AP Physics 1 Combination Circuits Lab

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Background

Gustav Kirchoff expanded on Ohm's law (V = IR) by considering how energy and charge must be conserved in a circuit. This work can be summarized into two rules which are necessary when determining the current and voltage in simple and complex circuits.

Kirchoff's Loop Rule states that *following a closed loop from any point in a circuit, the net change in voltage (electric potential) is equal to zero*.

Kirchoff's Junction Rule states that *the sum of currents flowing into a node (i.e. a place where two or more wires meet) is equal to the sum of the currents flowing out of the node*.

Pre-Lab Questions

Figure 1 is a simplified model of the circuit in Ohm's Law Lab. Use the figure to answer the following questions.

1. What is the voltage drop between points A and B? Why?

> The voltage drop is equivalent to 6[V]. Kirchoff's law states that, in series, the voltage drop across each component is equal to the power source.

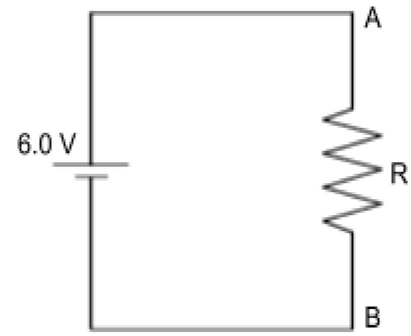


Figure 1

2. The current at A is measured with an ammeter to be 0.125 A. What would be the expected current at B? Why?

> The current at point B would be the same as the current at point A because the circuit is in series.

3. Use the given values to calculate the resistance of the resistor.

> $V = IR \rightarrow 6 = .125R \rightarrow R = 48[\Omega]$

Figure 2 is a graph showing the electric potential as a function of position through the circuit in Figure 1. The red arrow indicates the direction of the current flowing in the circuit.

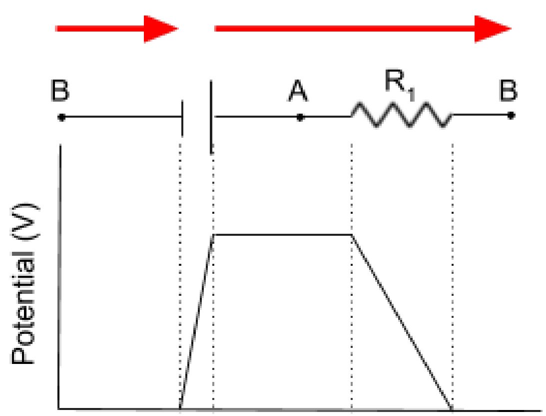


Figure 2

4. Explain how the graph supports Kirchoff's Rules.

> This makes sense because the voltage drop across the resistor is 6, and therefore, the voltage would 'drop' from the 6 it was to 0 after the resistor. The voltage then builds back up when it moves through the battery,

and it creates this discharge ‘cycle.

Guided Design of Series and Parallel Circuits

Part A. Series Circuit

Figure 3 is a schematic of a circuit with R_1 and R_2 in series. Use the schematic and circuit building materials to help you answer the following questions.

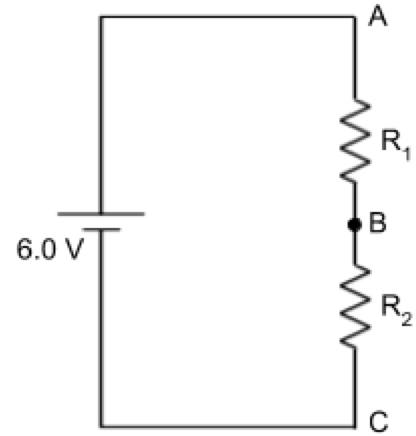


Figure 3

5. What is the voltage drop (potential difference) between points A and C? Explain your reasoning.

The voltage drop would be 6[V] because in a series, the sum of the voltage drop across al, components is equal to the power source

6. If the current at point A is measured with an ammeter to be 0.155 A. What would be the expected current at points B and C? Explain your reasoning.

Current is uniform throughout a series, and is therefore .155[A] at any point on this circuit.

