**Experiment 1: Multimeter Measurements on DC Resistive Circuits**

**Objectives:**
- Measurement of voltage, current, and resistance using the multimeters provided in the lab.
- Proficiency creating electrical circuits using resistors, wires, and power supplies.
- Verify theoretically calculated results using basic network laws.

**Pre Lab:**
- Read and understand text sections: 1.2 through 1.7 and 2.1 through 2.2.
- Complete Prelab for Part A and Part B of experiment.

**Components Used:**
Variable Power Supply, Fluke 45 Multimeter (Autoscale), and Keithley 2000 Multimeter
Seven resistors with nominal values: 100Ω, 110Ω, 200Ω, 220Ω, 470Ω, 1kΩ, and 1.5kΩ.

**Part A: Resistance Measurements**

**Prelab:** Appendix B of the text describes the color code scheme used to identify resistor values. Determine color code for each of the seven nominal resistor values and enter in the *Color Code* column of the Data Sheet.

**Procedure:**
1. *Fluke 45 Multimeter Operation (Resistance Measurement)*
   - Turn the meter ON and press Ω for Resistance Measurement. Insert two wires in the jacks labeled **VΩ** and **COM**. The multimeter can now be used to measure the resistance of a component connected between these two wires. Initially the meter reads OL MΩ because the resistance of an open circuit is infinity.

2. Measure the resistance of each of the seven resistors and enter in the *Measured Value* column of the Data Sheet.

3. Determine the tolerance of each resistor as described on each component by the color of its band. A gold band represents 5%, a silver band represents 10%, and no band represents 20% tolerance. Enter in the *Tolerance* column of the Data Sheet.

4. Calculate the %Error for each resistor using the following formula:
   \[
   \%\text{Error} = \left( \frac{(\text{Nominal} - \text{Measured})}{\text{Nominal}} \right) \times 100\%
   \]
   Enter in the %Error column of the Data Sheet.

**Conclusions:**
1. Does each resistor meet manufacturer specifications?
Part B: Voltage and Current Measurements

Prelab: Calculate theoretical voltages and currents for each component of the circuit described in Figure 1. Enter these calculated values on the Data Sheet.

Procedure:

1. **Fluke 45 Multimeter Operation (Voltmeter - Voltage Measurement)**
   - Remove all connected wires. Turn the meter ON and press $V_{\text{--}}$ for DC Voltmeter Mode.
   - Insert a red wire in the jack labeled $V$ and a black wire in the jack labeled $\text{COM}$.
   - Voltmeters have very high resistance that typically exceeds 1 M$\Omega$. **When making voltage measurements, make certain the voltmeter is connected in parallel with the circuit components across which voltage is measured.** A common mistake is to connect the voltmeter in series with the circuit components. This error would add a 1M$\Omega$ series resistance to the circuit and drastically change the circuit parameters.

   - Remove all connected wires. Turn the meter ON and press $DCI$ for Ammeter Mode. Insert a connector to the white and black jacks. Select ‘auto’ range. For this experiment the 20mA range is the most appropriate.
   - Ammeters have very low resistance that typically is less than 0.5 $\Omega$. A common mistake is to connect the ammeter in parallel with the circuit components. **When making current measurements, make certain the ammeter is connected in series with the circuit components through which current is measured.** This error would effectively cause a short circuit and drastically change the circuit parameters.
   - *CAUTION: Never connect an ammeter directly across a power supply as it will cause a short circuit and be damaged.*

   - Use the 0-20V Supply on the far right labeled POWER TWO. The red jack provides a voltage source to the circuit and the black jack is considered the 0V reference voltage. Always begin by turning the VOLTS knob to the counter-clockwise stop so that voltage begins at 0V. After the circuit has been connected, switch the power supply ON. Turn the VOLTS knob slowly clockwise until the desired voltage is reached.
   - The meter reading on the power supply should not be used as accuracy is not insured. Use a calibrated DMM to measure voltage, such as the Fluke 45 Multimeter.
   - Current limit may be used to limit the current to a maximum amount.
   - *CAUTION: Always turn off the power supply before connecting a circuit.*

4. Connect the components as shown in the schematic shown in Figure 1.

*Figure 1*
5. Turn ON the power supply and adjust it so that the output is 6V as measured on the Fluke 45. Measure the source current using the Keithley 2000 and enter the current value on the Data Sheet.

6. Remove the Voltmeter from the power supply and measure voltages across each of the resistors in the circuit. Enter the voltage values for each resistor on the Data Sheet.

