# E12a: Resistance & the Slide-Wire Wheatstone Bridge

## Introduction:

The Wheatstone Bridge, named after Charles Wheatstone, is a circuit that is designed to make very precise measurements of resistance. The basic design of the bridge circuit is so effective that it has also been included in other types of precision measurement components such as transducers and strain gauges. This experiment makes use of a Slide-Wire Wheatstone Bridge, explained more in the **Discussion** section, to explore the relationships between the resistance of a conductor and the properties of the conductor such as its length and resistivity. In the slide-wire bridge the resistance can be transposed from two known resistors to two known lengths of wire. The ratio of the lengths can then be used to experimentally determine the resistance of an unknown. This experimental resistance is then compared to the theoretical resistance of the unknown, which can be calculated using known properties of the resistor material.

## Apparatus:

- Slide-Wire Bridge component
- Sensitive Current Meter
- Power Supply
- Known Variable Decade Resistor component
- Unknown Resistance Coils
- Hook-up wire

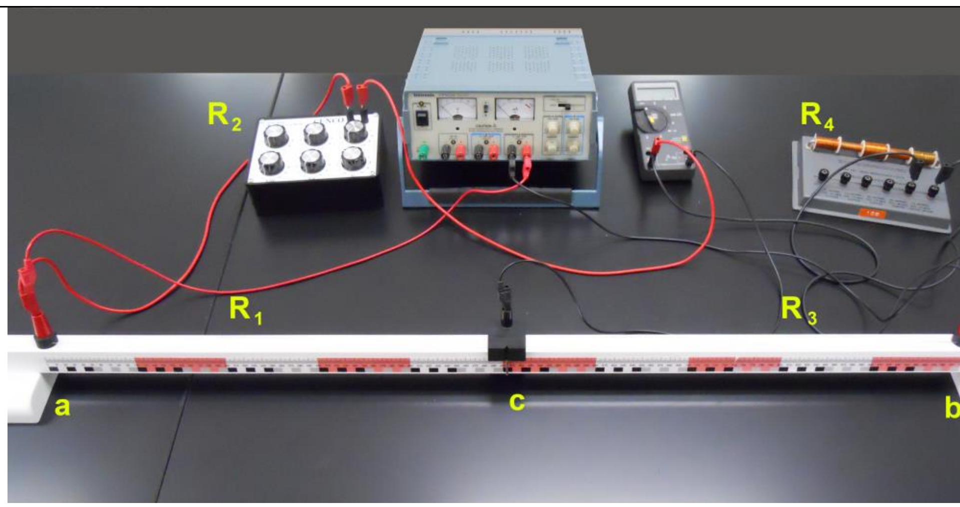


**Figure 1**

## Discussion:

The bridge circuit is a design that can be constructed with a variety of circuit components depending upon the intended function of the circuit. This specific bridge circuit will be composed of resistors exclusively and will function to measure very small resistances. The basic design for a bridge circuit of resistors is demonstrated in Figure #2.

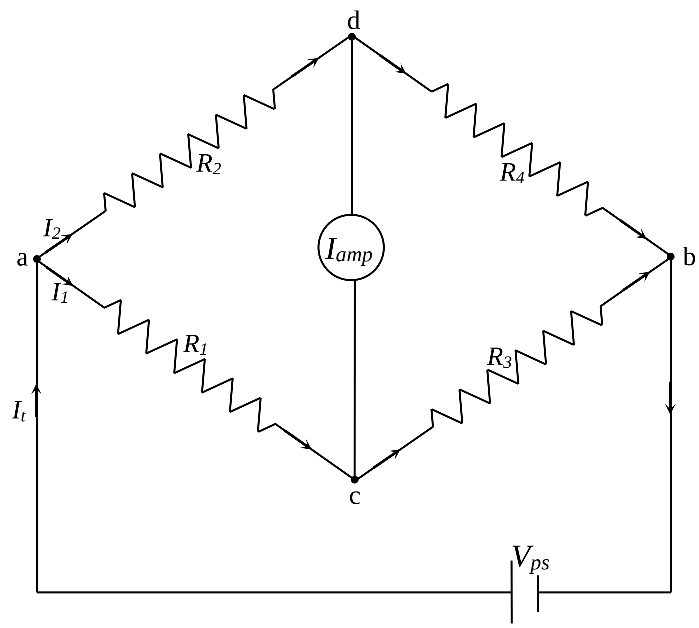


**Figure 2**

A balanced condition of the bridge exists when no current flows through the meter measuring current ($I_{amp}$). Applying Kirchhoff's current junction rule and voltage loop rule results in the following expressions.

$$I_t - I_1 - I_2 = 0$$
$$I_1 R_1 - I_2 R_2 = 0$$
$$I_1 R_3 - I_2 R_4 = 0$$

Solving the two voltage equations for a ratio of currents and then combining them develops an expression relating the resistors.

