Section	
Bench No.	

ECE110 Introduction to Electronics

Experiment 3: Validating Kirchhoff's Law

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This part is reserved for your instructor

Score	
Instructor Signature	
Date	

Experiment 3: Validating Kirchhoff’s Laws

Laboratory Outline

In today’s lab we will carry on developing the fundamental knowledge and skills you’ll need to conduct basic experiments. You will learn much about the terminology, tools, and basic laws that govern circuits in an electrical engineering laboratory.

Also, we will continue to use networks of resistors in series with the motors for speed control of the wheels. As we observed before, the resistive networks allow us to create smaller resistive values with higher power ratings. In the prelab, we use switches to alter the wheel speeds by small amounts for fine-tuning of the wheel speeds by tuning resistor networks without completely stopping the wheels. In lab, we will be able to do analysis considering Kirchhoff’s Voltage Law and Kirchhoff’s Current Law using the DC V option of the voltmeter. As we use the switches to alter the resistive network, we can use multimeter to see the change of the voltage. And the signal is actually a time-varying signals, usually we will use *oscilloscope t*o observe the signals, but we’ll save the oscilloscope for next week.

Learning Objectives

- Learn to pulse wheels for fine-tuned control of motors speed and car direction.
- Investigate and confirm Kirchhoff’s law for DC analysis of our car.
- Dispute common misconceptions of the application of Kirchhoff’s current law.

Experimental Setup

Schematics, Breadboards, and Laying Down the Law

First your instructor will introduce today's lab and tell you what need to be noticed in today's lab. Then students can start today's work.

We already know that the breadboard is a very convenient tool for electrical circuit prototyping. It allows for *quickly building and reconfiguring* detailed circuits with few wires. It is very important to understand how the board is internally connected.

The following figure depicts a physical diagram and the corresponding circuit schematic. While both tell the same story, the physical diagram is more suggestive on the components to be used and a physical location and orientation in which you might place them. The circuit schematic is more abstract and requires that the student be familiar with the circuit symbols used for various circuit lab elements.

