PHYS 1112L - Introductory Physics Laboratory II

Laboratory Advanced Sheet
Resistors (IBEAM)

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1. Introduction.

Most introductory physics courses contain problems of objects flying through the air or rolling along the ground without considering the effects of wind resistance. One of the main reasons why wind resistance is left out of consideration is that its addition to the problem makes the equations of motion almost impossible to solve, as the force term for wind resistance depends on velocity of the object to some power. An equally important reason is that the effect of wind resistance is minor for a great many of the problems that investigated in such a class. For example, objects that are thrown through the air at 5-10 m/s are affected minimally by wind resistance, as its effect is to cause the ball to fall only about 1-2% short of its intended target, which is a fairly small amount.

In the world of electronics, this situation is much different. Resistive effects can be quite large. Even excellent conductors like copper, gold, and silver provide a healthy amount of resistance to the flow of electrons through them. One way to see this is to touch the wire going to an appliance that draws a lot of current, such as a refrigerator, air compressor, or microwave. If the appliance has been on for quite some time, the wire will be warm to the touch, as the resistance in the wire will cause energy to be lost and heat to be created. It is the rare case of special substances called superconductors that must be chilled below liquid nitrogen temperatures in which the effects of resistance can be ignored.

When it comes to electricity and humans, large resistances can be good things. As discussed in the Capacitors laboratory, the membranes of the nerve and muscle cells in our body operate as a capacitor to keep ion concentrations/charges separated to maintain an electric potential between the inside and the outside of the cell. Whenever external currents enter the body, such as when you touch a loose wire or get struck by lightning, they will disrupt the charge distributions in the body. If the external currents are very small (micro amps and less), this might cause slight to no damage. Mostly, currents of this size will cause muscle cells to contract as the extra negative charges flowing through the body change the potential difference across the membranes, causing all of the channels in the membrane to open up and allow ions to flow. As long as the currents remain away from critical muscles, such as the heart, there is merely a tingling sensation as the nerves and muscle cells are activated. At higher levels, though, these currents can do severe damage, as they will physically damage the membranes and cause cell death.

Thus, limiting the amount of external current that can enter the body is considered a wise maneuver. One way to do this is to increase the overall resistance of the body whenever it is near electrical wiring. Wearing rubber soled shoes or rubber gloves are two ways to do this; another is to stand on dry land instead of a puddle of water. You can also lower the lethality of any electricity that does enter the body by preventing it from going near the heart by always keeping one hand behind your back attached to your belt or other clothing.

2. Objectives. The objectives of this laboratory are

a. to verify the linear dependence of resistance upon length of a conductor of uniform diameter, and

b. to understand the use of a Wheatstone bridge to measure unknown resistances.

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3. Theory.

a. The resistance of a conducting wire is given by

$$R = \rho L/A \qquad (1)$$

where

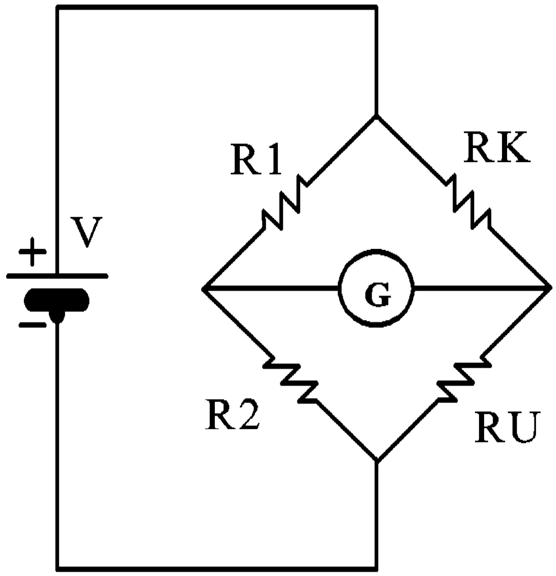
R is the resistance of the conductor in units of ohms (Ω),

ρ is the resistivity of the conducting material in units of (Ω m),

L is the length of the conductor in units of m, and

A is the cross-sectional area of the conductor in units of m^2.

b. The Wheatstone bridge consists of three resistors of known resistance, one resistor of unknown resistance, a voltage source and a galvanometer connected in a circuit which allows the resistance of the unknown resistor to be determined. Figure 1 below shows the Wheatstone bridge circuit.