7. What is the overall effective resistance (R_{eff}) of the circuit? Use Ohm’s Law to calculate.

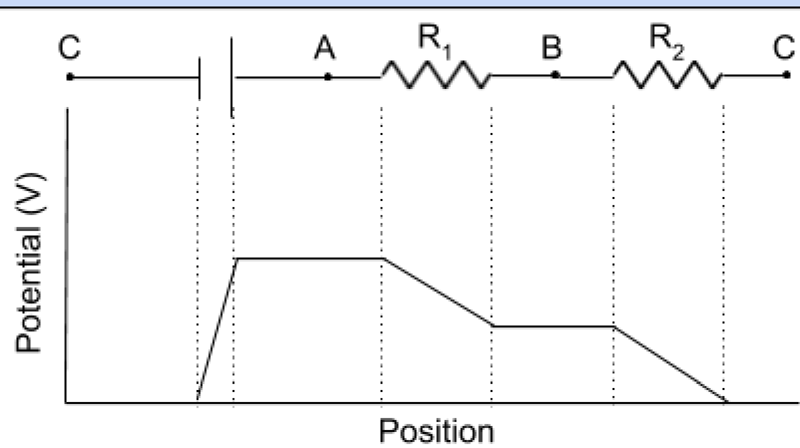
$V = IR \rightarrow 6/.155 = R \rightarrow R = 38.71[\Omega]$

8. Considering your answers to the previous questions, write a formula that relates the effective resistance (R_{eff}) to the individual resistors. (Note: to insert subscripts on a google doc, go to Format > Text > Subscript)

$$R_{eff} = \sum_{1}^{i} R_i$$

9. Construct a graph of potential versus position for the circuit in Figure 4. Hint: See figure 2 from the Pre-Lab.

Double click here to edit this drawing to include lines to graph the potential (V). It’s not the easiest, so take your time. If you would rather draw by hand and upload a picture, you can do that



Part B. Parallel Circuit

Figure 4 is a schematic of a circuit with R_1 and R_2 in parallel. Use the schematic and your circuit building materials to help you answer the following questions.

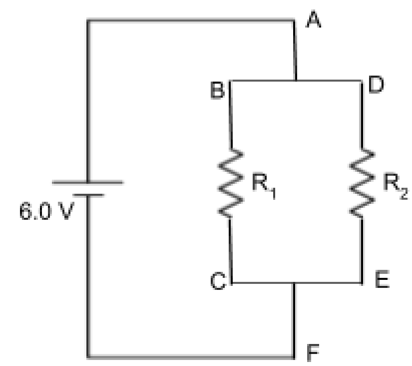


Figure 4

10. What is the voltage drop (potential difference) between points A and F? Would this potential difference be observed between points B and C or between points D and E? Explain your reasoning.

The voltage drop from point A to F is still 6[V]. This is because, although the resistors are attached in parallel, the circuit continues as though it is in series when it passes through the resistors. The voltage drop would be 6[V] for all other points as well. This is because in a parallel circuit, all 'loops' have the same voltage drop as the source supplying it.

11. If the current at point A is measured with an ammeter to be 0.205 A. What would be the expected current at point F?

The current at point A is the same as the current at point F. This is because, although inside of the parallel resistors it is different, the current adds back together to come back to .205[A]

12. Would you expect the same value of current, 0.205 A, at points B, C, D, and E? Explain your reasoning.

No, because inside of a parallel piece, the current splits. This makes sense logically, because it is like water flow splitting into two pipes.

13. What is the overall effective resistance (R_{eff}) of the circuit? Use Ohm's Law to calculate.

$V = IR \rightarrow 6 = .205R \rightarrow R = 29.27\,[\Omega]$

14. Considering your answers to the previous questions, write a formula that relates the effective resistance (R_{eff}) to the individual resistors.

$$\frac{1}{R_{eff}} = \sum_{1}^{i} \frac{1}{R_i}$$

15. After point A, there is a junction where current can flow into R_1 or R_2.
    a. Explain what the conditions must be for the current to split equally between R_1 and R_2.

