \ difference = \frac{\left(109.99892 \times 10^{8} \ \Omega m\right) - \left(110.0 \times 10^{8} \ \Omega m\right)}{\left(110.0 \times 10^{8} \ \Omega m\right)} x100\%$$

$$\boxed{\% \ difference = 0.0\%}$$

Material D:

We determined that Material D was a "Gold" color. From the graph of Resistance versus Length, we also obtained the following resistivity, since we knew the cross-sectional area of the wire, as well.

$$\rho_{Material\,D} = 6.600036 \times 10^{-8} \ \Omega m$$

There are two potential choices for this material: Tungsten and Brass; however, using the color (gold) we know that **Brass** is the only possible choice. If we perform a percent difference:

$$\% \ difference = \frac{\left(6.600036 \times 10^{8} \ \Omega m\right) - \left(6.33 \times 10^{8} \ \Omega m\right)}{\left(6.33 \times 10^{8} \ \Omega m\right)} x100\%$$

$$\boxed{\% \ difference = 4.27\%}$$

Conclusion

You write the details. ← Include your answer here. Use complete sentences!!!!

** NOTE: There are several components of error which could significantly modify the results of this experiment. Some of these are listed below:

- Gauge accuracy
- Bad power supply (recall we used the DMM to attempt to alleviate this problem.)

- Buckling, bending, etc… of wire
- Elemental components/material makeup of the wire
- Parallax with meter stick
- ??

It is recommended that you take these and explain the "***why***" part of each for your results and conclusions sections – and possibly what could have been done (if anything) to minimize the effects of these errors.