EXPERIMENT 4
OHM'S LAW, RESISTORS IN SERIES AND PARALLEL

I. THEORY

The purposes of this experiment are to test Ohm's Law, to study resistors in series and parallel, and to learn the correct use of ammeters and voltmeters.

Ohm discovered that the ratio of voltage to current in a metallic resistor is constant as long as the temperature is held constant. This ratio is called resistance. For small temperature variations the resistance can be considered essentially constant. Ohm's Law is usually written

$$V = IR$$

in which V is the potential difference across the resistor (often called simply voltage across the resistor), in volts. I is the current in amperes and R is the resistance in ohms.

According to Ohm's Law, if we plot a graph of the voltage across a resistor vs. the current flowing through the resistor, we should obtain a straight line through the origin. The slope of this line is the resistance.

When two or more resistors are connected in series, the equivalent resistance is given by

$$R_{eq} = R_1 + R_2 + R_3 + \cdots$$

When two or more resistors are connected in parallel, the equivalent resistance is given by

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

In order for an ammeter to measure the current flowing through a resistor, the ammeter must be connected in series with the resistor so that the same current flows through both. An *ideal* ammeter has zero resistance, so that the current flowing in each branch of a circuit is unaffected by its presence. A *real* ammeter has a very small resistance so that the effect of its presence in the circuit can be neglected. A *small* resistance means small compared to the other resistances in the circuit. Similar to *real* strings used in Physics 250 which were considered to have *small masses*.

Because an ammeter has a very small resistance, it must never be connected directly across a voltage source, because a large current will flow through it and burn it out.

In order for a voltmeter to measure the potential difference across a resistor, the voltmeter must be connected in parallel with the resistor. An *ideal* voltmeter has infinite resistance so that no current flows through it and therefore it does not affect the rest of

the circuit. A *real* voltmeter has a very high resistance so that the small current which flows through it can usually be neglected without serious error. Because a voltmeter has a high resistance, it is protected from burnout, **unless** it is connected to a source of voltage substantially higher than its range.

II. LABORATORY PROCEDURE

NOTE: Set the VOLTAGE and CURRENT control knobs on the triple-output power supply to zero (full counter-clockwise position) and turn the power supply off before making any changes to your circuit..

1. The three resistors you will work with have nominal (approximate) values of 2 Ω, 5 Ω and 10 Ω. Record the more precise value of each resistor, as listed on the back of its mounting board.

2. Do not plug in or turn on your power supply until your instructor has checked your first circuit.

3. Using the wiring board with nine Fahnestock clips arrayed in a three by three grid, wire up Circuit #1, referring to the diagram in section IV. Each line represents a connecting wire. Polarities of the power supply, ammeter and voltmeter must be exactly as shown. You will be using an analog ammeter and a digital multimeter (Extech MN36). The multimeter will be used as a voltmeter. Use the 1 A range of the ammeter. The multimeter is autoranging, meaning that it will choose the most accurate scale available for your readings. Use banana to spade wires to connect the multimeter to your circuit. You will not be using the banana jack labeled "10 A" on the multimeter. Connect the banana plugs to the other two jacks (the jack labeled "COM" is the negative jack). Use the binding post connections on the portable power supply, not the fixed 12 V and 5 V outputs. To connect a wire to a Fahnestock clip, depress the end of the clip and insert the terminal of the wire into the hole which opens up in the clip. Have the instructor check your circuit before proceeding.

4. With both the VOLTAGE and CURRENT control knobs of the power supply set to zero, turn the power supply on. Rotate the VOLTAGE control knob approximately halfway. Slowly rotate the CURRENT control knob, while watching both meters for either excessive deflection or reverse deflection. Should either of these occur, turn both the VOLTAGE and CURRENT control knobs to zero immediately and obtain help from the instructor.

5. If you are unable to obtain any current while rotating the CURRENT control knob, check with your instructor. You may have a wire with a break in it. Your instructor can show you how to test each wire with a multimeter. Ideally, the resistance of each wire should be 0.0 Ω. A reading of 0.2 Ω or above indicates a problem with a wire. ***Present any suspect wire to your instructor for further checking. If you return a broken wire to the wire cart, you may end up with it again in a later lab.***

6. Adjust the CURRENT control knob so that the ammeter reads 0.5 A. Record the current and voltage in a table which leaves room for three more sets of readings. Record the current and voltage to the correct number of significant figures, recalling that the least significant figure is an estimate and contains uncertainty. The uncertainty in the voltage reading of the Extech MN36 multimeter is in the third digit displayed. If you are not sure if you are recording to the correct number of significant figures, check with your instructor or you may be asked to repeat the measurements.

7. Using the same circuit, repeat the procedure above for an ammeter reading of 1.0 A. Turn the VOLTAGE and CURRENT control knobs to zero and turn off the power supply. Switch the ammeter to the 10 A range. Continue for ammeter readings of 1.5 A and 2.0 A. Turn the VOLTAGE and CURRENT control knobs to zero and turn off the power supply.

