Experiment 2
Ohm's Law and Kirchhoff's Rules

Preparation

Prepare for this week's quiz by reviewing last week's experiment and reading about Ohm's and Kirchhoff's laws. Look up resistors and resistors in parallel and series circuits.

Principles

Ohm's Law

Ohm's law states:

$$I = \frac{V}{R}$$

Here V is the voltage difference between two points in a circuit, I is the current flowing between the two points, and R is the resistance between the two points. If any two of these values are known, the third can be computed.

This is a rule followed by some materials, usually over some defined range of temperatures. It is not a universal law like $F = ma$ which is always true in ordinary life.

Kirchhoff's Rules

Kirchhoff's first and second rules are sometimes called the loop rule and the junction rule. They state:

1. **The loop rule**: The algebraic sum of the voltage differences around a circuit must equal zero. Another way to put this is: The sum of the voltage rises must equal the sum of the voltage drops.

    As current passes through a resistor it must do work to get through the resistor material. It loses energy which is dissipated in the form of heat. This means that every charge carrier has more potential energy before it goes through a resistor than it has after it goes through it. The loss of energy per unit charge is the potential difference. We say that there is a **potential drop** or **voltage** across the resistor. Where does the energy come from? It comes from the voltage source. Each time the charge carrier goes through a battery it acquires energy and goes through a **voltage rise**. The current carries energy from the voltage source to the resistor where it dissipates the energy.

    If one or more resistors are wired in series the charge carriers will lose energy as they pass through each one, thus creating a series of potential drops. In any loop of a circuit the sum of the voltage drops must equal the sum of the voltage rises.

2. **The junction rule**: The sum of the currents entering a junction must be equal to the sum of the currents leaving the junction. The circuit does not "use up" the charge carriers and they don't leak out of the wires.

Equivalent Resistance

In this experiment you will investigate these three ideas using combinations of resistors in series and in parallel. Remember that the **total**, or **equivalent, resistance** in a series circuit is given by:

$$R_{eq} = R_1 + R_2 + \ldots$$

For a parallel circuit the equivalent resistance is given by:

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

In this experiment you will be using a **digital multimeter (DMM)** which can function as either a voltmeter or an ammeter. The voltmeter must always be wired in parallel with the resistor whose voltage you are measuring. The ammeter, used to measure current, must always be wired in series. Disconnect the meter from the circuit before you change the function setting. **Failure to follow these procedures can result in serious damage to the meter.** Be sure that you use the correct units with your data.

Equipment

- 1 multimeter
- 1 330 Ω or 240 Ω resistor
- 1 1000 Ω (1K) resistor
- 1 2000 Ω (2K) resistor
- 1 3000 Ω (3K) resistor or 1 3300 Ω (3.3K) resistor
- 1 0- 10K resistor substitution box
- 2 spade lugs
- 2 2' red banana wires
- 2 2' black banana wires
- 4 4" black banana wires

Procedure

1. Set the DMM function switch to "Ohms" (Ω). Measure and record the resistance of the resistors R_1, R_2, R_3, R_4.

2. Figure 1 is a sketch of the components. In this sketch, the DMM is wired in parallel with R_3 in order to measure the voltage V_3. Wire the circuit shown in Figure 1, but do not connect it to the power supply until it has been approved by your lab instructor. Once it has been approved, apply power. Set the DMM to DCV . Connect the black banana wire to COM and the red wire to the V-Ω input. Measure the power supply voltage (V_{ps}) and the voltages across R_1 (V_1), R_2 (V_2), R_3 (V_3), and R_4 (V_4) as indicated in Figure 2.
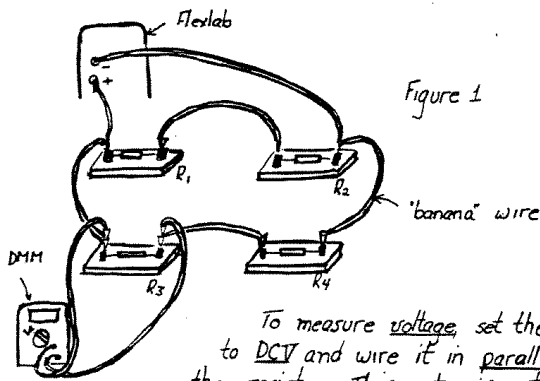
Figure 1

'banana" wire

To measure voltage, set the meter
to DCV and wire it in parallel with
the resistor. This meter is set up
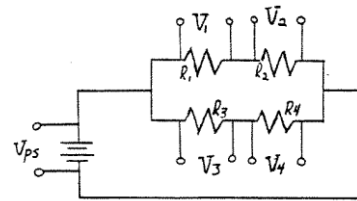to measure V3, the voltage across R3.

Figure 2
Voltage measurements

3.   Unplug the circuit and disconnect the meter. Change the function switch on the DMM to direct current amperes. Move the red wire to the "mA/μA terminal. Study Figure 3 and notice the way the ammeter is wired in series with the resistors. Again, have the lab instructor approve the circuit before you plug it in. Make the current measurements I_1, I_2, and I_3 indicated in Figure 4.
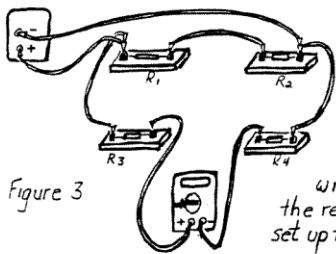

Figure 3

To measure
current, set the
meter to DCmA and
wire it in series with
the resistors. This meter is
set up to measure I_3, the
current through R3 and R4
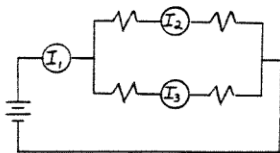
Note that
the positive lead
to the meter must
be moved

Figure 4
Current measurements

4. R_1 and R_2 are in series. R_3 and R_4 are also in series. The two series circuits are in parallel. Calculate the equivalent resistance, R_{eq}, for the entire circuit. Show your work.

5. Set the decade resistance box to the value you calculated for R_{eq} for the circuit.

Be sure the DMM is set on DCA and wire the DMM and the resistance box in series with the power supply. Measure I_{eq}.

6.   Turn everything off, disconnect the components and put the equipment away neatly.