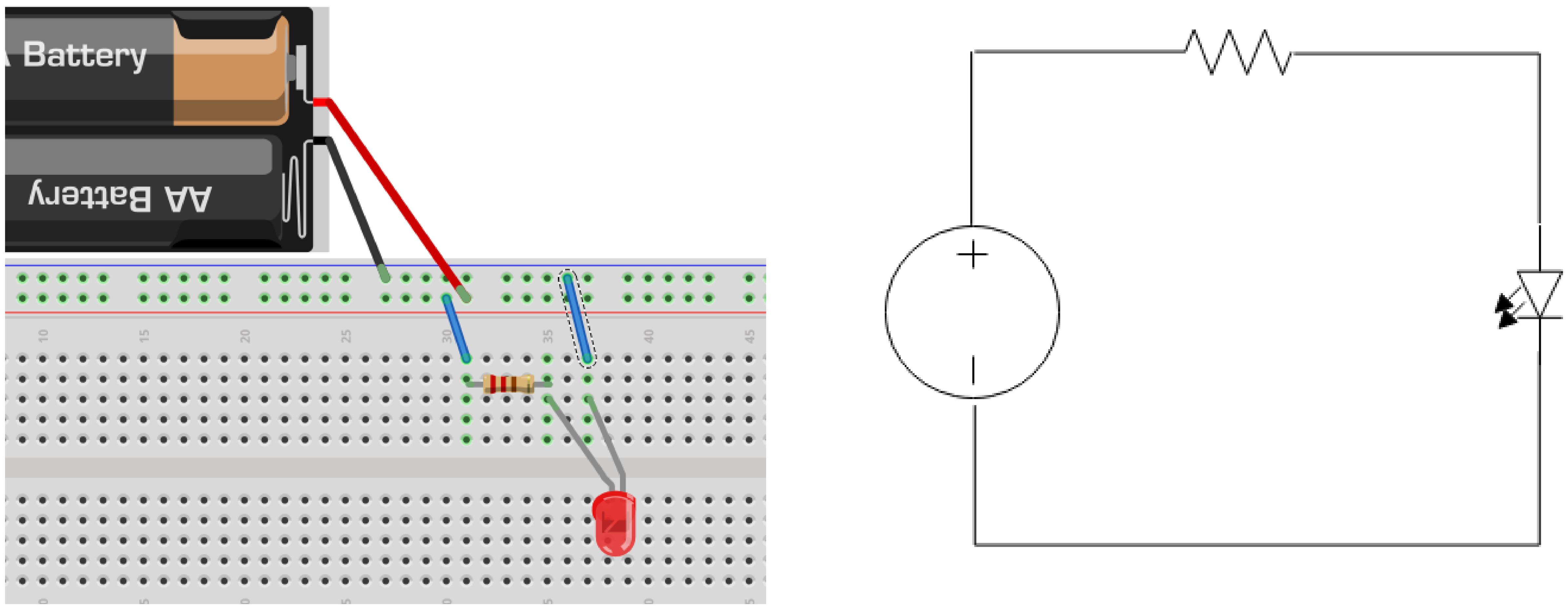
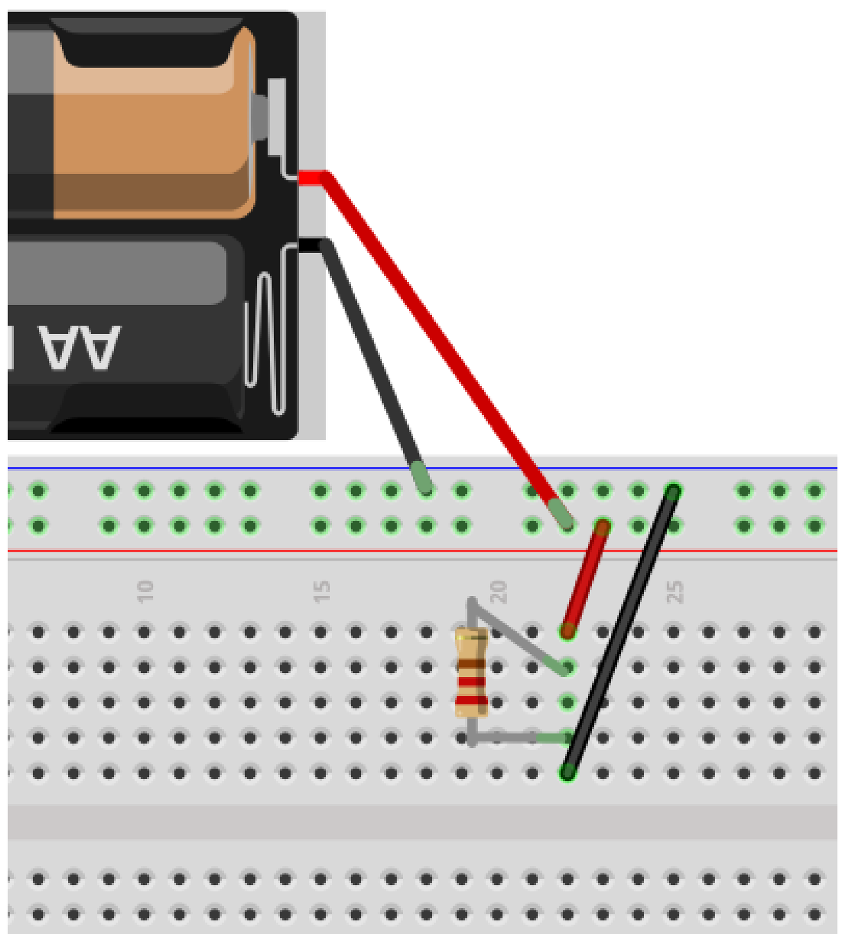


Figure 1: A wired breadboard and the corresponding circuit schematic

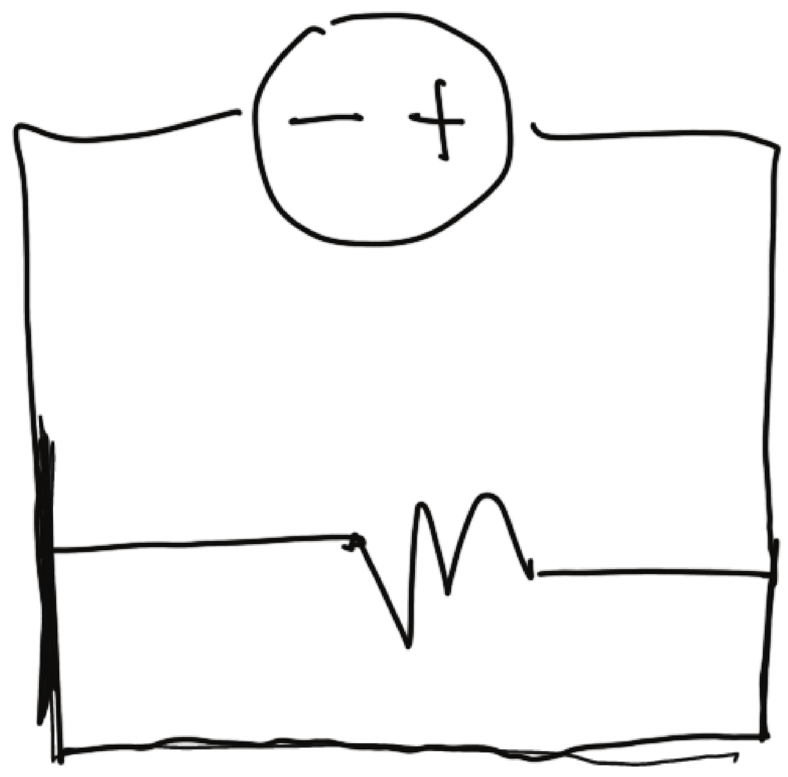
Question1: Recall the internal connections of the breadboard to produce a circuit schematic of each physical diagram of the following circuits in the space to the right of each. Then, explain why each is **not** properly connected if the goal is to apply voltage across a resistor.

