

Name: _____ Period: _____ Due Date: _____ Lab Partners: _____
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F ACTORS E FFECTING R ESISTANCE - WebAssign

Purpose: To measure and evaluate three factors determining the resistance of a resistor; resistivity of the resistor material, the length of the resistor, and the cross-sectional area of the resistor. Temperature dependence is not covered in this lab, although temperature changes will change the resistivity of most materials.

Theory: Resistance depends on a number of factors. The first is the resistivity of the material itself. Some materials are naturally very good conductors with low resistivity (ρ), such as copper, silver and gold. Others are very poor conductors with high resistivity, such as glass and rubber. Good conductors have resistivities approaching zero, while insulators have resistivities approaching infinity. The second factor is length (L). Resistance is directly proportional to the length of the material. The third is the cross-sectional area (A_x) of the material. A narrow wire forces the charges closer together and their mutual repulsion increases the resistance. Resistance is inversely proportional to the cross-sectional area; the larger the area the smaller the resistance.

In this laboratory exercise you will investigate the relationships among these factors; resistivity of the material (ρ), its length (L), and its cross-sectional area (A_x). These three are related according to the equation

$$R = \rho L / A_x \qquad \text{(Equation 1)}$$

As a warm-up exercise, use the space below to derive the units of resistivity (ρ). Express the result in fundamental units only (kg, m, s, C, only). You can find the units of resistance by using Ohm's Law ($V = IR$). Then recall that volts are joules per coulomb and current is measured in amperes = coulombs per second. Finally, recall that a joule is a N·m and the newton is defined from Newton's Second Law as $F = ma$.

Derivation of the units of Resistivity:

Units of resistivity = units of ρ = _____ (in terms of kg, m, s and C, only)

Part One: The effect of Cross-Sectional Area on Resistance

Procedure:

1. Gauge is the American industrial standard measure of the diameter of a wire. You will be working with #30 gauge and #28 gauge wire.

#30 gauge = 0.01003 inch in diameter
 #28 gauge = 0.01264 inch in diameter

You must first convert these measures to centimeters (2.54 cm = 1 inch) and then to meters. Find the cross-sectional area of each gauge wire (in square meters) using $A_x = \pi r^2$. (The term "area" may sometimes be used as short-hand for "cross-sectional area" in this lab handout and elsewhere in life.)

	Radius (<i>in</i>)	Radius (<i>cm</i>)	Radius (<i>m</i>)	(Cross-Sectional Area) $A_x (m^2)$
#30 gauge				
#28 gauge				

2. Compare the resistances of two, 200-cm length samples of Nickel-Silver alloy wire (NS) with these two gauges. Use a multi-meter as an ohmmeter. (*Do not drain the batteries in the Ohmmeter by overuse.*)

Table I

Gauge of NS wire	Resistance of 200 cm of NS wire (<i>ohms</i>)	Which has the higher resistance; the wire with the <i>larger</i> or <i>smaller</i> (Circle One) cross-sectional area? Explain.
#30 gauge		
#28 gauge		

Part I Analysis:

What happens to the resistance as the diameter of a wire decreases? _____

Since $R = \rho L / A_x$, it follows that $R A_x = \rho L$
 Then, since ρ and L are constants, in this particular case, it follows that

$$R_{\#30} A_{x\#30} = R_{\#28} A_{x\#28}$$

Check this conclusion using appropriate data to see if it holds true.
 Specify which two wire samples you are using to check this relationship.

Material of the two wires used in this analysis: _____

#30 Gauge wire: resistance = _____ Ω , length _____ m, and cross-sectional area = _____ m^2 .

#28 Gauge wire: resistance = _____ Ω , length _____ m, and cross-sectional area = _____ m^2 .

$$R_{\#30} A_{x\#30} = \frac{\quad}{\quad} \times \frac{\quad}{\quad} = \frac{\quad}{\quad} \times \frac{\quad}{\quad} = R_{\#28} A_{x\#28}$$

$$R_{\#30} A_{x\#30} = \frac{\quad}{\quad} = \frac{\quad}{\quad} = R_{\#28} A_{x\#28}$$

Are they equal within a reasonable experimental difference of each other? _____.

Part Two: The effect of Length on Resistance

Procedure:

1. Measure the resistance of the five different lengths of #30 gauge NS wire on the spools provided.

Table II

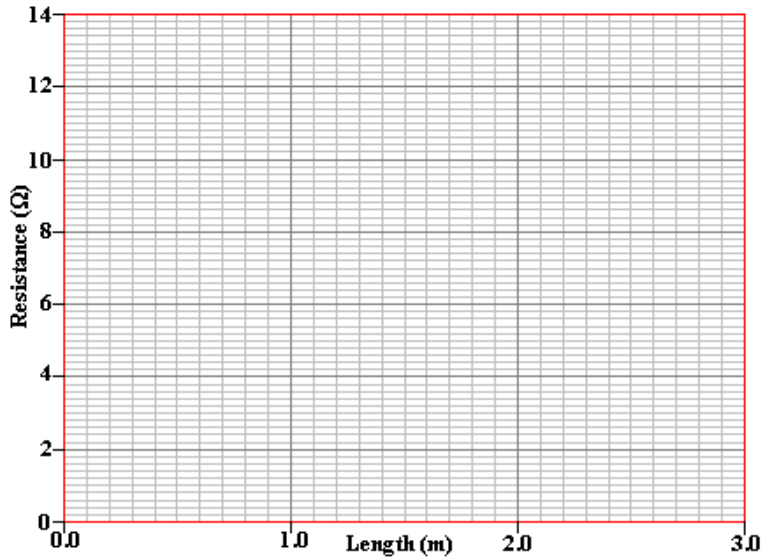
Length (meters)	Resistance (ohms - Ω)
0.40 m	_____
0.80 m	_____
1.20 m	_____
1.60 m	_____
2.00 m	_____ = R _{NS}

