How Do We Sense, Think, and Move? -- Lab #8
Batteries, Bulbs, and Circuits

Task #1 - An Introduction to Two New Tools

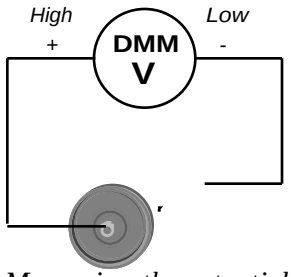
Your instructor will briefly introduce the following two new measurement tools. You will then use these tools to investigate the properties of a variety of circuit configurations during this lesson.

1. Write a brief summary of each tool in your logbook. Describe its name, what it measures, and how to use it correctly. Be sure to note the correct orientation of the meter when placing it in a circuit.

Using A Digital Multimeter to Measure Voltage

To measure the potential difference (V) between two points with the digital multimeter:

- Make sure that the voltage (V) button is pressed.
- Set the scale to its maximum value (1000 V).
- Place the two leads of the DMM on either side of the component you wish to measure. Place the high (+) lead on the positive terminal and the low (-) lead on the negative terminal.
- Adjust the scale to an appropriate range.
- Record the value.

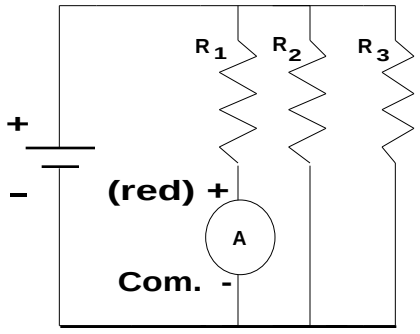


Measuring the potential difference V across a battery

Using An Analog Ammeter to Measure Current

Current flow is measured in units of amperes where 1 Ampere = 1 A = 1 C/s. Current can be measured by an instrument called an ammeter.

When connecting the ammeter into a circuit, make certain that the lead connected to the negative terminal of the battery connects to the negative (COM.) terminal of the ammeter. To measure the current flowing through a circuit, the ammeter must be connected directly into the circuit, in series with another component. That way, all the current flowing through the component of interest will flow through the meter!



Using an ammeter to measure the current I_1 through R_1

For our ammeters, each red terminal is labeled with the maximum current it can measure. Currents larger than the labeled values can damage the meter, so always start measuring currents using the terminal with the largest rating (5 A). If the pointer moves to the extreme right at any time, disconnect the meter (or the battery) immediately to avoid damage.

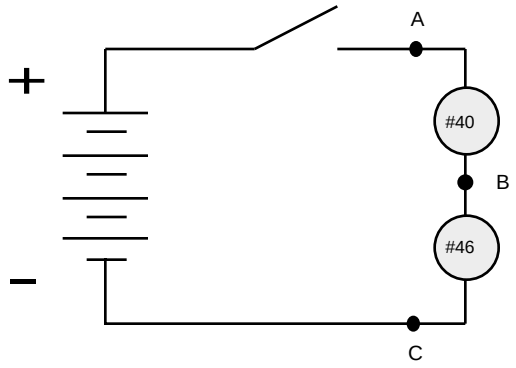
Task #2 - Measuring Potential Differences and Currents

Equipment: Digital multimeter (DMM), Ammeter, 4 D-cell battery set, Wood block with two mini sockets, Mini bulb #46 (red base), Mini bulb # 40 (blue base), Key switch, Banana leads

Experiment #1 – Two non-identical bulbs in series

Build the following circuit. This circuit is identical to one of the circuits that you built in recitation, except the bulbs are different from each other instead of being identical.

Circuit with two bulbs in series



2. Close the key switch and carefully observe the behavior of the two bulbs. Describe the brightness of each of the bulbs.

3. Discuss in your group the following prediction questions. Record a summary of your predictions and your rationale for making these predictions.

   - How would the potential difference measured across the #40 bulb and across the #46 bulb (if the switch were closed) compare to the potential difference across the batteries?
   - How would the current measured at points A, B, and C be related to each other (if the switch were closed)? Which currents would be largest, smallest, and / or identical?

You will now test your predictions by completing the following procedures. Be sure to close the key switch whenever you are taking a measurement. However, open the key switch any time you are not taking a measurement (to preserve the life of the batteries!).

- Draw a picture of the circuit in your logbook so you can clearly label what you are measuring.
- Using the DMM, measure the following three potential differences: across the battery set, across the #40 bulb, and across the #46 bulb. Label these values as V_{AC}, V_{AB}, and V_{BC}.
- Using the ammeter, measure the current flowing through the following three locations: A, B, and C. Label these values as I_A, I_B, and I_C.

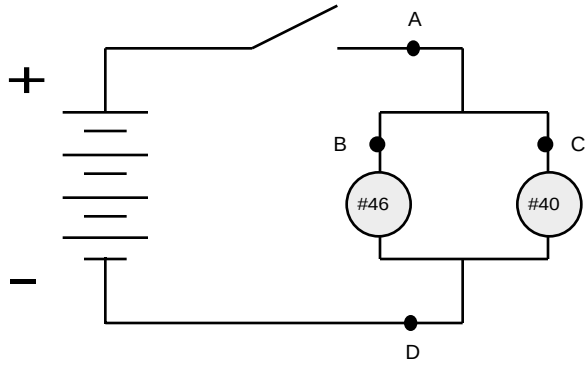
4. Compare the values of the potential differences that you measured. How do they appear to be related? Does this match your prediction (question #3)?