Physical Diagram | *Circuit Schematic*

The battery is short connected

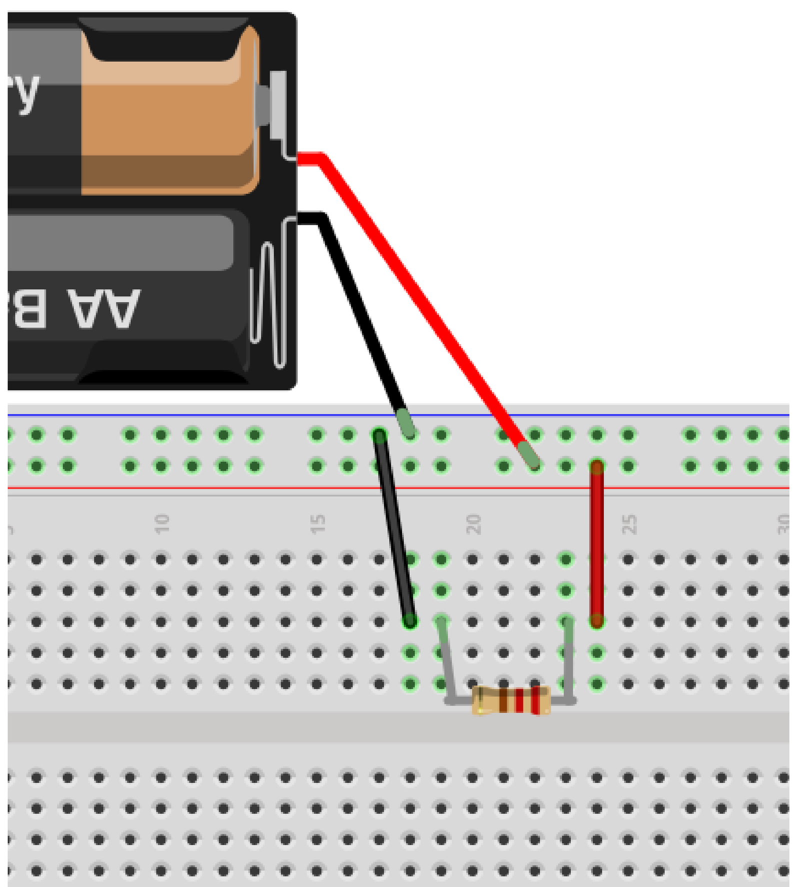


(a)

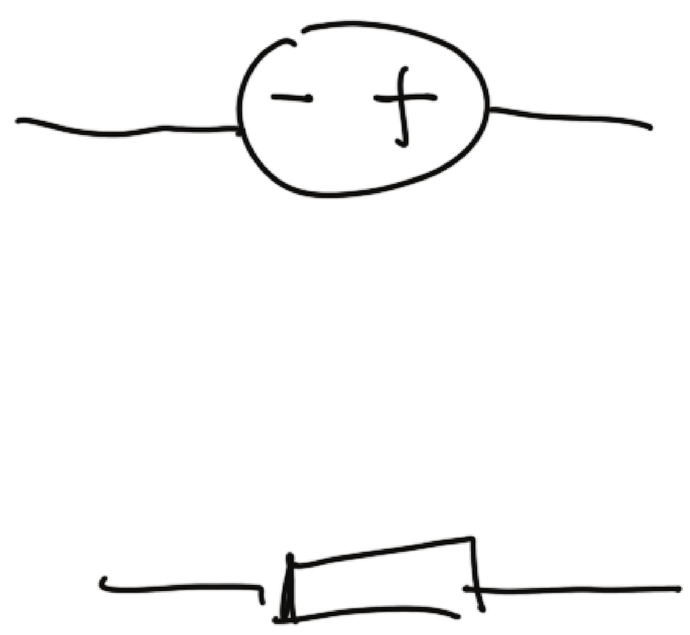


(b)

