Experiment 15: Ohm's Law

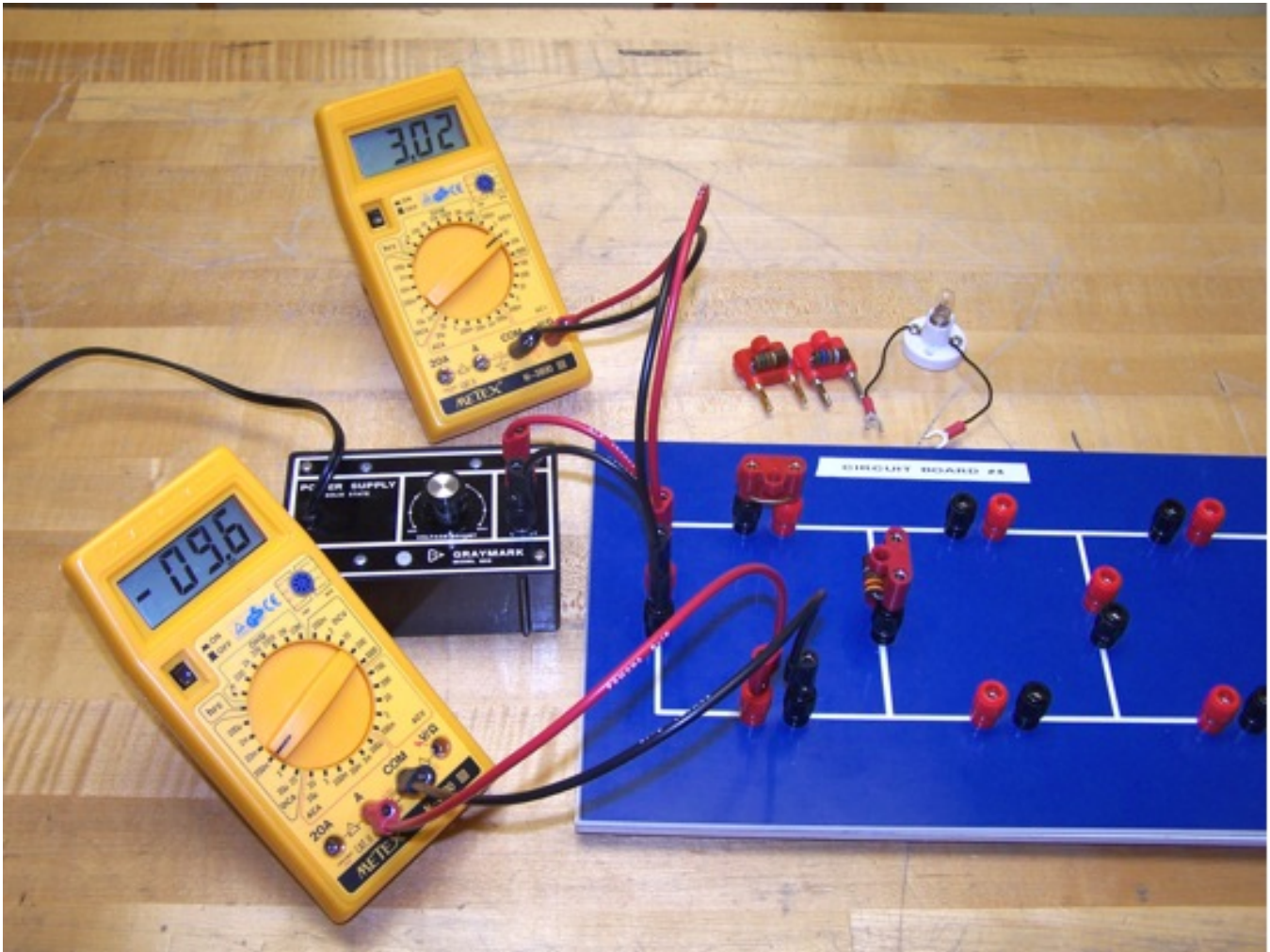Figure 15.1: Simple Series Circuit

EQUIPMENT

Universal Circuit Board
Power Supply
(2) DMM's
150 Ω Resistor (R_1)
330 Ω Resistor (R_2)
560 Ω Resistor (R_3)
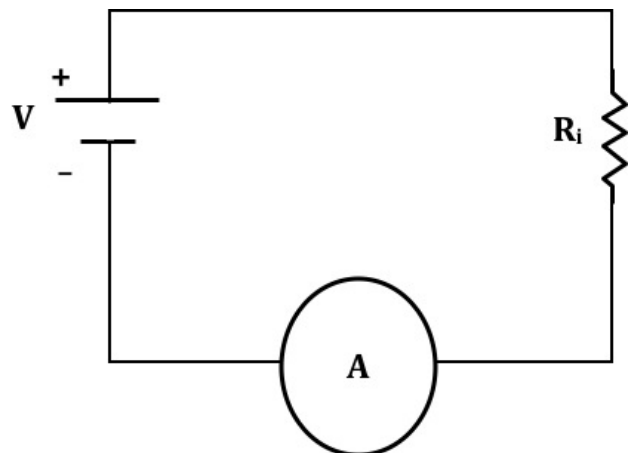Miniature Light Bulb and Socket (R_4)
(1) Jumper
(6) Wire Leads

Figure 15.2: Schematic: Simple Series Circuit

Advance Reading

Text: Ohm's Law, voltage, resistance, current.