7. Now turn OFF the power supply.

8. Connect the 220Ω resistor in parallel with the 1000Ω resistor as shown by the schematic in Figure 2.

![Figure 2](image)

9. Turn ON the power supply and adjust it so that the output is 6V as measured on the Fluke 45.

10. Measure the source current using the Keithley 2000 and enter the current value on the Data Sheet.

11. Measure the voltage across each of the four resistors of the circuit and the source voltage using the Fluke 45. Enter these voltage values on the Data Sheet.

12. Measure the current through each resistor by connecting the Keithley 2000 in series with each component of the circuit. Enter these current values on the Data Sheet.

* CAUTION: The ammeter must always be placed in series with the resistor and never parallel.
**Part C: Wheatstone bridge circuit**

Calculate theoretical value for the equivalent resistance across points A and B in Figure 3. Also calculate the value of current in the ammeter of Figure 5. Enter these calculated values on the Data Sheet.

**Procedure:**

1. Turn OFF the power supply and connect the components as shown in Figure 3.

   ![Figure 3](image)

2. Turn ON the power supply.

3. Measure the resistance across points A and B, using Fluke 45 Multimeter and enter into the Data Sheet.

4. Turn OFF the power supply and modify the circuit as in Figure 4:
This circuit can be realized by using 2 sets of power supplies. Short the terminals of both sets to form the common point C per drawing in Figure 5.

5. Turn ON the power supplies.


7. Turn OFF the power supply and modify the circuit as in Figure 6:
8. Turn ON the power supply.

9. Measure the current across the branch XY, using Keithley 2000 Multimeter and enter into the Data Sheet.

**Conclusions:**
1. Examine the pre-lab theoretical and measured values for voltage and current of the circuit in Figure 1. Comment on the differences.
2. Calculate theoretical voltages and currents using the measured resistance values for the circuit of Figure 2. Tabulate your results. Comment on the correlation of measured and theoretical values? Explain possible sources of error.
3. Calculate the power supplied to the circuit from the power supply. Determine the power dissipation of each resistor in the circuit of Figure 2. Does your result satisfy the conservation of power law? Explain.
4. Do the theoretical results agree with what is expected by Kirchoff’s Laws? Explain.
5. Did the voltages $V_{470}$, $V_{1000}$, $V_{1500}$ in Figure 1, conform to the Voltage Divider?
6. Did the currents $I_{1000}$ and $I_{220}$ in Figure 2, conform to the Current Divider?
7. For Figure 3, did the theoretical and measured value of $R_{AB}$ match. If not comment.
8. For Figure 4, which nodes can be considered a “ground” node.
9. For Figure 6, why is the current $I_{XY}$ nearly zero.
Data Sheet

Part A: Resistance Measurements

<table>
<thead>
<tr>
<th>Nominal Value (Ohms)</th>
<th>Color Code</th>
<th>Tolerance (%)</th>
<th>Measure Value (Ohms)</th>
<th>Percent Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>220</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>470</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1000</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>1500</td>
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</table>

Part B: Voltage and Current Measurements

Figure 1 Circuit

<table>
<thead>
<tr>
<th>Calculated (Prelab)</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_s$</td>
<td></td>
</tr>
<tr>
<td>$I_s$</td>
<td></td>
</tr>
<tr>
<td>$V_{470}$</td>
<td></td>
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<td>$I_{470}$</td>
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<tr>
<td>$V_{1000}$</td>
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<tr>
<td>$I_{1000}$</td>
<td></td>
</tr>
<tr>
<td>$V_{1500}$</td>
<td></td>
</tr>
<tr>
<td>$I_{1500}$</td>
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</table>

Figure 2 Circuit

<table>
<thead>
<tr>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_s$</td>
</tr>
<tr>
<td>$I_s$</td>
</tr>
<tr>
<td>$V_{470}$</td>
</tr>
<tr>
<td>$I_{470}$</td>
</tr>
<tr>
<td>$V_{1000}$</td>
</tr>
<tr>
<td>$I_{1000}$</td>
</tr>
<tr>
<td>$V_{1500}$</td>
</tr>
<tr>
<td>$I_{1500}$</td>
</tr>
</tbody>
</table>

Part C: Voltage and Current Measurements

Figure 3 Circuit

$R_{AB}$ (Calculated in Prelab) =

$R_{AB}$ (Measured) =

Figure 4 Circuit

$V_{AB}$ =

$V_{BC}$ =

$V_{AC}$ =

Figure 6 Circuit

$I_{XY}$ (Calculated in Prelab) =

$I_{XY}$ (Measured) =

Your Name_____________________________

Partner Name___________________________

Lab Instructor________________________ Date______________