This circuit is an open circuit



(c)



(d)

*Figure 2: Two example of **incorrectly** wired circuits.*

Fine-turned speed control of motors

In pre-lab we already draw the schematic that can do the fine-tuned speed control of the motor. So please connect the physical motor and resistor network together according to the schematic show below.

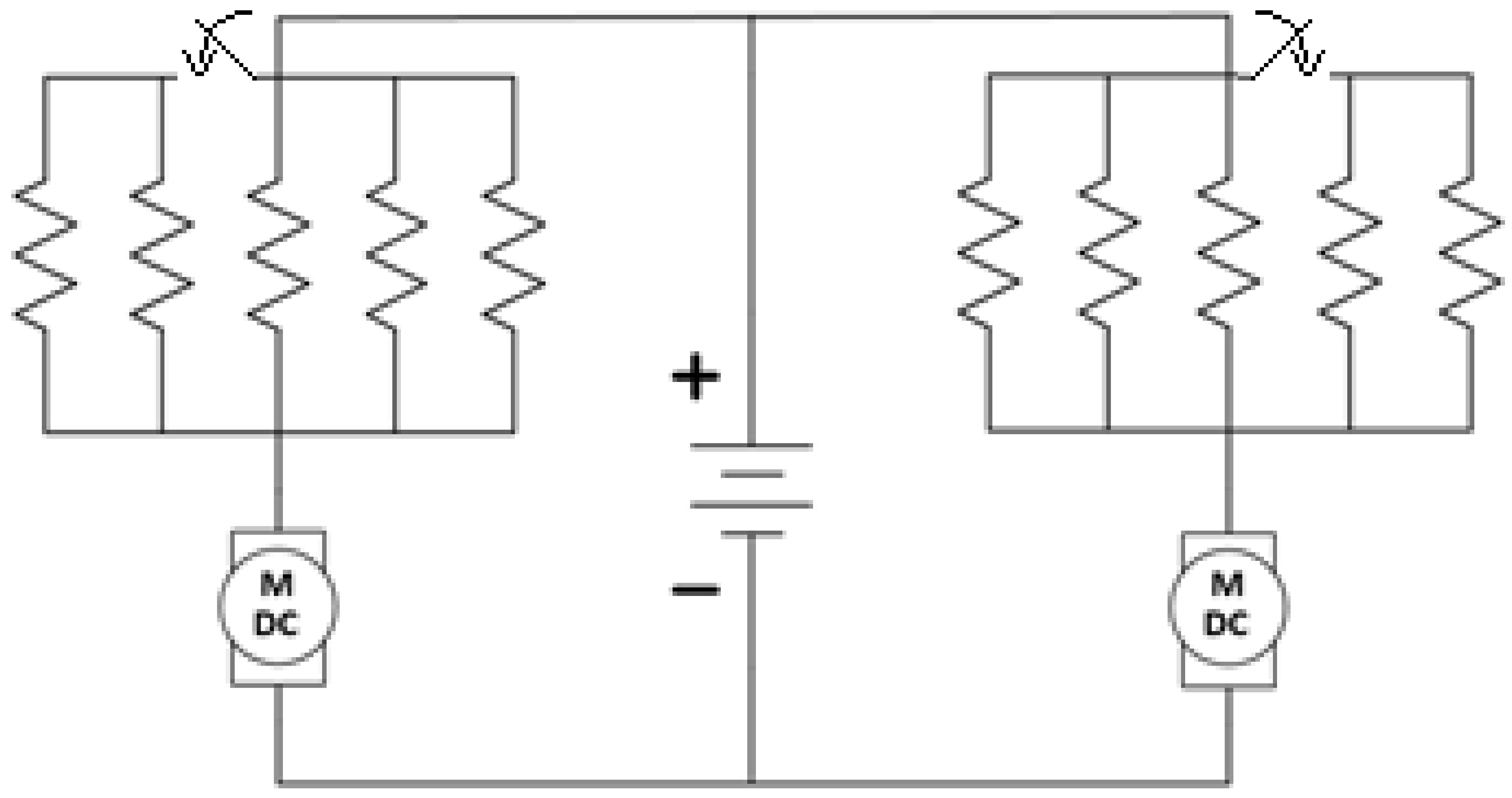


Figure 3: Example circuit using snap-action switches to fine tune the wheel speed without stopping. Figure is intended only as a conceptual idea, ***not to suggest numbers and orientation of resistors****.*

After connection, when you press the snap action switch, instead of directly make the motor turn on and off, it will change the speed of the motor.