5. Compare the values of the currents that you measured. How do they appear to be related? Does this match your prediction (question #3)?

Experiment #2 – Two non-identical bulbs in parallel

Build the following circuit. This circuit is also identical to one of the circuits that you built in recitation, except the bulbs are different from each other instead of being identical.

Circuit with two bulbs in parallel



6. Close the key switch and carefully observe the behavior of the two bulbs. Describe the brightness of each of the bulbs. Compare the result to what you observed when the bulbs were in series.

7. Discuss in your group the following prediction questions. Record a summary of your predictions and your rationale for making these predictions.

   - How would the potential difference measured across the #40 bulb and across the #46 bulb (if the switch were closed) compare to the potential difference across the batteries?
   - How would the current measured at points A, B, C, and D be related to each other (if the switch were closed)? Which currents would be largest, smallest, and / or identical?

You will now test your predictions by completing the following procedures. Be sure to close the key switch whenever you are taking a measurement. However, open the key switch any time you are not taking a measurement (to preserve the life of the batteries!).

- Draw a picture of the circuit in your logbook so you can clearly label what you are measuring.
- Using the DMM, measure the following three potential differences: across the battery set, across the #40 bulb, and across the #46 bulb. Label these values as V_{AD}, V_{CD}, and V_{BD}.
- Using the ammeter, measure the current flowing through the following four locations: A, B, C and D. Label these values as I_A, I_B, I_C, and I_D.

8. Compare the values of the potential differences that you measured for this parallel circuit. How do they appear to be related? Does this match your prediction (question #7)?

9. Compare the values of the currents that you measured. How do they appear to be related? Does this match your prediction (question #7)?

10. Based on your data, describe how series and parallel circuits seem to be similar and how they seem to be different.

11. The word "resistance" is used to quantify how much of an obstacle a component adds to current flow through a circuit. Based on this description, which light bulb seems to have the greater resistance? Describe your reasoning.

Task #3 - What happens if you change the number of batteries?

Equipment: Digital multimeter (DMM), Ammeter, 4 D-cell battery set, Plastic circuit block, Three assorted resistors, Key switch, Banana leads

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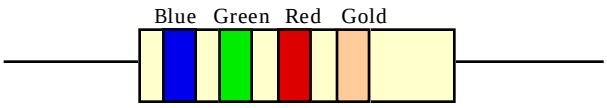
Introduction to A New Tool: Resistor Color coding

Resistors are circuit elements that have been manufactured to have a specific value of resistance within a given tolerance (say, within ± 5%). To assist in the easy identification of resistors, the industry has adopted a color code system to identify the resistance values.

Sample Resistor:



6 5 2 5%

R = 65 x 10 ^{2} Ω ± 5%

R = 6500 Ω ± 325 Ω

Last (fourth) band = Tolerance

Gold	± 5%
Silver	±10%
None	±20%

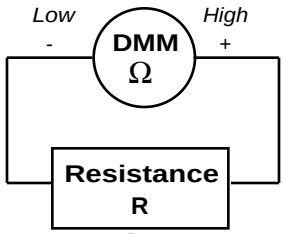
Resistor Color Code Scheme

silver	-2
gold	-1
black	0
brown	1
red	2
orange	3
yellow	4
green	5
blue	6
violet	7
gray	8
white	9

Using a Digital Multimeter to Measure Resistance

To measure the resistance (Ω) of something:

- Press the resistance (Ω) button on the DMM.
- Set the scale to its maximum value (20M).
- Place the two leads of the DMM on either side of the component you wish to measure. Make sure the component is isolated. That is, nothing should be connected to the component except the two leads of the DMM.
- Adjust the scale to an appropriate range.
- Record the value.



Measuring the resistance R of a circuit element

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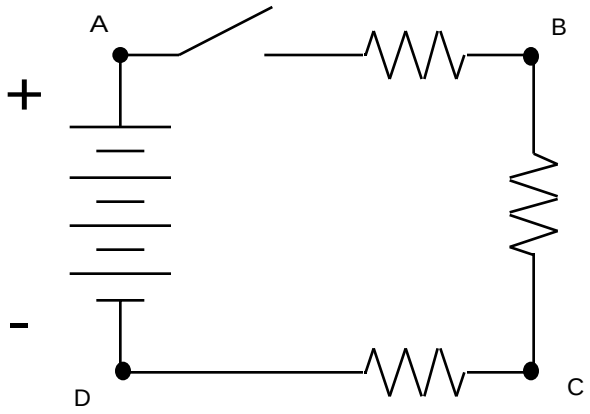
12. Using the color codes, identify and record the expected resistance of your 3 resistors. Securely install the resistors to the plastic circuit block. Using the DMM, measure and record the actual resistance of each of these resistors. Label these values as R_1, R_2, and R_3. How well did the color code system work?

