Series & Parallel Circuits
Spring 2019

Introduction

The purpose of this experiment is to observe the behavior of current & voltage for two resistors connected in series and in parallel, and to measure the equivalent resistance of these pairings. You will also observe the effect of a short circuit and an open circuit on some light bulbs.

Recall that voltage is measured across a circuit element, and current is measured through the element. When assembling circuits, first connect all the circuit elements, then the ammeter, and then connect the voltmeter last. This will ensure that the circuit is connected properly for your measurements. Record your meter settings, and always calculate % difference when comparing measurements. Remember to pull on the end connectors, not the wires.

Experiment

1. Resistors in Series: The goal in this section is to determine how current, voltage and resistance behaves for resistors in series

a. Predictions:
   i. What is the relationship between the voltages across resistors in a series circuit?
   ii. What is the relationship between the currents through resistors in a series circuit?

b. Measuring Resistance:
   i. Set the voltmeter so that it becomes an ohmmeter, allowing you to measure resistance directly (choose a scale setting to read with the greatest precision for your resistors).
   ii. Measure the resistance of each resistor, R₁ and R₂, without connecting them to a circuit.
   iii. Use a short wire to connect the two resistors together in series (don’t connect the resistors to any voltage source or other meters at this time). Use the multimeter to measure the equivalent resistance, Rₑq, for the pair of resistors.
   iv. Calculate the % difference between the Rₑq reading and the sum of the measured resistances, R₁ + R₂. When finished, switch your ohmmeter back to a voltmeter.

c. Measuring Voltage:
   i. Circuit set up: Connect the two resistors and an ammeter in series after the positive (+) terminal of the power supply, as shown. Set the ammeter to display to 0.1 mA, and then turn up the voltage knob on the power supply until the current reads 0.2 mA on the ammeter. Draw a circuit diagram in your report.
   ii. Set the voltmeter to display to 0.01 V, and then measure the voltage at these three locations:
      a) Across the pair of resistors, V.
      b) Across each resistor, V₁ and V₂.
      c) Across the power supply, Vₚ.
   iii. What is the algebraic relationship between V₁, V₂, and V? Use this relationship and your measured values to find an appropriate value to compare to your measured value of V.
   iv. Be sure to show the position of the voltmeter in your diagram as it was moved around the circuit.
d. **Measuring Current:**
   
   i. **Set up:** Remove the voltmeter from the circuit. Check that the current is still set to 0.2 \( mA \).
   
   ii. Turn off the DC power supply by turning off the switch (*don’t turn down the voltage*), and move the ammeter \emph{between} the two resistors. Turn on the power supply, and record the current.
   
   iii. Repeat once again, this time moving the ammeter between the negative (\(-\)) terminal and the pair of resistors.
   
   iv. Draw a circuit diagram that shows the position of the ammeter as it was moved around the circuit.
   
   v. What is the algebraic relationship between \( I, I_1 \) and \( I_2 \)? Use this relationship and your measured values to find an appropriate value to compare to your measured value of \( I \).

2. **Resistors in Parallel:** The goal in this section is to determine how current, voltage and resistance behaves for resistors in parallel

   a. **Predictions:**
      
      i. What is the relationship between the voltages across resistors in a parallel circuit?
      
      ii. What is the relationship between the currents through resistors in a parallel circuit?

   b. **Measuring Voltage:**
      
      i. **Circuit set up:** \emph{Turn the voltage knob on the power supply down to zero, and turn it off.} Connect the two resistors in parallel, and then place the ammeter in position \( A \), as shown. Turn on the power supply, and adjust the voltage knob until the total current, \( I \) through the circuit is 10 \( mA \).
      
      ii. Measure the voltage, without changing the DC power supply setting:
          
          a) Across resistor 1, \( V_1 \)
          
          b) Across resistor 2, \( V_2 \)
          
          c) Across the power supply, \( V \)
          
          d) Draw a sketch showing the position of the voltmeter for each of these measurements

      iii. What is the algebraic relationship between \( V_1, V_2 \), and \( V \)? Use this relationship and your measured values to find an appropriate value to compare to your measured value of \( V \).