Today, we will focus on engineering analysis. Hobbyists are able to follow instructions and even make small adjustments to a design to alter the results. It takes engineering expertise, however, to fully understand, make significant improvements, and even create fresh designs.

Place alligator clips with wires onto the banana ends of this cable for monitoring the voltage across your left motor as shown in the figure below. Use the black probe where the negative polarity is indicated and the red probe where the positive polarity is indicated.

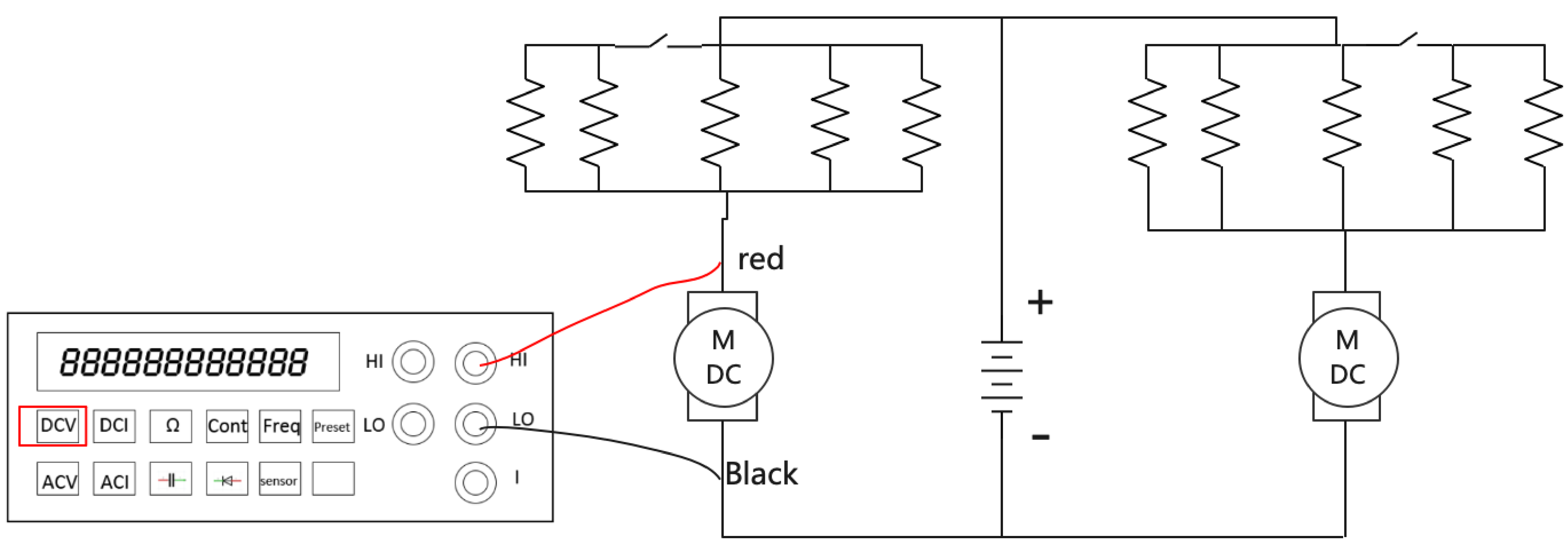


Figure 4 Using DDM to monitor the voltage on left motor

Question 2: Toggle the snap action switch on the left side, observe the voltage change by the multimeter, and record the voltage below. Explain why the voltage will change.

before: 2.59 V after: 6.10V

after Toggling the snap, the Rnetwork decrease so the motor's voltage increase

Kirchhoff's Laws

Now, let's use the voltmeter to validate Kirchhoff's Laws for our circuit.

Remove the switches and the four $47 - \Omega$ resistors from the circuit. Set the car on the stand (wooden block, so it doesn't run away). **Turn on the battery** so that the wheels are turning.