Lab Manual: Appendix B, Appendix C - DMM

Objective

The objective of this lab is to determine the resistance of several resistors by applying Ohm's Law. Students will also be introduced to the resistor color code and refresh their graphing skills.

Theory

Ohm's Law states that the current, I, that flows in a circuit is directly proportional to the voltage, V, across the circuit and inversely proportional to the resistance, R, of the circuit:

$$I = \frac{V}{R} \qquad (15.1)$$

In this experiment, the current flowing through a resistor will be measured as the voltage across the resistor is varied. From the graph of this data, the resistance is determined for Ohmic resistors (R_i, $i = 1, 2, 3$). Non-Ohmic resistors (R_4, light bulb) do not obey Ohm's Law.

Ammeters are connected in series so that the *current flows through* them. The ideal ammeter has a resistance of zero so that it has no effect on the circuit. Real ammeters have some internal resistance.

Voltmeters are connected in parallel to resistive elements in the circuit so that they measure the *potential difference across* (on each side of) the element. The ideal voltmeter has infinite internal resistance. Our voltmeters have approximately 10 MΩ (10×10^6 Ω) internal resistance so that only a minuscule amount of current can flow through the voltmeter. This keeps the voltmeter from becoming a significant path for current around the element being measured.

Resistors are labeled with color-coded bands that indicate resistance and tolerance. The first two color bands give the first two digits of the value (Fig. 15.3). The third band gives the multiplier for the first two, in powers of 10. The last band is the tolerance (Fig. 15.3), meaning the true value should be $\pm x\%$ of the color code value. Refer to Table 15.1 for standard color values.

There is no need to memorize the color codes for lab.

For example, a resistor that has two red bands and a black multiplier band has a resistance of 22 Ω.
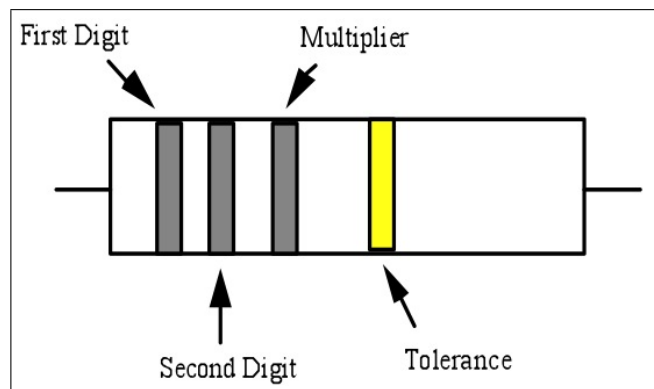

Figure 15.3: Color Code Schematic

Color	Number	Multiplier
Black	0	10^0
Brown	1	10^1
Red	2	10^2
Orange	3	10^3
Yellow	4	10^4
Green	5	10^5
Blue	6	10^6
Violet	7	10^7
Grey	8	10^8
White	9	10^9

Tolerance	
Gold	5%
Silver	10%
(No Band)	20%

Table 15.1: Resistor Color Code Values

Name: _____

1. Write the equation and a qualitative statement for Ohm's Law. (20 pts)

2. What are "ohmic" and "non-ohmic" devices? (20 pts)

3. Complete the following statement: An ideal ammeter has an internal resistance of _____, while an

   ideal voltmeter has an internal resistance of _____. Explain why these are desirable attributes for

   the respective measuring instruments. (20 pts)

4. If I $vs.$ V is plotted, what value is obtained from the slope? *Note* that we are investigating the function $I = V/R$
   and fitting our data to the slope-intercept equation of a line. (40 pts)

PROCEDURE

PART 1: Measures of Resistance

1. Determine the nominal resistance for the three resistors: interpret the color codes according to the color code chart in Table 15.1.

2. Measure the actual resistance, R, of the three resistors using the ohmmeter and record them in the table provided.

3. An ideal ammeter has no resistance; this ammeter does have a small resistance. Measure the resistance of the ammeter (200 mA DCA).

PART 2: Ohm's Law Applied

4. Build a simple series circuit using R_1, an ohmmeter, an ammeter, and a jumper (This will look similar to Fig. 15.1, but without the power supply).

5. Measure the equivalent resistance of the circuit using the ohmmeter and record this value in the table provided. Include units and uncertainty.

6. Remove the ohmmeter and connect the unplugged power supply to the circuit. Connect a voltmeter to the circuit, across the power supply leads (in parallel).

