EXPERIMENTAL LAB #1 – INTRO TO EQUIPMENT & OHM'S LAW

This set of laboratory experiments is to be completed during the two-hour lab/recitation session. Please keep this handout, and make sure to write down (and keep) all calculations and measurements made. A brief, written lab report will be due at the beginning of the next lab session. Details of the lab report format are available on the course website.

PROCEDURE

1. Using the Digital Multimeter (DMM)
   1.1. The multimeter, as its name implies, is used to measure a multiplicity of electrical quantities – namely voltage, current, and resistance. To use the DMM, attach red and black cables to the appropriate inputs. First, the resistance of a few resistors will be measured. Select three different resistor values from the reels. Attach red and black cables to the DMM to measure resistance (Ω). Set the DMM to resistance mode.
   1.2. For three different value resistors, measure and record the resistance in Table 1.
   1.3. Each resistor uses a set of color bands to indicate its resistance. Use the provided resistor color code chart to calculate the expected resistance of each resistor in Table 1. Also calculate the percent error for each resistor as ((measured – expected)/expected*100) and record this in Table 1. Are these resistors within specification?

2. Using the DC Power Supply
   2.1. The DC power supply on the lab bench can supply both fixed (5V) and variable (0-30V) voltages. This instrument provides a constant (DC) voltage, and this will serve as the primary power source for all of the circuits in these labs. Locate the fixed 5V output, and attach red and black cables to these outputs. Turn on the power supply.
   2.2. Measure the 5V power supply output using the multimeter. It may be easier to connect the power supply and multimeter clip leads together with jumper wires, instead of connecting these together directly. The multimeter will need to be changed to DC voltage mode (notice that the DMM has separate AC and DC modes). What voltage is measured? (Two decimal places is fine for these measurements.)

   \[ V_{\text{out}} = \]

   2.3. Reverse the polarity of the measurement. What voltage is measured now?

   \[ V_{\text{out}} = \]

   2.4. Now locate the variable voltage output A on the power supply. Make sure the power supply is set to Independent Mode. Use the power supply and multimeter to set and measure a range of voltages from the power supply. This will demonstrate the operation of the variable power supply output.
3. **Using the Breadboard**

3.1. A solder-less breadboard is a convenient way to prototype electrical circuits without permanently attaching components (i.e. electrical elements) to a circuit board. Each numbered row on a breadboard contains two nodes; A-E are all wired together in each row, and F-J are all wired together in each row. Along each long edge are two long wires called bus bars; each side has a + wire and a – wire that run the length of the breadboard. Insert component leads or jumpers into the holes to make connections: inserting two (or more) wires into the same node (not the same hole) will connect these together.

![Breadboard Diagram](image)

3.2. Take a few minutes to understand the breadboard. Use a couple of jumper wires or resistors and the multimeter to verify that the breadboard layout makes sense.

3.3. Use the test leads and a couple of jumper wires to supply +3V to one of the two bus bars on the breadboard. Make sure the polarity is correct. Check this voltage somewhere else along the bus bar using the multimeter.

4. **Verifying Ohm’s Law**

4.1. In addition to measuring voltage (voltmeter), the multimeter can also measure current (ammeter). To use the DMM as an ammeter, three things must be done:

- Connect the leads to the correct multimeter inputs that correspond to DC current measurement. Notice that there are different connections for small (mA) and large (A) current measurements.

- Place the multimeter leads such that the multimeter is part of the circuit loop. The meter only measures current that runs through it. (In comparison, the voltmeter is used to measure voltage across an element.)

- Set the DMM to current mode.

4.2. Build a simple circuit on the breadboard using a large (1kΩ to 100kΩ) resistor and the variable voltage supply output. Be sure to include the multimeter in the circuit loop to measure the current. If a second multimeter is available, the voltage across the resistor can also be measured at the same time. This is described by the circuit diagram in Figure 1.

![Circuit Diagram](image)

**Figure 1.** Experimental setup for measuring current-voltage relationship in a resistor.
4.3. Adjust the supply voltage and measure the circuit current for at least 5 evenly spaced voltages. Do not exceed 12V. Record these values in Table 2.

4.4. Using Ohm’s Law, calculate the resistance for each voltage and current pair. Does this match with the measured and labeled resistor value? **Plot these recorded values as voltage vs. current in your lab report.** What is the slope of the line of best fit? What is the approximate y-intercept of this line?

5. **Equivalent Resistance**

5.1. The series and parallel resistor combinations described in class will now be verified. First, construct the resistor network shown in Figure 1 using a breadboard.
   - Measure the resistance between A and B. What is measured?
   - What theoretical resistance is expected for this series combination? (Show work.)

![Figure 1. Resistors in series.](image1)

5.2. Construct the resistor network shown in Figure 2.
   - Measure the resistance between A and B. What is measured?
   - What theoretical resistance is expected for this parallel combination? (Show work.)

![Figure 2. Resistors in parallel.](image2)

5.3. Consider the resistor network shown in Figure 3.
   - What theoretical resistance is expected for this combination (i.e., the equivalent resistance between A and B)? Build this resistor network on a breadboard.
   - Measure the resistance between A and B. What is measured?

![Figure 3. Network of series-parallel resistors.](image3)
6. **Voltage Divider**

6.1. Consider the circuit in Figure 4. This is commonly referred to as a voltage divider. Develop an expression for the output voltages ($V_{AB}$ and $V_{BC}$) in terms of $R1$, $R2$, and the source voltage ($V_o$).

\[
V_{AB} = \quad V_{BC} =
\]

6.2. With $R1 = 10k$ and $R2 = 22k$, what output voltages are expected for $V_{AB}$ and $V_{BC}$ when $V_o = 10V$?

6.3. Build the voltage divider shown in Figure 4 on a breadboard, using $R1 = 10k$ and $R2 = 22k$ and $V_o = 10V$.

6.4. Verify that $V_o = 10V$ with a voltmeter. Now measure $V_{AB}$ and $V_{BC}$ using a voltmeter. What voltages are measured?

6.5. Take measurements of $V_{AB}$ and $V_{BC}$ for at least five evenly spaced values of $V_o$, and record these in Table 3. Do not exceed $V_o = 10V$. At each voltage step, use a voltmeter to measure $V_o$, $V_{AB}$, and $V_{BC}$ directly. Move the voltmeter connections back and forth between $V_o$ and $V_{out}$ to accomplish this.

6.6. Repeat this experiment using $R1 = 10k$ and $R2 = 10k$, and record the values in Table 4.

6.7. Do measured $V_{AB}$ and $V_{BC}$ values match the values expected for 6.5 and 6.6?

![Circuit diagram for a resistive voltage divider.](image)

**Figure 4.** Circuit diagram for a resistive voltage divider.

7. Clean up the lab station, return all parts to the TA, and make sure to take home all lab tools.
Tables for Experimental Measurements

Table 1

<table>
<thead>
<tr>
<th>Resistor</th>
<th>Measured Resistance (Ω)</th>
<th>Expected Resistance (Ω)</th>
<th>Percent Error</th>
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Table 2

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<tr>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Calculated Resistance (Ω)</th>
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Table 3

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Table 4

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