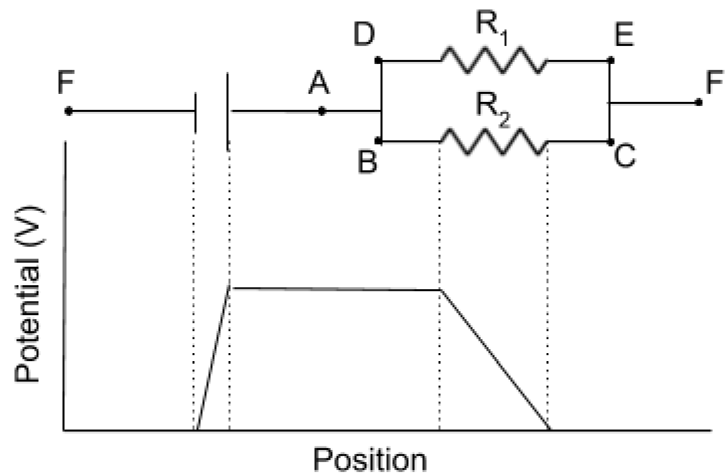
The resistors must have equivalent resistance in order to split evenly

    b. Explain what the conditions must be for the current in R_1 to be greater than the current in R_2.

The resistance in R_1 must be lower than the resistance in R_2 for the current to be greater

16. Construct a graph of potential versus position for the circuit in Figure 4. Hint: See figure 2 from the Pre-Lab.

Double click here to edit this drawing to include lines to graph the potential (V). It's not the easiest, so take your time. If you would rather draw by hand and upload a picture, you can do that



17. What data would you need to collect in order to determine the resistance of each individual resistor, R_1 and R_2?

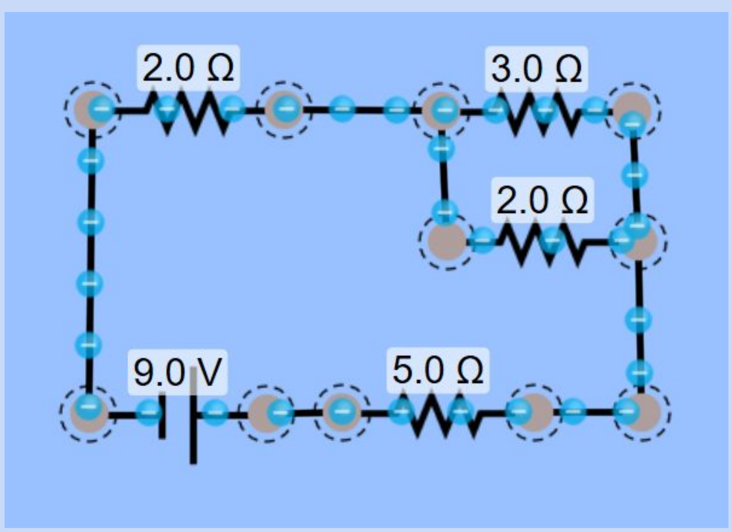
You would need to know the voltage supplied, the total current, and one of the currents, either in R_1 or R_2

Design Your Own!
For this part of the lab, you are welcome to work with up to a group of 4 (via phone, google hangouts, etc.). Note that this does not mean you are copying the work of those people, it means you are discussing the lab and making decisions together. If you decide to work with others, indicate the names of those people you worked with here:

Just Me

Design a circuit using three to four resistors with **both series and parallel components**.

1. Draw a schematic for your design. I would recommend doing this on paper, taking a picture of it, and inserting the picture in the space below. You can also do this electronically, it is just much more tedious. Label the resistance for each resistor and the voltage of the power source your group intends to use. (recommended 9.0 V, as this is the voltage of the default battery in the simulation)



2. Before constructing your circuit, complete a V-I-R chart using the theoretical values specified in the circuit diagram. Do this before constructing your circuit!
   - ★ Yellow boxes are the information you should know from your circuit diagram above.
   - ★ Blue boxes are values you will need to calculate using that information

	V[V]	**I[A]**	**R[Ω]**
1	2.196	1.098	2
2	1.314	.438	3
3	1.314	.657	2
4 ***(optional)***	5.49	1.098	5
Total	9	1.098	8.2

3. Now construct your circuit using the [Circuit Construction PhET](). Use the ammeter and voltmeter to determine the experimental current, potential differences, and effective resistances for each component.