   c. **Measuring Current:**
      
      i. **Circuit set up:** Remove the voltmeter from the circuit, and set it aside. Turn off the power supply \emph{(again without turning down the voltage)}, and move the ammeter to position \( A_2 \). Turn the DC power supply back on.
      
      ii. Measure \( I_2 \), the current through resistor 2.
      
      iii. Again turn off the DC power supply without turning down the voltage, and move the ammeter to position \( A_1 \). Check with your instructor that the meter is connected correctly, and then turn on the DC power supply.
      
      iv. Measure \( I_1 \), the current through resistor 1.
      
      v. What is the algebraic relationship between \( I, I_1 \) and \( I_2 \)? Use this relationship and your measured values to find an appropriate value to compare to your measured value of \( I \).
d. Measuring Resistance:
   i. **Set up**: Turn off the power supply. Disconnect the two resistors from the rest of the circuit, but leave the pair connected to each other.
   ii. Use the ohmmeter to measure the equivalent resistance, $R_{eq}$, for the pair of resistors.
   iii. Compare your measurement of the equivalent resistance to the expected value as calculated below, where $R_1$ and $R_2$ are the measured resistances from step (1b, part ii):

   \[
   \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}
   \]

3. **Open Circuits**: You will now qualitatively examine the effect of an *open circuit* (a break in the current path) on a pair of light bulbs. **No Meters Are Necessary For This Circuit**
   a. **Series**:
      i. **Circuit set up**: Set the meters aside, and turn them off. You have been provided with two small DC two light bulbs of the same wattage. Connect these two bulbs in *series*. Draw a circuit diagram, and then increase the voltage on the power supply until the built-in meter reads $7.0 \, V$.
      ii. Unscrew one of the bulbs and remove it. What happens? Screw this bulb back in, then unscrew the other. Record your observations.
      iii. Use your circuit diagram to briefly explain your observations (represent the bulb that was unscrewed by omitting it from the diagram and leaving a gap in its place).
   b. **Parallel**:
      i. **Circuit set up**: Turn off the DC power supply using the power button, leaving the voltage set to $7.0 \, V$. Connect the two bulbs in *parallel*, draw a circuit diagram, and turn on the DC power supply.
      ii. Unscrew one of the bulbs and remove it. What happens? Screw this bulb back in, then unscrew the other. Record your observations, describing the appearance of the bulbs at each step, and compare their appearance to that when they are connected in series.
   c. **Thought Questions**:
      i. Based upon your observations, explain whether you think the light bulbs in your house are wired in parallel or series.

4. **Short Circuits**: You will now qualitatively examine the effect of a *short* (a current path with zero resistance) on a pair of light bulbs. **No Meters Are Necessary For This Circuit**
   
   **Important Note**: Have your instructor check your circuit before turning on the DC power supply!
   a. **Bulbs in Series**:
      i. **Circuit set up**: Connect the two light bulbs in series, as shown. Your instructor will show you how to connect a knife switch across one of the bulb. Draw a diagram of the circuit.
      ii. **Make sure the switch is open**, then turn on the DC power supply (set to $7.0 \, V$), and observe the results.
      iii. Close the switch, and record your observations. Show the path that current will follow in your circuit diagram when the switch is closed, and briefly explain what you observed.
b. Bulbs in Parallel: **IMPORTANT NOTE: THIS EXPERIMENT CANNOT BE PERFORMED WHEN THE BULBS ARE CONNECTED IN PARALLEL! UNPLUG THE DC POWER SUPPLY FROM THE ELECTRICAL OUTLET BEFORE PROCEEDING!**

i. **Unplug the DC power supply's power cord before connecting this circuit.** Connect the two bulbs in parallel, and include a knife switch to short out one of the bulbs.

ii. Draw a circuit diagram, including the path that current will follow when the switch is closed.

iii. Briefly explain why you can't turn the DC power supply on.

**Discussion:**

- Summarize what you observed about the voltages and currents of resistors in series. Likewise, what did you observe about voltages and currents of resistors in parallel?
- Also summarize what you observed about the equivalent resistance of a pair of resistors connected in series and in parallel.
- Briefly summarize your observations for connecting bulbs in parallel and series. Explain why the bulbs are brighter when connected one way versus the other.