Experiment #3 – Three resistors in series

Build the following circuit with the three resistors.



Circuit with three resistors in series

Carefully draw this circuit in your logbook including the corresponding labels (R_1, R_2, and R_3). Clearly identify the value of resistance you measured for each on your drawing.

You will now study the properties of this circuit in the same way you investigated the circuits with the bulbs. Be sure to close the key switch whenever you are taking a measurement. However, open the key switch any time you are not taking a measurement (to preserve the life of the batteries!).

- Using the DMM, measure the following four potential differences: V_{AB}, V_{BC}, V_{CD}, and V_{DA}.
- Using the ammeter, measure the current flowing through the following four locations: A, B, C and D. Label these values as I_A, I_B, I_C, and I_D.

Record all data clearly in your logbook.

13. Compare the values of the potential differences that you measured for this series circuit. How do they appear to be related to each other?

14. Compare the values of the currents that you measured. How do they appear to be related to each other?

15. Based on this series circuit and your results to the circuit with the bulbs in series…

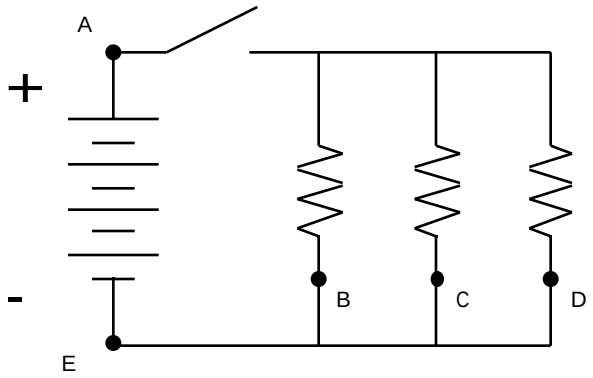
    - In words, write a rule that describes the potential differences that can be found in a series circuit.

    - In words, write a rule that describes the currents that can be found in a series circuit.

16. In a series circuit, what effect do the relative sizes of the three resistors seem to have?

Experiment #4 – Three resistors in parallel

Build the following circuit with the same three resistors.



Circuit with three resistors in parallel

Carefully draw this circuit in your logbook including the corresponding labels (R_1, R_2, and R_3). Clearly identify the value of resistance you measured for each on your drawing.

You will now study the properties of this circuit in the same way you investigated the circuits with the bulbs. Be sure to close the key switch whenever you are taking a measurement. However, open the key switch any time you are not taking a measurement (to preserve the life of the batteries!).

- Using the DMM, measure the following potential differences: V_{AB}, V_{AC}, V_{AD}, and V_{EA}.
- Using the ammeter, measure the current flowing through the following locations: A, B, C, D, and E. Label these values as I_A, I_B, I_C, I_D, and I_E.

Record all data clearly in your logbook.

17. Compare the values of the potential differences that you measured for this parallel circuit. How do they appear to be related?

18. Compare the values of the currents that you measured. How do they appear to be related?

19. Based on this parallel circuit and your results to the circuit with the bulbs in parallel…

    - In words, write a rule that describes the potential differences that can be found in a parallel circuit.

    - In words, write a rule that describes the currents that can be found in a parallel circuit.

20. In a parallel circuit, what effect do the relative sizes of the three resistors seem to have?

Task #4 - Comparing Your Results with Theory

Using the ideas of Ohm's Law (Discussed in section 20.2 of the textbook), you can make theoretical predictions for the behavior of series circuits (See section 20.6) and parallel circuits (See section 20.7). A summary of this theory includes:

Series Circuits

- The same current flows through each device in the circuit.
- The voltage applied by the battery is divided among the resistors.
- The equivalent resistance of the circuit, R_S, can be calculated by $R_S = R_1 + R_2 + R_3 + ...$
- The current flowing through the circuit for a known applied battery potential difference $V_{Battery}$ can be calculated by $V_{Battery} = I R_S$.

21. Using your measured values of resistance, potential differences, and currents,
    - Estimate the equivalent resistance R_S of your series circuit.
    - Using this value of R_S and the potential difference across the batteries to predict the value of the current flowing through the circuit. Show your work.
    - Compare your predicted current value with what you actually measured.

Parallel Circuits

- The same potential difference voltage is applied across each device.
- The total current flowing from the battery is divided among the resistors.
- The equivalent resistance of the circuit, R_P, can be calculated by $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...$
- The current flowing through the circuit for a known applied battery potential difference $V_{Battery}$ can be calculated by $V_{Battery} = I R_P$.

22. Using your measured values of resistance, potential differences, and currents,
    - Estimate the equivalent resistance R_P of your parallel circuit.
    - Using this value of R_P and the potential difference across the batteries to predict the total value of the current flowing from the battery. Show your work.
    - Compare your predicted current value with what you actually measured.

23. Did you find the same current flowing from the batteries for the two circuits?

24. How well did the theory match your experiments? What effect might the meters have had on your results?

<u>End of Lab Cleanup</u>

Complete the following before you leave…
- Turn off the multimeter.
- Unplug all banana leads.
- Return the three resistors to the box provided at your station.