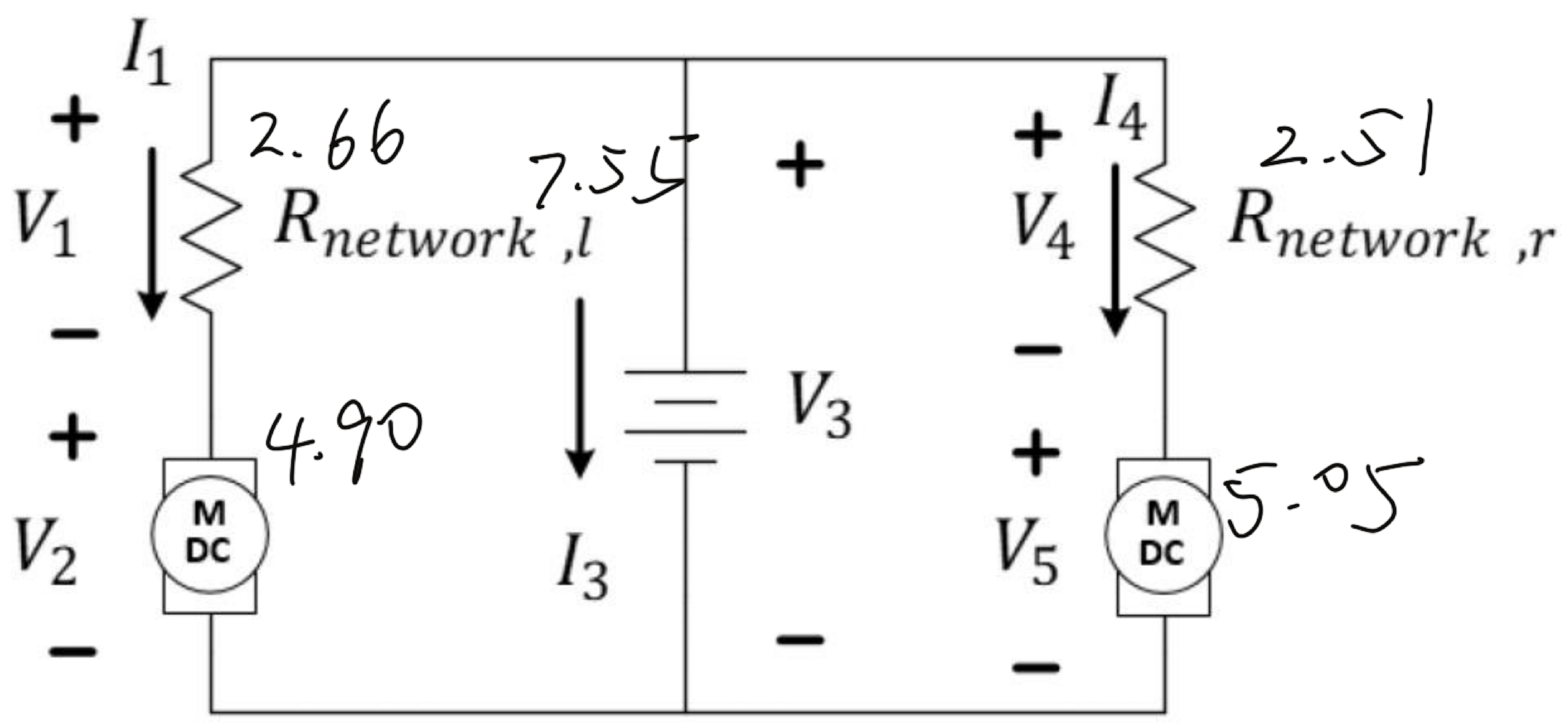


Figure 5: Voltage measurements to be recorded. Note that the – symbol represents the location of the black (COM) wire of the multimeter and the + symbol the location of the red (VV − ΩΩ) wire for each measurement

Question 3: Beginning with the left resistor network circuit, attach the voltmeter to measure each of the five voltages above and report them in Table 1. Note that the "–" symbol represents the location of the black (LO) wire of the multimeter and the "+" symbol the location of the red (HI) wire for each measurement of the meter.

Voltage Symbol	Voltage（measured， in V）	Comment
V_1	2.66	
V_2	4.90	
V_3	7.55	
V_4	2.51	
V_5	5.05	

Table 1 Voltage measurements of Figure 5.

With these measurements, we can determine the validity of Kirchhoff's Voltage Law.

Question 4: For the loop indicated below, write the KVL expression using first the symbols for the voltages, then solve using the actual voltages to determine if the equation is approximately correct. Start by writing the voltage labels and polarities on the schematic (ref. Figure 5).