Component	Experimental Voltage (V)	Experimental Current (A)	Experimental Resistance (Ω)
1	2.20	1.10	2
2	1.32	.44	3
3	1.32	.66	2
4	5.49	1.10	5
Total	9	1.10	8.2

4. Check your measurements against your calculations in the previous table. Any discrepancies? Were there any mistakes that you made in your calculations? How can you fix those mistakes moving forward?

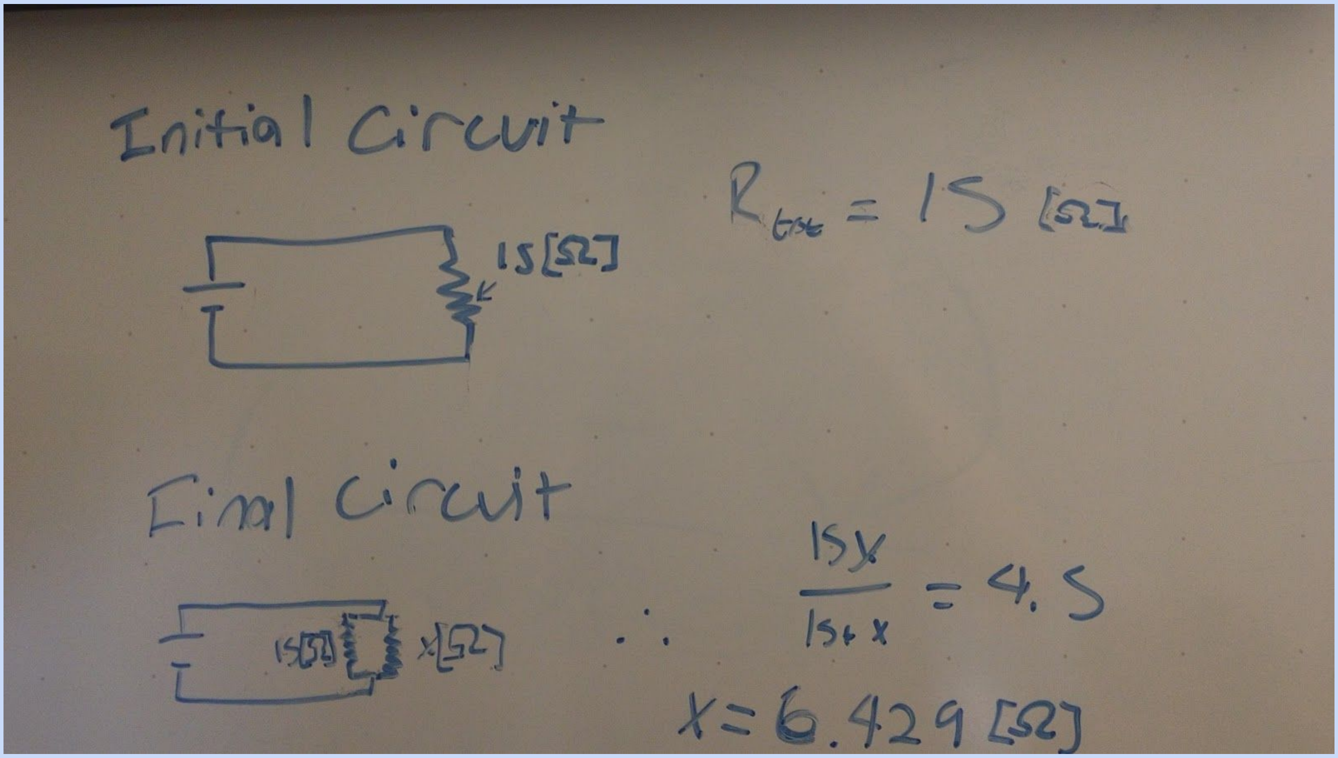
The only differences most likely occurred because of rounding differences.

