Series & Parallel Circuits
Spring 2024

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 a pair of light bulbs.

Important Notes to Remember

Recall that voltage is measured *across* a circuit element, and current is measured *through* the element. <u>When assembling circuits, *first* connect all the circuit elements, *then* the ammeter, and then connect the voltmeter last</u>. This will ensure that the circuit is connected properly for your measurements. ***Always** record meter settings and 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 behave 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*:

        Figure 1: Direct measurement of 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, R_1 and R_2, <u>without</u> connecting them to a circuit (**Figure 1**).
        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 just yet). Use the ohmmeter to measure the *equivalent resistance*, R_{eq}, for the pair of resistors.
        iv. Calculate $R_1 + R_2$, the sum of the individual measurements, and then calculate the % difference between this sum and R_{eq}. When finished, switch your ohmmeter back to a voltmeter.
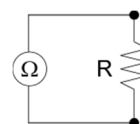
    c. *Measuring Voltage*:

        Figure 2: Resistors in Series

        i.   <u>Circuit set up</u>: Connect an ammeter and two resistors in series as shown in **Figure 2**. Draw this circuit diagram in your journal.
        ii. Choose an ammeter setting so that current is displayed to *one-hundredth of a milliampere*, and then set the voltage on the power supply until the current reads 1.00 *mA* on the ammeter.
        iii. Choose a voltmeter setting so that voltage is displayed to *one-hundredth of a volt* and measure the voltage at these three locations. *Show the position of the voltmeter in you circuit diagram for each measurement*:

            a) Across the *pair* of resistors, V (as shown in **Figure 2**)
            b) Across *each* resistor, V_1 and V_2.
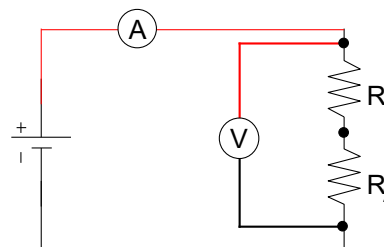   c) Across the power supply, V_P.

    iv.   What is the algebraic relationship between the voltages you just measured in (a) and (b)? Use this relationship and your measured values to find an appropriate value to compare to your measured value of V.

  d. *Measuring Current*:

      i.   <u>Set up</u>: Remove the voltmeter from the circuit. Check that the current is still set to 1.00 *mA*.

      ii.   Turn off the DC power supply by turning off the switch (***don't turn down the voltage***), and move the ammeter *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 algebraic relationship were you expecting between these measured currents? 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 behave 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*:

Figure 3: Resistors in parallel

      i.   <u>Circuit set up</u>: *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** (**Figure 3**). Turn on the power supply, and adjust the voltage knob until the total current, *I* through the circuit is 10.00 *mA*.

      ii.   Measure the voltage at the following positions, <u>without</u> changing the DC power supply setting. *Show the position of the voltmeter in you circuit diagram for each measurement*:

              a)   Across resistor 1, V_1

              b)   Across resistor 2, V_2

              c)   Across the power supply, V

      iii.   What algebraic relationship were you expecting between the three voltages just measured? Use this relationship and your measured values to find an appropriate value to compare to your measured value of V.
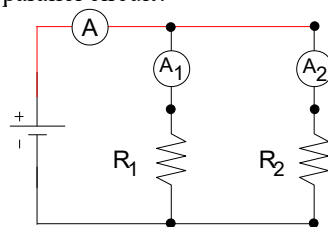
  c. *Measuring Current*:

      i.   <u>Circuit set up</u>: Remove the voltmeter from the circuit, and set it aside. Turn off the power supply (**again *without* turning down the voltage**), and move the ammeter to position **A₂**. 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 **A₁**. <u>Check with your instructor that the meter is connected correctly</u>, 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 and the currents just measured? Use this relationship and your measured values to find an appropriate value to compare to your measured value of I.

    d.   *Measuring Resistance*:

        i.   <u>Set up</u>: Turn off the power supply. Disconnect the two resistors from the rest of the circuit, but leave the resistor pair connected to each other.

        ii.   Use the ohmmeter to measure the equivalent resistance, R_{eq}, for the pair of resistors. *Check with your instructor that you are measuring this correctly* and draw a diagram showing this measurement.

        iii.   Calculate the equivalent resistance of the parallel resistors using the equation below (R_1 and R_2 are the measured resistances from *Experiment 1b, part ii*). Compare the calculated equivalent resistance to R_{eq} just measured.

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2}$$

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. Represent the illumination state of bulbs in your circuit diagram as shown in **Figure 4**.

    a.   *Series*:

        i.   <u>Circuit set up</u>: *NO METERS ARE NECESSARY FOR THIS CIRCUIT*, so set the meters aside, and turn them off. You have two small DC 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 (**Figure 4b**).
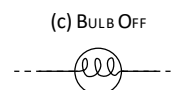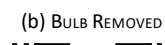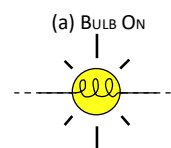
(a) BULB ON

(b) BULB REMOVED

(c) BULB OFF

Figure 4: Illumination state of bulbs

    b.   *Parallel*:

        i.   <u>Circuit set up</u>: 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 and briefly explain your observations*, describing the appearance of the bulbs at each step.

        iii.   Compare the appearance of the bulbs connected in parallel to their series connection. Why do you think the bulbs are brighter during one of these connections?

    Thought Question: Based upon your observations, do 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 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, **A** and **B** in series (**Figure 5**). Your instructor will show you how to connect a knife switch across one bulb. Draw a diagram of this circuit.

Figure 5: Knife switch & series bulbs

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 (**Figure 6**) and record your observations. Draw arrows on your circuit diagram to show the path that current will follow when the switch is closed (*obviously, the switch should be drawn <u>closed</u> here*).

iv. You should notice that something happens to each bulb when the switch is closed. Briefly describe and explain what you observe.
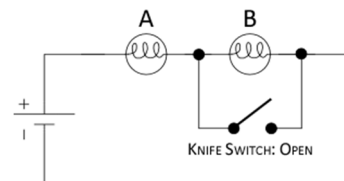
Figure 6: Closed knife switch

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 *with a closed switch*. Also show 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:

- Were your predictions from Experiment 1a and 2a correct? 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.