$V_3 = 7.55$

$V_1 + V_2 = 7.56\ V$

$V_1 + V_2 \approx V_3$

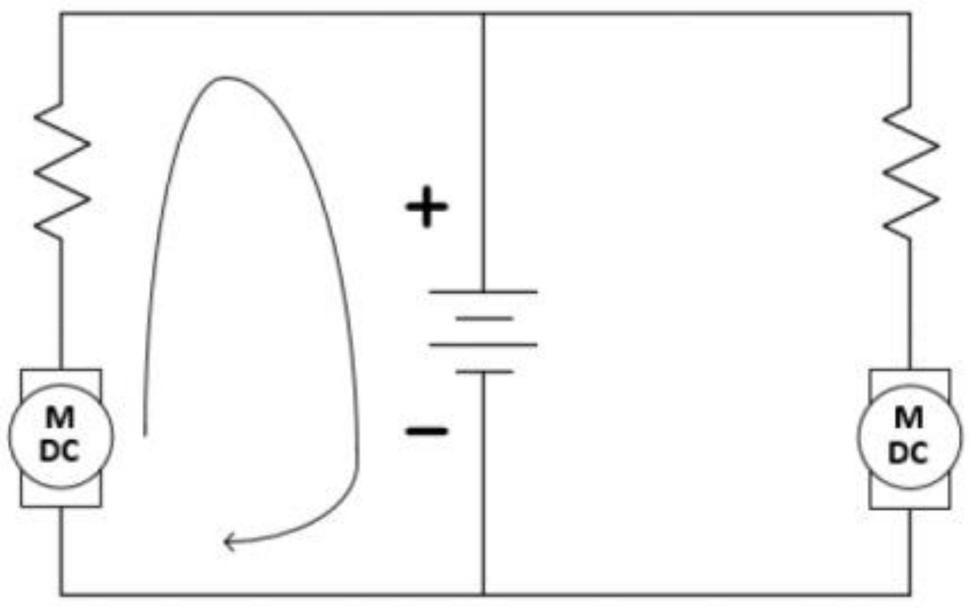


Figure 6 Loop 1.

Question 5: For the loop indicated below, write the KVL expression using first the symbols for the voltages, then solve using the actual voltages to determine if the equation is approximately correct.

$V_3 = 7.55\ V$

$V_4 + V_5 = 7.56\ V$

$V_4 + V_5 \approx V_3$

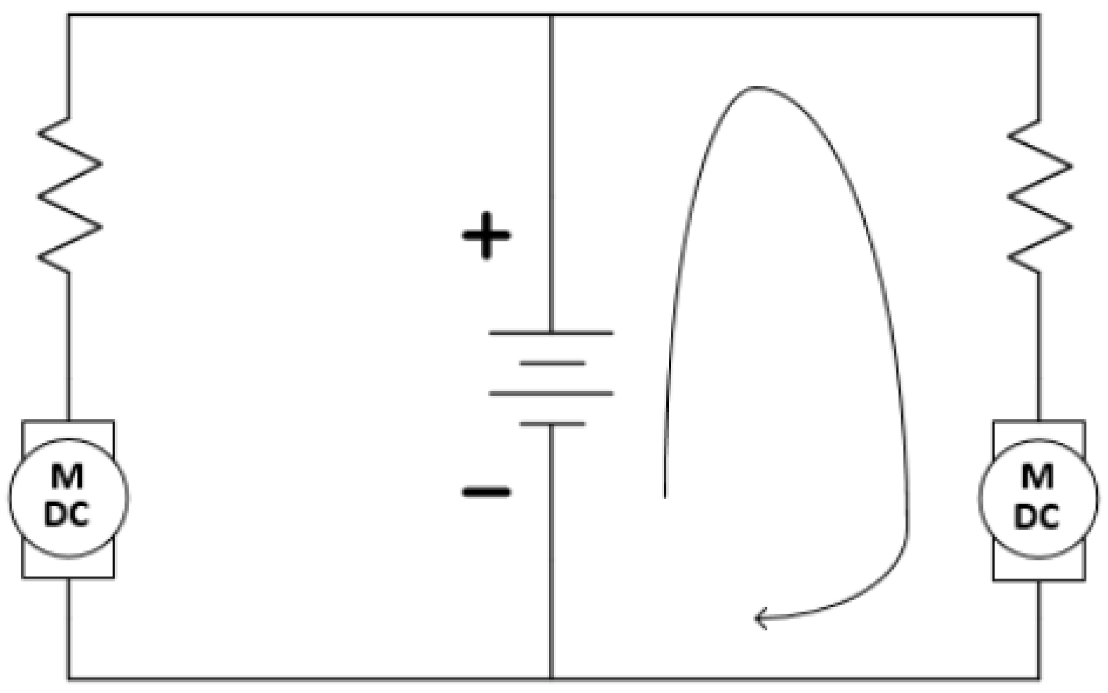


Figure 7 Loop 2.

