

# WHEATSTONE BRIDGE

## Physics 230, Lab 4

### Objectives

1. To experimentally determine unknown resistances by means of a Wheatstone bridge.
2. To experimentally measure the resistance of known resistances when connected in series and parallel; to compare results with known laws.
3. To experimentally determine the thickness of the insulation on a wire.

### Apparatus

Slide-wire Wheatstone bridge, resistance box, battery, galvanometer, wire coil and wires

### Theory

The resistance of a wire of length,  $l$ , cross-sectional area  $A$ , and resistivity  $\rho$ , is given by

$$R = \frac{\rho l}{A}. \quad (1)$$

When resistors are connected in SERIES, the total resistance  $R_s$  is given by

$$R_s = R_1 + R_2 + R_3 + \dots \quad (2)$$

When resistors are connected in PARALLEL, the total resistance  $R_p$  is given by

$$\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots \quad (3)$$

A Wheatstone bridge (see schematic in Figure 1) can be used to accurately determine an object's electrical resistance. If the resistances of  $R_{W1}$  and  $R_{W2}$  are known and  $R_K$  is known and variable, then a simple series of steps can determine the resistance  $R_U$ . When the current between points B and D is zero, the "bridge" is balanced, and the unknown resistance is given by

$$R_U = R_K \left( \frac{R_{W2}}{R_{W1}} \right). \quad (4)$$

If  $R_{W1}$  and  $R_{W2}$  are two wires of the same resistivity and cross-sectional area, then equation (4) can be rewritten in terms of the lengths of the wires,  $L_1$  and  $L_2$ ,

$$R_U = R_K \left( \frac{L_2}{L_1} \right). \quad (5)$$

## Experimental procedure

1. Observe the circuit diagram of a Wheatstone bridge (Figure 1) and the actual schematic diagram of the laboratory slide-wire Wheatstone bridge (Figure 2) below. Note the corresponding points (A, B, C and D) in each figure.
2. Assemble the Wheatstone bridge circuit as shown in the schematic diagram. The unknown resistance is the coil of wire. Do not close the key until your instructor checks the circuit. The power supply is the battery. Set the resistance box  $R_K$  at about  $15\Omega$ .

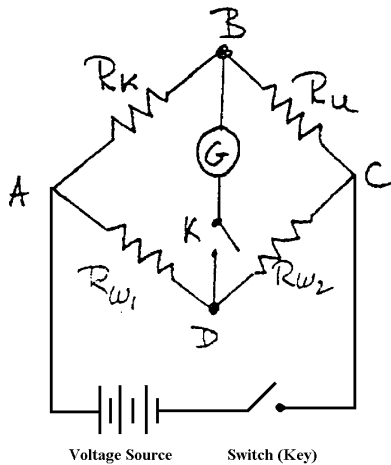


Fig. 1. Circuit Diagram

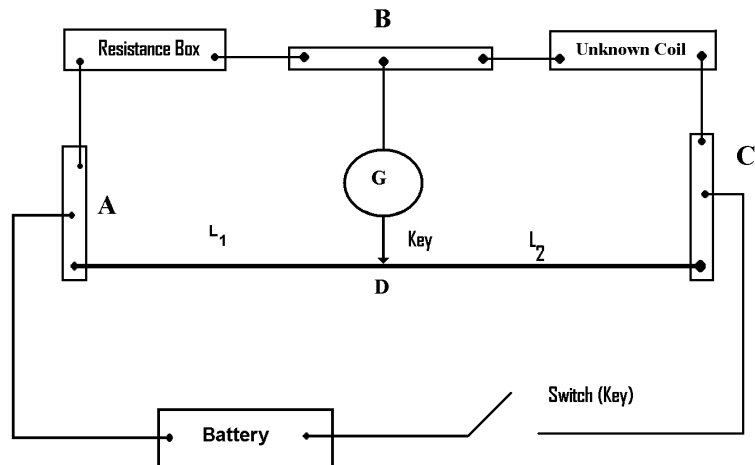


Fig. 2. Schematic Diagram

**Do not hold the key down for a long time or slide the key along the wire.**

3. Set the key to about the 50 cm mark and, after your instructor checks the circuit, close the switch. Then press the “coarse” button (button 3) on the galvanometer to close the galvanometer circuit. Adjust  $R_K$  so the bridge “balances” (zero current through the galvanometer on its most sensitive setting) at about the 50 cm mark. It may not be possible to balance the bridge using only the resistance box. If this is the case, adjust the key location slightly to completely zero the galvanometer. Record the lengths  $L_1$  and  $L_2$  corresponding to the resistances  $R_{W1}$ ,  $R_{W2}$  and the box resistance,  $R_K$ . You can now use these values to find the unknown resistance. Remember, you should be estimating the uncertainties for all of the quantities you measure.
4. Repeat this procedure twice, once with the key near the 20 cm mark, and once with the key near the 80 cm mark.
5. Obtain another coil from a neighbor and measure its resistance. Place these two coils in series and measure their combined resistance. Repeat this measurement with the coils in parallel. (You need only measure these resistances once with the key near the 50 cm mark.)
6. Measure the wire diameter with a micrometer. Estimate the uncertainty in your measurement. Be sure to correct for any error in the micrometer zero reading.

### Calculations and Analysis

1. Are there differences in the measured resistances of a single coil when using different key settings? How much variation is present between the center key measurement and the measurements where the key is near the edges of the wire (you can quantify it using percent difference)? Why is it best to keep  $L_1 \approx L_2$ ?

2. Are the relationships  $R_s = R_1 + R_2$  and  $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2}$  for resistors in series and parallel valid for your experiment? (A good way to compare two numbers is by calculating their percent difference.)

3. Combine Eq. 1 and Eq. 4 to show that the diameter of the conductor ( $D$ ) is given by:

$$D = 2 \sqrt{\frac{\rho l}{\pi R_k} \frac{L_1}{L_2}}. \quad (6)$$

Using your data from the single coil measurement (with the key at 50 cm), calculate the diameter of the wire in your coil and its uncertainty. The resistivity of the wire is  $\rho = 1.678 \times 10^{-8} \Omega \text{ m} \pm 1 \times 10^{-11} \Omega \text{ m}$ . Take the uncertainty in  $R_k$  as  $\pm 0.05\%$  of its value. Estimate the errors in the lengths  $L_1$  and  $L_2$ . Assume the uncertainty in the length of the coil to be  $\pm 0.1 \text{ m}$ .

4. Measure the wire diameter using the micrometer (as always, estimating its uncertainty) and using this information, find the thickness of the insulation. Report the thickness and its uncertainty with the proper significant digits.

5. Your lab report should include:

- a clearly written derivation of Eq. 6,
- a well-organized spreadsheet that displays your measured values and their uncertainties, and any appropriate calculations,
- the error propagation worksheet from Maple that gives your calculation of the wire diameter, the thickness of the insulation, and their uncertainties, and
- answers to questions 1. and 2. above.