Describe how the resistance varies with the length of the wire as the other physical variables of the wire; composition, and cross-sectional area, are held constant.

Part II Analysis:

Graph your results (*resistance in ohms vs. length in meters*). Force the line fitting this graph through the

origin. According to **Equation 1**, the result should be linear with a zero intercept. The slope of the line should equal ρ / A_x . You can estimate the resistivity of Nickel-Silver wire from the slope, if you know its cross-sectional area. Make the graph twice, once by hand, here, and once in **Graphical Analysis**.



Graph the data by hand; first, and then make the more accurate graph in **Graphical Analysis**. Fit both to straight lines through the origin. Use the two slopes to estimate ρ (of Nickel-silver alloy). Remember that ρ (of Nickel-silver alloy) = (slope) \times ($A_{x\#30}$), because the slope = ($\rho_{NS} / A_{x\#30}$).

Compare the slope of the hand-drawn line on this graph with the one you create using **Graphical Analysis**.

Use the fact that $\rho = (\text{slope}) \times (A_x) = (\rho / A_x) \times (A_x)$ to calculate ρ for wire made of nickel-silver alloy.

slope (by hand) = $\rho_{NS} / A_{x\#30} =$ _____, and $A_{x\#30} =$ _____; $\rho_{NS} =$ _____ Ω·m
from manual graph from page 2

slope (by GA) = $\rho_{NS} / A_{x\#30} =$ _____, and $A_{x\#30} =$ _____; $\rho_{NS} =$ _____ Ω·m
from GA graph from page 2

Part Three: Material: The effect of Resistivity on Resistance -- Determining the Resistivity (ρ) of Copper.

Procedure:

1. Determine the resistance of the copper spool. There is only one copper spool. Notice the length and gauge of the copper on the spool.
2. Using the length, cross-sectional area (calculated from the gauge) and the measured resistance, determine the resistivity (ρ) of copper. Rearrange *Equation 1* to solve it for ρ ; then calculate ρ_{Cu} .

Table III $\rho =$ _____
(Show rearranged version of *Equation 1*)

Gauge (given, see spool label)	_____
Cross-sectional Area (A_x – see Part I)	_____ m ²
Length (L) (given in cm, see spool label)	_____ m
Resistance (R_{Cu}) (measured)	_____ Ω
Resistivity (ρ_{Cu}) (calculated)	_____ $\Omega \cdot m$

Part III Analysis:

Check your answer against the book value for copper. Express the difference as %Error.

Textbook value for the resistivity of copper _____ $\Omega \cdot m$

%Error = [|your answer – accepted value| / accepted value] \times 100% = _____

Part III Comparison:

Calculate the resistance of 200 cm of 30 gauge copper wire: $R_{Cu-200} =$ _____ Ω

Find the resistance of 200 cm of 30 gauge NS wire in Part Two: $R_{NS} =$ _____ Ω

Because the lengths and cross-sectional areas are the same for both of the 200 cm wires, the ratio of the resistances should equal the ratio of the resistivities, assuming *Equation 1* is correct. Use your measured resistances and your calculated resistivities to compare these two ratios.

$\rho_{Cu} / \rho_{NS} =$ _____

$R_{Cu-200} / R_{NS-200} =$ _____

What do you think? Are these two ratios close enough to justify the continued use of *Equation 1*?

Part Four: Body Resistance with Dry Skin Contact

Procedure:

1. Set the Ohmmeter to the 2M or 2000K (2 million ohms) setting.
2. Hold an electrode between the fingers of each hand. Keep your arms spread wide. Measure your resistance with dry fingers. The number that appears on the screen is the number of kilo-ohms or mega-ohms depending on the particular multi-meter you are using. Check with your instructor if you are not sure how to read the numbers on your unit. Results are highly variable. Pick a representative value.

Dry resistance _____ Ω

Determine the cross-sectional area of your forearms and the distance between your wide spread hands. Use that information, along with your measured wet resistance, to calculate your resistivity. Show your calculations in the space below.