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

This experiment will use the bridge design to measure the resistance of several small unknown resistors. The unknown resistors will be inserted into the resistor $R_4$ position.

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

In the slide-wire form of the Wheatstone Bridge resistors $R_1$ & $R_3$ are replaced by a length of uniform wire between points (a & b). A sliding contact at point (c) provides a variable resistance ratio between $R_1$ and $R_3$. The resistance of a uniform wire conductor depends on the material, the length and the cross sectional area. This relationship is expressed in the following equation.

$$R = \rho \frac{length}{area}$$

In this equation the area is the cross sectional area of the wire and $\rho$ is the resistivity of the wire material. Since the apparatus uses a uniform wire the cross-sectional area and the resistivity are constant for the length of the wire. This makes the ratio of resistance equivalent to the ratio of length.

$$R_4 = R_2 \left( \frac{\rho l_{cb} / area}{\rho l_{ac} / area} \right)$$

$$R_4 = R_2 \frac{l_{cb}}{l_{ac}}$$

This last equation is used to experimentally determine the resistance of each of the unknown resistors.

The unknown resistors for the experiment are coils of wire. The wire coils will have varying lengths, diameters and materials. The theoretical resistance of a conductor depends on the material, the length, the cross sectional area and the temperature. The relationship is the same as express above for a uniform wire conductor.

$$R_{theo} = \rho \frac{Length}{Area}$$

In this equation Area is the cross sectional area of the conductor, Length is the total length of the conductor from connection junction to connection junction and $\rho$ is the resistivity of the material. Resistivity is a property of the material from which the conductor is made and is also dependent upon the temperature of the conductor. Table I provides the specifics for the coils used in the experiment. This information along with the above equation is used to calculate the theoretical resistance for each of the unknown resistors. Note: in Table I the resistivities are given for a temperature of 20 degrees Celsius.

## Table I

| Coil # | Material | Resistivity *(ohm cm) 20ºC* | Diameter *(cm)* | Length *(cm)* |
|---|---|---|---|---|
| 1 | copper | $1.678 \times 10^{-6}$ | .0644 | 1000 |
| 2 | copper | $1.678 \times 10^{-6}$ | .0311 | 1000 |
| 3 | copper | $1.678 \times 10^{-6}$ | .0644 | 2000 |
| 4 | copper | $1.678 \times 10^{-6}$ | .0311 | 2000 |
| 5 | nickel silver | $28.8 \times 10^{-6}$ | .0644 | 1000 |

## Procedures:

1. Analyze the set-up of the apparatus shown in **Figure 1**.
2. Calculate the theoretical resistance value for each unknown resistor (coil of wire) (Refer to experiment E4 to calculate the series and parallel resistor values). Check with a lab instructor in order to verify the theoretical resistances before proceeding.
3. Connect the first unknown resistance to the slide-wire bridge in the $R_4$ position.
4. Select an appropriate value for the known resistance on the decade resistor. This selected value should be similar to the resistor calculated in step 2.
5. Move the contact point (c) along the slide-wire until the position where the current meter indicates zero is found.
6. Measure $l_{ac}$ & $l_{cb}$ and calculate the experimental unknown resistance.
7. Compare the theoretical and experimental resistance values. If they are not similar check the bridge connections. Also examine if a different known resistor permits a better experimental determination. Any extra trial done to look for a better experimental value of the resistance should be documented in the data sheet.
8. Repeat the process using the other unknown resistors.

## Experiment E12a: Resistance & the Slide-Wire Wheatstone Bridge

Student Name________________________________________

*Lab Partner Name*________________________________________

*Lab Partner Name*________________________________________

Physics Course________________________________________

Physics Professor________________________________________

Experiment Start Date________________________________

| *Lab Assistant Name* | *Date* | *Time In* | *Time Out* |
|---|---|---|---|
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Experiment Stamped Completed

# Data Sheets: E12a: Resistance & the Slide-Wire Wheatstone Bridge

**NAME: ______________________________ DATE: __________________**

| coil # | theoretical resistance ***R*** *ohms* | known resistor ***$R_2$*** *ohms* | length **ac** *cm* | length **cb** *cm* | experimental resistance ***$R_4$*** *ohms* |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| series 1 thru 5 | | | | | |
| parallel 4 & 5 | | | | | |

## Extra Trials (if needed)

| coil # | theoretical resistance ***R*** *ohms* | known resistor ***$R_2$*** *ohms* | length **ac** *cm* | length **cb** *cm* | experimental resistance ***$R_4$*** *ohms* |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
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