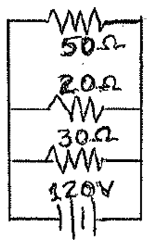
Name:______________________________ ID:______________________________

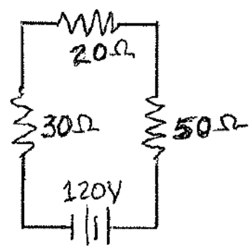
Pre-Lab 6: Simple DC Circuits

Pre-Lab Due 5/25

The pre-lab questions are to be answered using the provided template. Only the pre-lab work needs to be digitized into PDF format and uploaded to gradescope.com by the due date.

Consider the two simple circuits shown. Fill-in the blanks below each, doing any needed calculations.





1. ___________________________ resistors in series? or parallel? ___________________________

2. ___________________________ total (equivalent) resistance? ___________________________

3. ___________________________ total current? ___________________________

4. ___________________________ total power dissipated? ___________________________

5. ___________________________ 30 Ω resistor current? ___________________________

6. ___________________________ 20 Ω resistor current? ___________________________

7. ___________________________ 50 Ω resistor current? ___________________________

8. ___________________________ sum 30 Ω, 20 Ω, 50 Ω currents? XXXXXXXXXXXXXXXX

9. ___________________________ compare #3 and #8 XXXXXXXXXXXXXXXXX

10. __________________________ 30 Ω voltage drop? ___________________________

11. __________________________ 20 Ω voltage drop? ___________________________

12. __________________________ 50 Ω voltage drop? ___________________________

13. XXXXXXXXXXXXXXXX sum 30 Ω, 20 Ω, 50 Ω voltages? _________________________

14. XXXXXXXXXXXXXXXX compare #13 to battery? ___________________________

15. If the resistors were replaced by hotdogs, which ones would cook the fastest? Why?

16. For the parallel circuit, does adding more resistors (in parallel) increase or decrease the total current? Why?

17. For the series circuit, does adding more resistors (in series) increase or decrease the total current? Why?

Lab 6: Simple DC Circuits

I. Using Voltmeters and Ammeters and Analyzing Circuits
In this part you will learn how to use voltmeters and ammeters to measure the voltage and the current in a circuit. You will use a ***digital multimeter*** which can measure different things.

A. <u>Measuring voltage.</u> To measure the voltage drop (potential difference) between two points in a circuit, the two leads of the voltmeter are connected across those two points. In other words, the voltmeter is connected *in parallel* with the portion of the circuit between those points.

Consider a simple circuit consisting only of a battery of terminal voltage *V* and a resistor of resistance *R*. Current *I* flows in the circuit.

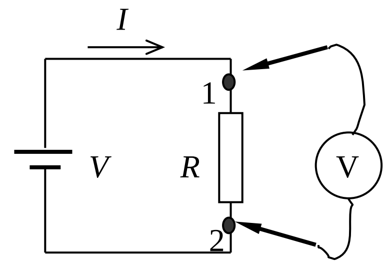


Figure 1

To find the voltage drop across the resistor, the two leads of the voltmeter can be connected to points 1 and 2, as shown. Note that this can be done *without* breaking the circuit or disconnecting any of the circuit components. An ideal voltmeter is a device with infinite resistance, so that it should not have any effect on the circuit if it is connected as in Figure 1.

Symbolically, the voltmeter connection is shown as in Figure 2.

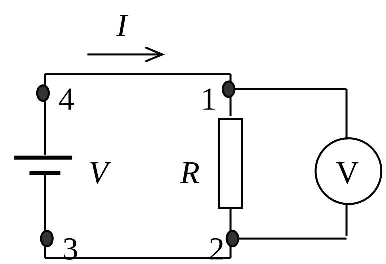


Figure 2

Set the multimeter to **DCV**. Plug one of the leads into the **COM** (common) terminal and the other into the **V/Ω** terminal.

