Ohm's Law
Spring 2009

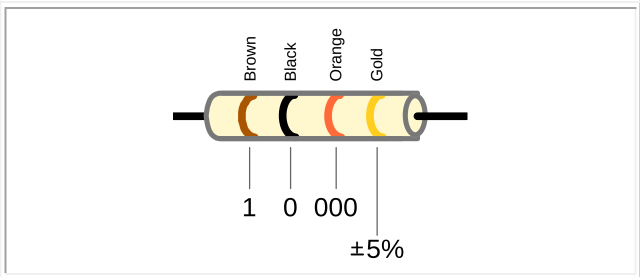
Introduction

This week we will measure the current through two resistors in series. We will work with voltages supplied by a power supply which can be continuously adjusted, and fixed resistors. The goal is to measure the resistance of two resistors, and see if, when connected in series, they act like a single resistor equal to the sum of the two.

***Note**: The success of this experiment (**and the next**)*
depends upon the care and precision of your measurements!

Experiment

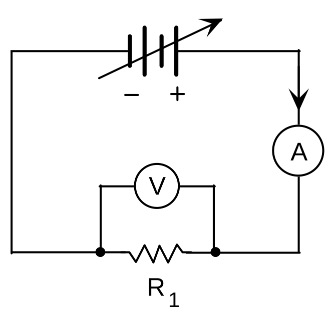
1. Use the table below to identify the resistance of each resistor as indicated by its color code. Record these values in your report, as well as the set designation ("A", "B", etc.) written on the block; you'll need this information for the next experiment!



0 – Black	**5 – Green**		*Tolerance*
1 – Brown	**6 – Blue**		None: ±20%
2 – Red	**7 – Violet**		Silver: ±10%
3 – Orange	**8 – Gray**		Gold: ±5%
4 – Yellow	**9 – White**		

The first two colored bands give the first two significant figures; the third band gives the multiplier, 10^x. The fourth band gives the tolerance to which the resistor has been manufactured. So, in the example shown above, the first band is brown (1), the second is black (0), the third is orange (3, so the multiplier is 10^3), and the fourth is gold (±5%). Therefore, the resistance is 10000 Ω, or 10 kΩ, with a tolerance of ±5%.

2. Connect the circuit shown at right, beginning at the (+) terminal and working around the circuit until you've reached the (–) terminal. Add the voltmeter *last*. Draw a new circuit diagram whenever you change any of the components.



3. Measure and plot the current as a function of the voltage for R_1. Begin with the voltage at the maximum of 30 volts, then decrease by 5-volt increments down to 0 (set the multimeters so that the voltage is read to 0.1 *V*, and current read to 0.01 *mA*). Plot your data on graph paper *as it is measured*. This is important in identifying bad points or incorrect measurements. Take your readings from the digital ammeter and voltmeter, *not* the built-in meters on the power supply!

4. Now repeat the measurements on R_2, and finally on the set of R_1 and R_2 *in series* (we'll call these measurement V_{set} and I_{set}). Use the **same** voltages as for R_1, so that in KaleidaGraph you'll need to enter the voltages only once. Plot all the data on one graph.

Analysis

For most single solid materials *at constant temperature*, the relation between current and voltage is linear, making it useful to define resistance and Ohm's law: $I = \left(\frac{1}{R}\right)\mathcal{V}$. Here R is the reciprocal slope of your graph, and has units of *ohms* ($\Omega = {}^{\text{volts}}/_{\text{amperes}}$), or for today, *kilohms* ($k\Omega = {}^{\text{volts}}/_{\text{milliamperes}}$).

7. Enter your voltage and current measurements into KaleidaGraph, again plotting all your data on one graph. Fit a straight line (use "Linear w/Uncertainties") to each of your three current measurements; record the slopes and their uncertainties in your report (recall that the uncertainty is twice the standard error calculated in KaleidaGraph). *Save this graph on your p: drive – you'll need it for the experiment next week.*
8. Calculate R_1, R_2, and R_{set} from the reciprocals of the slopes for each line. *Watch for rounding errors!*
9. The calculation of resistance is meaningless without considering the uncertainty of the measurements. First calculate the % uncertainty of the slope:

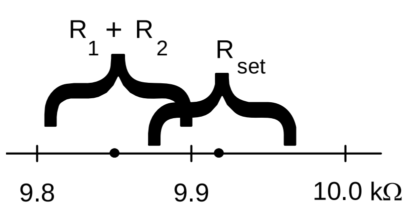
$$\%\ \text{uncertainty of slope} = \frac{\text{uncertainty of slope}}{\text{slope}} \times 100\%$$

This % uncertainty is *the same* for the slope and its reciprocal, so you can use it for the % uncertainty of R. Therefore, if the slope is 0.339 mA/volt, and *twice* the uncertainty of the slope is ± 0.001 mA/volt, then the % uncertainty is 0.3 %. So, the resistance is: $R = 1/slope = 2.95\ k\Omega \pm 0.3\%$.

Now you can use this % uncertainty to calculate the uncertainty of the resistance. 0.3% of 2.95 kΩ is 0.009 kΩ, so R = 2.95±0.009 kΩ.

Discussion

- Begin with your experimental results: a table of the slopes, the values for the resistances and their uncertainties. Also include the resistance values from the color codes
- In class we found that two resistors connected in series can be replaced by a single equivalent resistor whose value is the sum of the two resistors. Today we are checking this: does R_{set} (the measured resistance of the series) equal $R_1 + R_2$ (the sum of the individual measured resistances)? You must include the uncertainties to answer this question. Display your results on a number line, using your calculated uncertainty to show the spread in values:



If you find that $R_{set} \neq R_1 + R_2$ within the range of uncertainty, discuss reasons why you think the data are inconsistent with the theory. Which value is greater? Look at the results from the other groups – do they agree with yours? This is not easy, but your instructor will offer hints, if asked *nicely*.