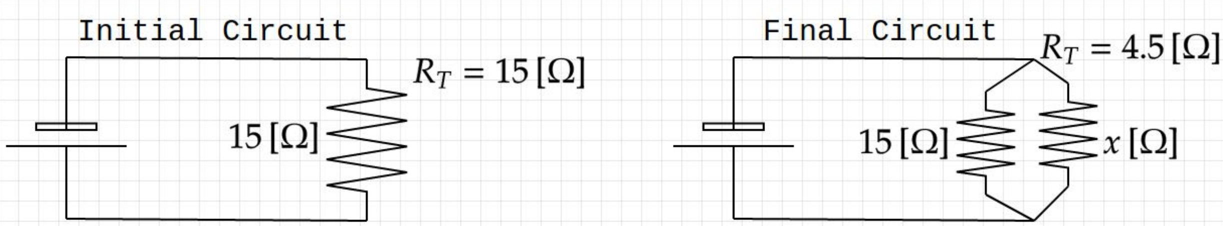
Analysis Questions:

1. The resistance through one branch of a circuit is measured to be 15.0 Ω. A resistor is added to the branch. The total resistance is now measured to be 4.5 Ω.
   a. Was the new resistor added in series or parallel to the branch? Explain your reasoning.

The new resistor is in parallel because overall resistance can decrease only if a weak resistor is added in parallel.

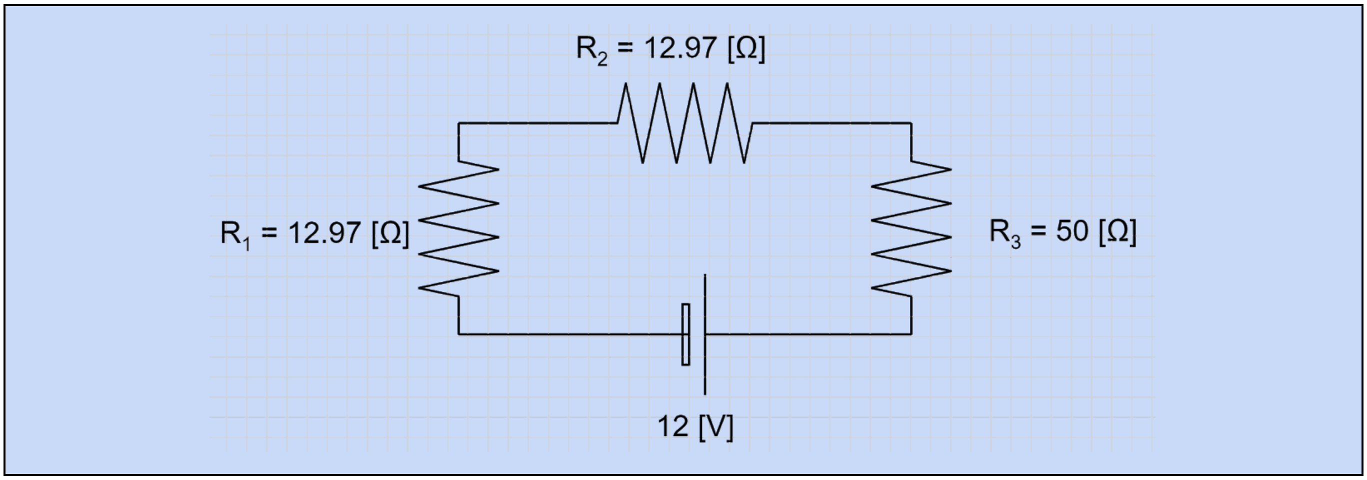
b. What is the resistance value of the added resistor? Show your work - take a picture and insert it below





$$\frac{15 \cdot x}{15+x} = 4.5$$
$$\therefore x = 6.429\,[\Omega]$$

2. A circuit constructed with a 12.0 V battery and three resistors R_1, R_2, and R_3, The resistors are connected in series. The resistance values of R_1 and R_2 are the same. The current entering R_3 is 0.158 A, and R_3 has a resistance of 50.0 Ω.
    a. Draw and label all components of the circuit.



b. Create a V-I-R chart for this circuit and solve for each value.

	V[V]	I[A]	R[Ω]
1	2.05	.158	12.975
2	2.05	.158	12.975
3	7.9	0.158	50.0
Total	12.0	.158	75.95