1. On the spring board, set up the circuit as shown in Figure 2 and measure the following voltage differences. In each case, put the voltage probe connected to the **V/Ω** terminal at the circuit point represented by the first subscript and the probe connected to the **COM** terminal at the circuit point represented by the second subscript. Thus $\Delta V_{BA} = V_B - V_A$ when the **V/Ω** probe contacts point B and the **COM** probe contacts point A. Also, record the sign of each potential difference (as given by the multimeter display.)

V (as on battery) __________________ *R* (as color coded on resistor)__________________

ΔV_{21} ______________ ΔV_{32} ______________ ΔV_{43} ______________

2. How does the magnitude of the voltage difference across the resistor (ΔV_{21}) compare with the magnitude of the voltage difference across the battery (ΔV_{43})?

3. Interpret your measurement of the voltage difference ΔV_{32}.

4. Remove the battery from the circuit. Measure the voltage difference between its terminals and compare with the value you obtained for ΔV_{43}. Same? Different? What does any difference tell you about the *internal resistance* of the battery?

B. Measuring current. To measure the current passing through any point in a circuit, the circuit must be broken and the two leads of the ammeter must be connected between the broken points of the circuit. In other words, the ammeter must be connected in series in the portion of the circuit where the current is to be measured.

A perfect ammeter has zero resistance so as to not to affect the circuit in which it is connected. **NEVER CONNECT AN AMMETER ACROSS A BATTERY (EMF SOURCE) OR A SINGLE CIRCUIT ELEMENT (RESISTOR). THE LOW RESISTANCE WILL RESULT IN HIGH CURRENT AND EITHER BLOW THE FUSE OR BURN UP THE METER. (DO NOT TRY THIS TO VERIFY!)**

Suppose we "break" the circuit at point 4 and connect the ammeter between the open points, as shown in Figure 3. The ammeter will then measure the current that flows through point 4. Figure 4 shows the symbolic representation of an ammeter in the circuit.

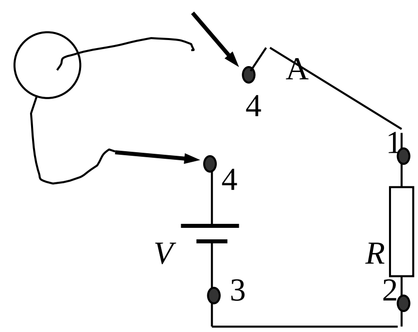


Figure 3

5. Set the multimeter to **DCA**. Plug one of the leads into the **COM** (common) terminal and the other into the **A** (ampere) terminal. Measure the current at points 1, 2, 3, and 4 for your set-up circuit (as in Figure 4.)

I_1________________ I_2________________

I_3________________ I_4________________

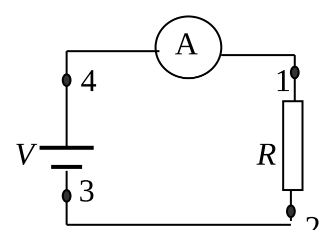


Figure 4

6. What do you conclude about the current at different points in this circuit?

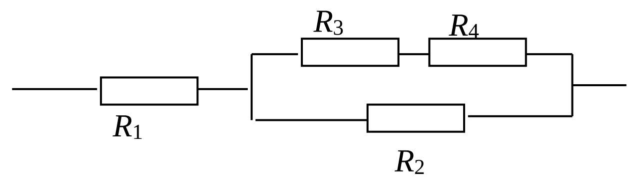
7. Does current get “used up” in passing through the resistor? Explain.

8.Use your values of the current through the resistor and the voltage drop across the resistor to calculate the value of the resistance. Compare to the value and tolerance expected based on the resistor color code.

II. Resistors in Series and in Parallel

9. Draw the portion of a circuit described by the following words: A series combination of R_1 and R_2 is in parallel with a series combination of R_3 and R_4.

10. Consider this portion of a circuit:



Write one sentence that describes this arrangement of four resistors.