The resistivity of _____ is _____ $\Omega\cdot m$
(your name goes here) (Dry hands)

Part IV Analysis:

Use the measured resistances of your own body to find the voltages that will produce the following current-induced effects on you. Use Ohm's Law to calculate the voltage for each case. *(Remember that your resistance is changing from moment to moment. The effects these voltages will have on your also vary dramatically from moment to moment, so these are only meant to be suggestive. Playing with voltage sources can be extremely hazardous to your health. Remember that contact with a wet floor or wet skin will decrease the required voltages.)*

Table IV

<u>Sensation</u>	<u>Current</u>	<u>Required Voltage with dry skin</u>
Threshold of sensation	0.002 A	_____
Mild tingling	0.008 A	_____
Painful shock	0.02 A	_____
Muscle Paralysis	0.04 A	_____
Severe Shock	0.05 A	_____
Breathing Upset	0.07 A	_____
Extreme Breathing difficulty	0.08 A	_____
Death	0.10 A	_____

Part Five: Find the Resistivity of a Carbon Rod

Procedure:

1. Determine the resistance of a carbon/clay rod and record it in the table.
2. Measure the length and diameter of the rod with a ruler and caliper and record these in the table.

Table V

Resistance = _____ Ω = ohms

Length = _____ m

Diameter = _____ m, therefore radius = _____ m, and thus A_x = _____ m^2 .

Part V Analysis:

Resistivity of carbon/clay rod = _____ $\Omega \cdot m$;

Accepted Value for the resistivity of pure carbon (*powered graphite*) = _____ $\Omega \cdot m$;

%Difference (*use the resistivity of pure carbon as the reference value*) = _____ %

The Fatal Current

(Taken from a Textronics training manual)
(Feb 2004)

Strange as it may seem, most fatal electric shocks happen to people who should know better. Here are some Electro-medical facts that should make you think twice before taking that last chance.

It's the current that kills

Offhand it would seem that a shock of 10,000 volts would be more deadly than one of a 100 volts. But this is not the case. Individuals have been electrocuted by appliances using ordinary house currents of 110 volts (alternating current) and by electrical apparatus in industry using as little as 42 volts (direct current). The real measure of a shock's intensity lies in the amount of current (amperes) forced through the body and not the voltage. Any electrical device used on a house wiring circuit can, under the right conditions, transmit a fatal current.

While any amount of current over 10 milliamperes (0.01 A) is capable of producing painful to severe shock, currents between 100 and 200 milliamperes (0.1 to 0.2 A) are lethal.

Currents above 200 mA while producing severe burns and unconsciousness do not usually cause death if the victim is given immediate attention. Resuscitation, consisting of CPR, will usually revive the victim.

From a practical viewpoint, after a person is knocked out by an electrical shock it is impossible to tell how much current passed through the vital organs of the body. CPR must be administered immediately if breathing has stopped.

The physiological effects of electric shock

The chart on the last page shows the physiological effects of various current densities. Note that voltage is not a consideration. Although it takes a voltage to make the current flow, the amount of shock-current will vary, depending on the body resistance between the points of contact.

As the chart indicates shock is relatively more severe as the current increases. At values as low as 20 mA, breathing becomes labored, finally ceasing completely even at values below 75 mA.

As the current approaches 100 mA, ventricular fibrillation of the heart occurs. This is an uncoordinated twitching of the walls of the heart's ventricles.

Above 200 mA, the muscular contractions are so severe that the heart is forcibly clamped during the shock. This clamping protects the heart from going into ventricular fibrillation, and the victim's chances for survival are good.

Danger – Low Voltage

It is common knowledge that victims of high voltage shock usually respond to CPR more readily than the victims of low voltage shock are. The reason may be merciful clamping of the heart, owing to the high current densities associated with high voltages. However, lest these details be misinterpreted, the only reasonable conclusion that can be drawn is that 75 volts are just as lethal as 750 volts.

The actual resistance of the body varies depending upon the points of contact and the skin condition (moist or dry). Between the ears, for example, the internal resistance (less than skin resistance) is only 100 ohms; while from hand to foot it is closer to 500 ohms. The skin resistance may vary from 100 ohms for wet skin to over 500,000 ohms for dry skin.

While working around electrical equipment move slowly. Make sure your feet are firmly placed for good balance. Don't lunge after falling tools. Kill all power and ground high voltage points before touching wiring. Make sure that power cannot be accidentally restored. Do not work on underground equipment. Do not examine live equipment when mentally or physically fatigued. Keep one hand in your pocket while investigating live electrical equipment.

Above all, do not touch electrical equipment while standing on metal floors, damp concrete or other well grounded surfaces. Do not handle electrical equipment while wearing damp clothing (particularly wet shoes) or while skin surfaces are damp.

Do not work alone. Remember the more you know about electrical equipment the more careless you are apt to become. Do not take unnecessary risks.

What to do for Victims

Cut voltage and/or remove the victim from contact as quickly as possible, but without endangering your own safety. Use a length of dry wood, rope, blanket, etc., to pry or pull the victim loose. Do not waste valuable time looking for the power switch. The resistance of the victim's contact decreases with time. The fatal 100 to 200 mA level may be reached if action is delayed.

If the victim is unconscious and has stopped breathing start CPR at once. Do not stop resuscitation until medical authority pronounces the victim beyond help. It may take as long as eight hours to revive the patient. There may be no pulse and a condition similar to rigor mortis may be present; however these are manifestations of shock and are not an indication the victim has succumbed.