7. Have your TA check your circuit. Plug in the power supply and turn it on.

8. Test Ohm's Law ($V = IR$) by verifying that the current increases linearly with applied voltage. Apply 1 V, 2 V, 3 V, and 4 V to the circuit. Measure current and voltage and record them in the table provided. Include units and uncertainty.

9. Repeat the *Part 2* procedure for R_2 and R_3.

PART 3: Non-Ohmic Device

10. Build a series circuit using R_4, the light bulb (Fig. 15.4).

11. Measure the current and voltage as you increase the applied voltage in 0.2 V increments up to 2.0 V, then continue in 1.0 V increments up to 4.0 V. Adjust the voltmeter scale to obtain the most significant figures possible.

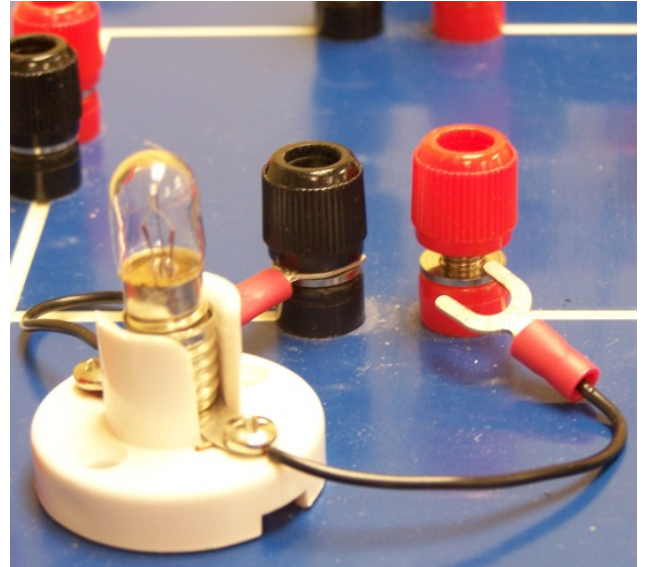12. Turn off and unplug the power supply; turn off the DMM's.

Figure 15.4: Spade Connection to Circuit Board

PART 4: Graphing

13. Open *Graphical Analysis*. Enter all of your voltage and current data as four separate data sets (one for each resistor). Include the point (0,0) in each set. [Other graphing software may be used, provided the graphs include all requisite elements.]

14. Plot I *vs.* V for the three Ohmic resistors on one graph. Apply a linear fit to each one.

15. Calculate the resistance of each circuit using the slope of your I *vs.* V graphs. Compare these R_{graph} values to the measured R_{eq} values using the percent difference formula (Eq. A.2, Page 155).

16. Plot a separate I *vs.* V graph for the light bulb.

17. Print a copy of both graphs.

QUESTIONS

1. Read the information in the next column. How much current would it take to cause pain? What was the maximum current you measured for this experiment?

2. Why was there no danger to you while you performed this experiment? The current required for this experiment is as high as 30 mA. Some experiments will require current as high as 5.0 A. Explain why there will be no danger to you. Read the information in the next column again, more carefully if necessary.

3. Is the graph of *I vs. V* for the light bulb linear? What does this tell you about the resistance of a light bulb as the filament gets hotter?

4. Compare the experimental (DMM, graph) values for each ohmic resistor.

5. Do the experimental values fall within the tolerance of the resistors? What might cause the values to exceed the tolerance?

6. The power output of a circuit is given by:

$$P = I^2 R = \frac{V^2}{R} = IV \qquad (15.2)$$

The resistors used in this experiment are 2-watt resistors. What is the maximum power output of R_1 when 9.0 V is applied across it (use your graph value)?

7. Calculate the power output of each ohmic resistor (use your graph value) when a potential of 7.00 V is applied.

8. Verify, using only the units provided in Table 14.1, that each part of Eq. 15.2 is equal to J/s. What is the unit of power output?

Can voltage kill you?

It's actually current that kills. So why are "*Hazardous Voltage*" signs so prevalent? Paul Hewitt[1] explains it very nicely:

> Consider Ohm's Law: $V = IR$. What is the resistance of your skin? That depends on the state of your skin: dry or wet. If it's wet, is it water or sweat? Sweat, of course, contains salt; salt water is a good conductor.

> The resistance will be dramatically different for different situations! Very dry skin has a resistance of about 500,000 Ω, while skin wet with salt water has a resistance of about 100 Ω. Once the voltage of a device and your skin's resistance are known, we can estimate the current that will flow through your body.

Current	Effect
0.001 A	Can be felt
0.005 A	Is painful
0.010 A	Causes involuntary muscle contractions (spasms)
0.015 A	Causes loss of muscle control
0.070 A	If through the heart, causes serious disruption; probably fatal if current lasts for more than 1 second

Table 15.2: Effect of Electric Current on the Body

Note that the effect caused by these currents are *approximate* values. It is quite difficult to get volunteers for this area of research!

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[1] Hewitt, Paul G., 2006. *Conceptual Physics*. Pearson Addison Wesley, San Francisco.