8. Referring to the diagram in section IV, wire up Circuit #2, which has the 2-Ω and 5-Ω resistors in series. Use the 1 A range of the ammeter. Have the instructor check your circuit before proceeding. Rotate the CURRENT control knob to its full clockwise position. While watching both meters as before, slowly rotate the VOLTAGE control knob until the voltmeter reads 2.0 V. Record the current and voltage. Repeat for voltages of 4.0 and 6.0 V, recording the results in tabular form. Turn the VOLTAGE and CURRENT control knobs to zero and turn off the power supply. Switch the ammeter to the 10 A range. Take a final set of readings at 8.0 V. Turn the VOLTAGE and CURRENT control knobs to zero and turn the power supply off.

9. Referring to the diagram in section IV, wire up Circuit #3, in which the 2-Ω and 5-Ω resistors are in parallel. Use the 10 A range of the ammeter. Have the instructor check your circuit before proceeding.

10. Repeat steps 4-6, but leave the ammeter on the 10 A range.

11. Referring to the diagram in section IV, wire up Circuit #4, in which the 2-Ω resistor is in series with the parallel combination of the 5-Ω and 10-Ω resistors. Use the 10 A range of the ammeter. Have the instructor check your circuit before proceeding.

12. With the power supply VOLTAGE and CURRENT control knobs set at zero, turn on the power supply. Rotate the CURRENT control knob to its full clockwise position. While watching both meters, slowly rotate the VOLTAGE control knob until the voltmeter reads 7.00 V. Record the voltage and the current along with which resistor you are measuring the current through. Turn the VOLTAGE and CURRENT control knobs to zero and turn off the power supply.

13. Turn the VOLTAGE and CURRENT control knobs to zero and turn the power supply off before disconnecting the circuit.

III. CALCULATIONS AND ANALYSIS

    Circuit #1
- Plot a graph of voltage vs. current in which current is the independent variable. Draw the straight line which best fits the plotted points. The line should come close to or pass through the origin.
- Use the Modified Least Squares Method to find the slope of the best fit line passing through the origin. This is the experimental value of resistance.
- Calculate the percent error using the value given on the resistor board as the accepted value.
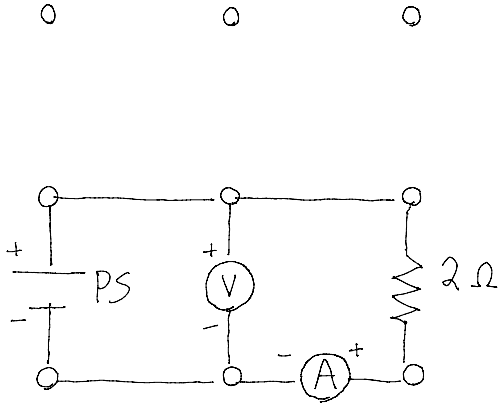
    Circuit #2
- Make a table with the columns potential difference, current, and equivalent resistance. The value for equivalent resistance should be calculated from your data using Ohm's Law.
- Calculate the average value for the equivalent resistance. This will be considered the experimental value of the equivalent resistance.
- Calculate the theoretical value of the equivalent resistance using the formula for resistors in series and the values given on the resistor boards.
- Calculate the percent error in your experimental value.

    Circuit #3
- Make a table with the columns potential difference, current, and equivalent resistance. The value for equivalent resistance should be calculated from your data using Ohm's Law.
- Calculate the average value for the equivalent resistance. This will be considered the experimental value of the equivalent resistance.
- Calculate the theoretical value of the equivalent resistance using the formula for resistors in parallel and the values given on the resistor boards.
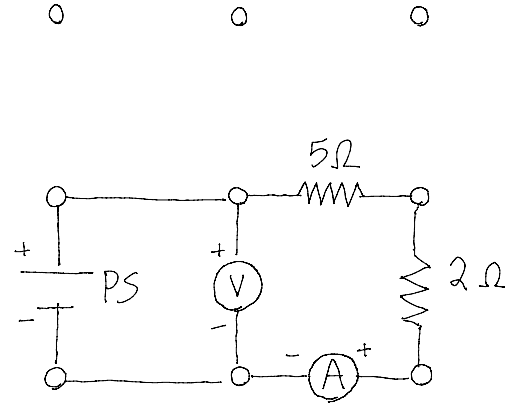- Calculate the percent error in your experimental value.

    Circuit #4
- Use the values of resistance given on the resistor boards to find the theoretical equivalent resistance of the entire circuit. Show your work in detail.
- Use the current and voltage measured in Circuit #4 to calculate the experimental equivalent resistance of the circuit.
- Calculate the percent error in your experimental value.
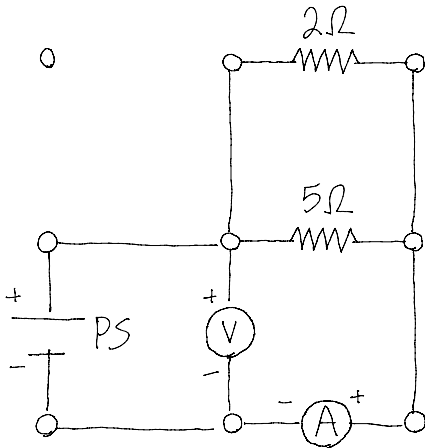
IV. DIAGRAMS

CIRCUIT #1

CIRCUIT #2

CIRCUIT #3

CIRCUIT #4