11. Set up the circuit as shown in Figure 5, measure the following voltage differences and currents.

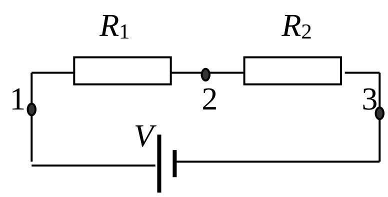


Figure 5

V__________ R_1__________ R_2__________

ΔV_{21}__________ ΔV_{32}__________

I_1__________ I_2__________ I_3__________

12. Calculate the expected value of the current and compare with your measured values.

13. Calculate the expected values of the voltage differences across the resistors and compare with your measured values.

14. For this circuit, we expect that $V = |\Delta V_{21}| + |\Delta V_{32}|$. Are your data consistent with this expectation?

15. Remove the battery from the circuit. With the multimeter probes set as for measuring voltage, turn the dial to measure resistance. Measure the total resistance (from points 1 to 3). Is this consistent with a calculated value based on the resistors color codes?

16. Set up the circuit as shown in Figure 6, measure the following voltage differences and currents.

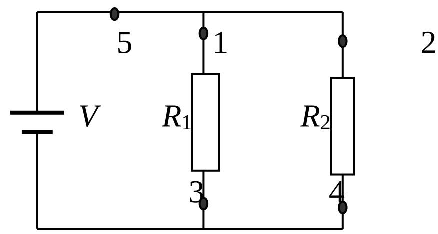


Figure 6

V__________ R_1__________ R_2__________

ΔV_{31}__________ ΔV_{42}__________

I_1__________ I_2__________

I_3__________ I_4__________ I_5__________

17. Calculate the expected value of the currents and compare with your measured values.

18. For this circuit we expect $I_5 = I_1 + I_2$. Are your data consistent with this expectation?

19. Remove the battery from the circuit. With the multimeter set to measure resistance, measure the total resistance (from points 1 to 3 or 2 to 4). Is this consistent with a calculated value based on the resistors color codes?

20. Set up a circuit of your own design, including at least five resistors with both series and parallel sections. Draw a circuit diagram of your circuit below. Calculate the total (equivalent) resistance of your circuit and compare to the multimeter resistance measurement of the whole circuit. Compute the total current through this circuit and measure (with the ammeter) the total current through this circuit. Do all values agree approximately (within resistor tolerances)?

III. Light Bulbs (another kind of resistor) in Series and in Parallel
For this activity, there are only 3 set-ups in the room. You will have to budget your time and share the equipment with others in the room.

Here, you will further consider some properties of resistors (light bulbs) in various series and parallel arrangements, connected to the AC line voltage of a conventional, 120V outlet. Even though we have been discussing only DC circuits, the same relationships ($V = IR$, $P = V^2/R = I^2R$) we have been using for DC circuits are also valid for AC circuits. Note one difference: In contrast to a real battery with internal resistance, the AC supply to the lab room (and your house) provides a voltage that is *regulated*, that is, it's independent of the current in the circuit.

Another difference here: The resistors used in the previous parts of this lab are said to be *ohmic*, that is, they obey Ohm's Law. But, the resistance of a light bulb filament depends on its temperature and this will change as the current through it changes. A light bulb filament is an example of a *non-ohmic* device. The relationship $V = IR$ is valid for any particular value of V or I, but R is not a constant and will change as V or I changes. However, that shouldn't be a factor in your observations below.

For each of these experimental set-ups, you will first make a prediction and then test your prediction with a corresponding trial and observation. Generally the answer to each question will be one of the following:
(A) Intensity increases (B) Intensity remains the same
(C) Intensity decreases but bulb remains lit (D) Intensity decreases to zero
After making the observation, explain why that particular result occurs.

DO THE EXPERIMENTS IN THE ORDER GIVEN IN THIS ACTIVITY.

21. Bulbs in parallel. Consider the circuit with three bulbs in parallel (Figure 7). What happens to bulbs 1 and 2 if bulb 3 is removed from the circuit (leaving an open circuit in its position)?

