Experiment 3

The Wheatstone Bridge

Preparation

Prepare for this week's quiz by reviewing old material and by reading about voltage dividers, Wheatstone bridges, and galvanometers.

Principles

The Voltage Divider

A **voltage divider** is shown in Figure 1a. It consists of a **voltage source** and a **variable resistor**. The variable resistor is often in the form of a straight or coiled wire with a sliding contact that can be moved along the length of the wire. The resistance of the wire is proportional to its length. The voltage difference between points *A* and *B* will be zero if the slider is all the way to the left, and equal to the battery voltage if it is all the way to the right. Therefore the voltage divider can be used to provide any voltage between zero and the power supply voltage. In this experiment you will use a type of voltage divider called a **rheostat**.

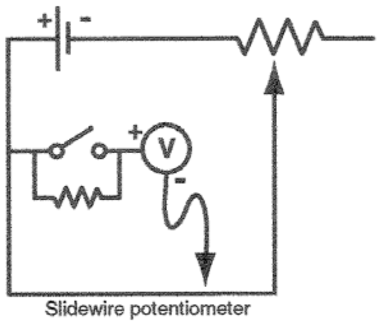

Figure 1a

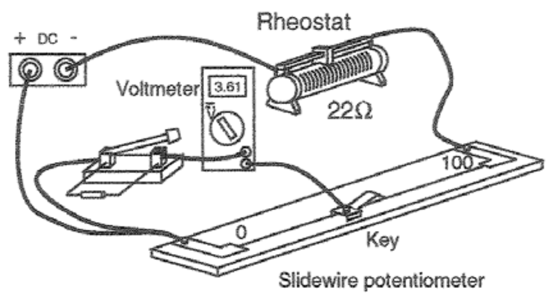

Figure 1b

The Wheatstone Bridge

The **Wheatstone bridge** is a circuit that is used to measure resistance. It contains three resistors and at least one must be variable. It also contains a **galvanometer**, an instrument that shows the amount and direction of current flow. Figure 2a shows the schematic for a Wheatstone bridge where R_2 and R_4 are the variable resistors and R_3 is the unknown.

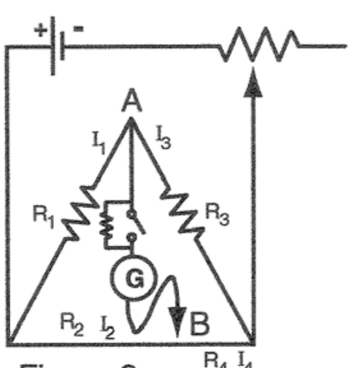

Figure 2a

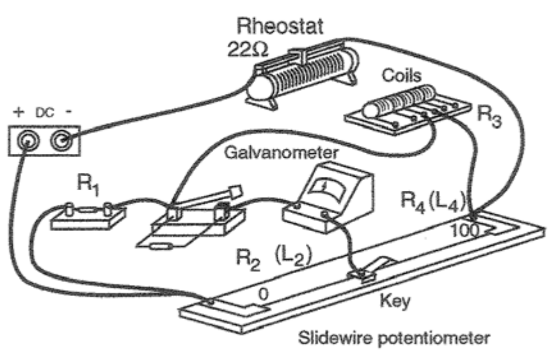

Figure 2b

The bridge is said to be "balanced" when no current is flowing through the galvanometer. For this to happen, the voltage at junction *A* must equal that at junction B. This means that:

$$I_1R_1 = I_2R_2$$

and also that:

$$I_3R_3 = I_4R_4$$

Since no current is flowing through the galvanometer, I_1 must equal I_3, and I_2 must equal I_4. Substitute these values into the first two equations to get:

$$I_3R_1 = I_2R_2$$

and:

$$I_3R_3 = I_2R_4$$

Divide the equations to get:

$$\frac{R_3}{R_1} = \frac{R_4}{R_2}$$

and rearrange to get:

$$R_3 = R_1\frac{R_4}{R_2} .$$

To measure an unknown resistance with the bridge, connect the unknown in the R_3 position. Then adjust the variable resistor (it does not matter which of the other resistors varies) until the galvanometer shows no deflection. Then use equation 6 to calculate the resistor value.

In this experiment you will use a slidewire for R_2 and R_4. A slidewire is a straight piece of high resistance wire with a contact that slides along the wire. The sliding contact is connected to the galvanometer so that the wire on one side of the contact is R_2 and the wire on the other side is R_4. (This is point *B* on the schematic.) As you move the contact one way, R_2 will increase and R_4 will decrease. If you move it the other way, R_2 will decrease and R_4 will increase.

The resistance of the wire is directly proportional to its length. Remember, $R = \frac{\rho L}{A}$. Let *K* be the constant of proportionality. The slider will divide the wire into two lengths, L_2 and L_4 so that:

$$R_2 = KL_2$$

and:

$$R_4 = KL_4.$$

The ratio of the two resistances is then the same as the ratio of the two lengths of wire. This ratio can then be used to get:

$$R_3 = R_1 \frac{L_4}{L_2}$$

This is the equation you will use in this experiment to find the unknown resistances.

Equipment

1 multimeter
1 slidewire
1 22 W rheostat
1 knife blade switch with 2K resistor
1 ± 5 galvanometer
1 resistance coil
1 10 Ω resistor
2 3' banana wires, one red, one black
4 2' banana wires, two red, two black
4 1' banana wires, two red, two black
8 spade lugs

Procedure

The Voltage Divider

1. Connect the circuit shown in Figure 1b. Have your lab instructor check it before you make the connection to the power supply.

2. You will use the voltage divider in this experiment to reduce the voltage provided by the power supply. Position the sliding contact on the rheostat at the midpoint of the coil and the sliding tap key on the slidewire at the 100 cm mark.

3. Depress the key and adjust the rheostat until the voltmeter reads 2 volts. Do not move the contact on the rheostat during the rest of the experiment.

4. Investigate the operation of the voltage divider by taking readings at 4 points along the slidewire. To take a reading, depress the key and record to position of the key and the voltage.

5. Connect the voltmeter across the slidewire and leave it there for the rest of the experiment.

The Wheatstone Bridge

1. Connect the circuit shown in Figure 2b with the known resistor in the R_1 position and spool 4 in the R_3 position.

2. The "knife-blade" switch has a large resistor in parallel with the low resistance switch. When the switch is open, the current is limited by the 2K resistor. This helps to protect the galvanometer from large current surges. With the switch open, depress the key briefly and see which way the galvanometer deflects. Move the key and find the position at which there is no deflection in the galvanometer when the key is depressed.

3. Close the switch and adjust the key position, if necessary. This is the balanced or "null" position. Record the position of the key and immediately open the switch.

4. Find and record the null position for spool 5.

5. Find and record the null position for spools 4 and 5 in series.

6. Find and record the null position for spools 4 and 5 in parallel.

7. Set the DMM to "ohms" and measure the resistances of spools #4 and #5 individually, in series, and in parallel.

8. Disassemble the apparatus and return it neatly.

Analysis

The Voltage Divider

1. Use the data to show that the ratio of voltage to wire length is constant along the slidewire.

The Wheatstone Bridge

1. Use your data to calculate the resistances of the individual spools 4 and 5.

2. Calculate the resistances of the series and parallel combinations of the two spools.

3. Find the percent differences between the calculated and measured values for each resistor and combination of resistors.