In this experiment (but not in all Wheatstone bridges), resistors, R_1 and R_2, are provided by a 1.00 m long conducting wire that may be tapped at any point along its length to divide its total resistance into two parts, R_1 and R_2. Resistor, R_K, is the resistor of known resistance; resistor, R_U, is the resistor of unknown resistance. The resistances of R_1 and R_2 are varied until the galvanometer indicates that no current flows across it. In this condition the potential difference across the galvanometer is zero. If current, I_1, flows through resistors R_1 and R_2, and current, I_2, flows through resistors R_K and R_U, then

$$I_1 R_1 = I_2 R_K$$

$$I_1 R_2 = I_2 R_U$$

Dividing the second of these equations by the first, and solving for R_U, yields

$$R_U = R_2 R_K / R_1$$

Since R_1 and R_2 are formed from the same wire conductor, when equation 1 substituted into the last equation, the result is

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$$\mathbf{R_U = L_2 R_K / L_1} \qquad \mathbf{(2)}$$

where

L_1 and L_2 are the lengths of the conducting wires forming R_1 and R_2.

c. In this experiment the use of equation 2 above depends upon the linear relationship between resistance and length of a conducting wire described in equation 1. Therefore, verification of the linear relationship between resistance and length of a conducting wire of uniform cross-sectional area must precede measurements with the Wheatstone bridge.

1) The first objective of this experiment is to verify that linear relationship. This will be accomplished by placing a constant potential difference across the full length of the wire and measuring the voltage drop across a variety of partial lengths of the wire. Since the current in the wire is constant, the voltage drop across a given portion of the wire is proportional to the resistance of that portion of the wire. Thus, a graph of voltage drop versus wire length should be a straight line.

2) For the second objective, a single known resistance will be used in the Wheatstone bridge apparatus to determine the resistances of a variety of resistors. The actual values of the resistances will be determined using a multimeter and the percent discrepancy in the results will be calculated.

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4. Apparatus and experimental procedures.

a. Equipment.

1) Wheatstone bridge apparatus.

2) Variety of resistors.

3) Galvanometer

4) Multimeter.

5) Power supply

6) Connecting wires.

b. Experimental setup. A figure for the experimental setup will be provided by the student.

c. Capabilities. Capabilities of the equipment items listed in paragraph 3a will be provided by the student.

d. Procedures. Detailed instructions are provided in paragraph 4 below.

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5. Requirements.

a. In the laboratory.

1) Your instructor will introduce you to the equipment to be used in the experiment.

2) Measurements to verify the linear relationship between resistance and length of a wire conductor will be made.

3) Measurements of unknown resistances will made using the Wheatstone bridge apparatus and a multimeter.

4) Your instructor will discuss methods to be used to prepare your data for plotting using the Microsoft Excel™ spreadsheet program.

b. After the laboratory. The items listed below will be turned in at the beginning of the next laboratory period. A complete laboratory report is **not** required for this experiment.

Para 3. Apparatus and experimental procedures.

1) Provide a figure of the experimental apparatus (para 3b).

2) Provide descriptions of the capabilities of equipment used in the experiment (para 3c).

Para 4. Data. Data tables are included at Annex A for recording measurements taken in the laboratory. A copy of these tables must be included with the lab report. Provide the items listed below in your report in the form a Microsoft Excel™ spreadsheet showing data, calculations and graphs. The spreadsheet will include:

1) A table of data from the linearity measurements.

2) A graph of the voltage drop versus length of wire conductor that includes a regression line (trend line) and its equation.

3) The value of the known resistance, R_K.

4) A table with data from the Wheatstone bridge measurements. The table should include columns for nominal resistance, resistance measured using the multimeter, lengths L_1 and L_2, the resistance calculated from the Wheatstone bridge measurements, and the percent discrepancy.

5. Results and Conclusions.

a. Results.

1) A statement regarding the verification of the linear relationship between resistance and length of a wire conductor.

2) A statement regarding the capability of the Wheatstone bridge apparatus to measure resistance when used in the configuration of this experiment.

b. Conclusions.

Description of the sources of error in the experiment.

Annex A
Data

1. Linearity measurements.

length (cm)	voltage drop (V)
10	
15	

20	
25	
30	
35	
40	
45	
50	
55	
60	
65	
70	
75	
80	
85	
90	
95	

2. Resistance measurements.

a. Known resistance, R_K. Use a nominal 3.3 kΩ resistor.

Known resistance R_K (kΩ)

b. Wheatstone bridge measurements.

Resistance nominal (kΩ)	Resistance multimeter (kΩ)	Length L_1 (cm)
0.47		
0.68		
1.0		
1.5		
2.2		
3.3		
4.7		
6.8		
10		
15		
22		
33		
47		

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