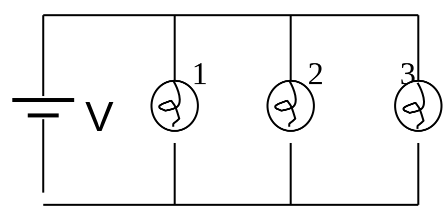


Figure 7

Prediction: Bulb 1 -
Bulb 2 -

Observation: Bulb 1 -
Bulb 2 -

Explanation:

Would your answers be different if you had removed bulb 1 or bulb 2 instead of bulb 3? Explain and then test your answer.

22. <u>Bulbs in series.</u> Consider the circuit with three bulbs in series (Figure 8). What happens to bulbs 1 and 2 if bulb 3 is unscrewed and removed from the circuit?

Prediction: Bulb 1 -
Bulb 2 -

Observation: Bulb 1 -
Bulb 2 -

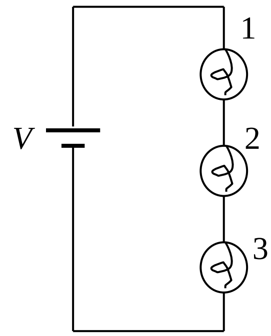


Figure 8

Explanation:

Would your answers be different if you had removed bulb 1 or bulb 2 instead of bulb 3? Explain and test your answer.

23. <u>Combinations of series and parallel connections.</u> Consider the five-bulb circuit shown in Figure 9. (The bulb numbers given in the figure match the numbers written on the circuit board.)
(a) What happens to the intensities of the other bulbs if bulb 5 is unscrewed and removed from the circuit?

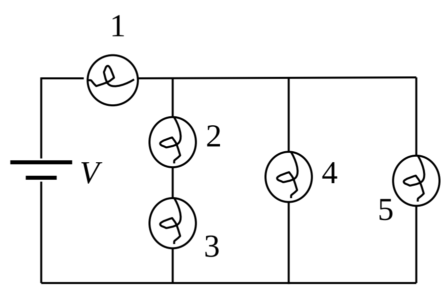


Figure 9

Prediction: Bulb 1 - Bulb 2 -
Bulb 3 - Bulb 4 -

Observation: Bulb 1 - Bulb 2 -
Bulb 3 - Bulb 4 -

Explanation:

(b) What happens to the intensities of the other bulbs if bulb 2 is unscrewed and removed from the circuit?

Prediction: Bulb 1 - Bulb 3 -
Bulb 4 - Bulb 5 -

Observation: Bulb 1 - Bulb 3 -
Bulb 4 - Bulb 5 -

Explanation:

(c) What will be the relative intensities of bulbs 1,2, and 3 if bulbs 4 and 5 are unscrewed and removed from the circuit?

Prediction: Bulb 1 - Bulb 2 -
Bulb 3 -

Observation: Bulb 1 - Bulb 2 -
Bulb 3 -

Explanation:

24. Changing the power of one bulb. All of the bulbs used in these circuits are 10-watt bulbs. Would you expect the resistance of a 25-watt bulb to be higher, or lower than the resistance of a 10-watt bulb? Explain briefly.

Back to the three-bulb parallel circuit , suppose you replaced one of the 10-W bulbs with a 25-W bulb. How would the intensity of the two remaining 10-W bulbs change (compared with their intensity before you made the switch)?

Would the intensity of the 25-W bulb be larger (brighter) or smaller (dimmer) than the intensity of the 10-W bulbs?

Test these predictions and explain your observations.

Back to the three-bulb series circuit, suppose you replaced one of the 10-W bulbs with a 25-W bulb. How would the intensity of the two remaining 10-W bulbs change?

Would the intensity of the 25-W bulb be larger (brighter) or smaller (dimmer) than the intensity of the 10-W bulbs?

Test these predictions and explain your observations.