Question 6: For the loop indicated below, write the KVL expression using first the symbols for the voltages, then solve using the actual voltages to determine if the equation is approximately correct.

$V_1 + V_2 = 7.56\ V$

$V_3 + V_4 = 7.56\ V$

$V_1 + V_2 = V_3 + V_4$

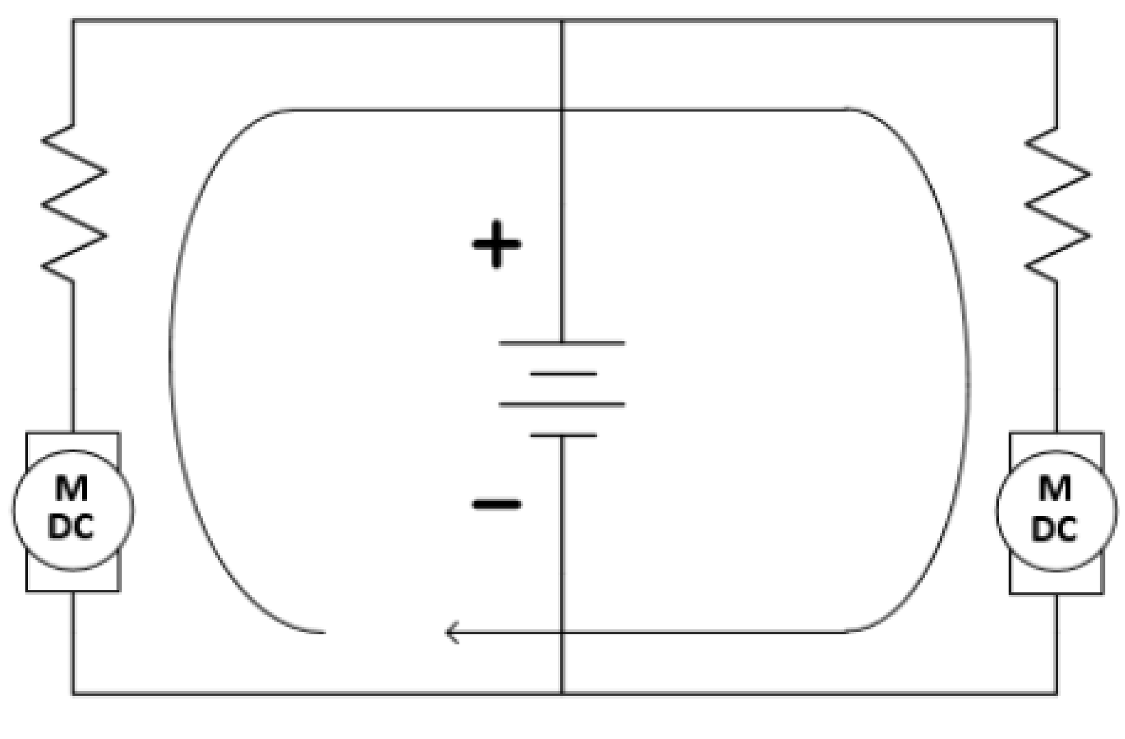


Figure 8 Loop 3.

Question 7: Now let's record the resistor network value again. Remove the battery, the motors, and the two" jumper wires" from your circuit, leave **ONLY the two resistor networks on either side** and measure each again using the ohmmeter. $R_{network,l}$ = 19.8 Ω, $R_{network,r}$= 20.0 Ω.

Question 8: Use Ohm's Law and your measurements to determine the values of I_1 and I_4 (ref Figure 5).

$$I_1 = \frac{V_1}{R_1} = \frac{2.66}{19.8} = 0.13A \quad I_4 = \frac{V_4}{R_2} = \frac{2.51}{20.0} = 0.13\ A$$

Question 9: Use Kirchhoff's Current Law to determine the value of I_3 (ref Figure 5). Start by circling the node being evaluated in the circuit below and drawing your current labels and assumed polarities (see Figure 5) on the schematic. Show your work. Briefly explain why I_3 takes on a negative value.

$$I_3 = -(I_1 + I_2)$$

$$= -0.26A$$

Because we define current's positive direction is down.

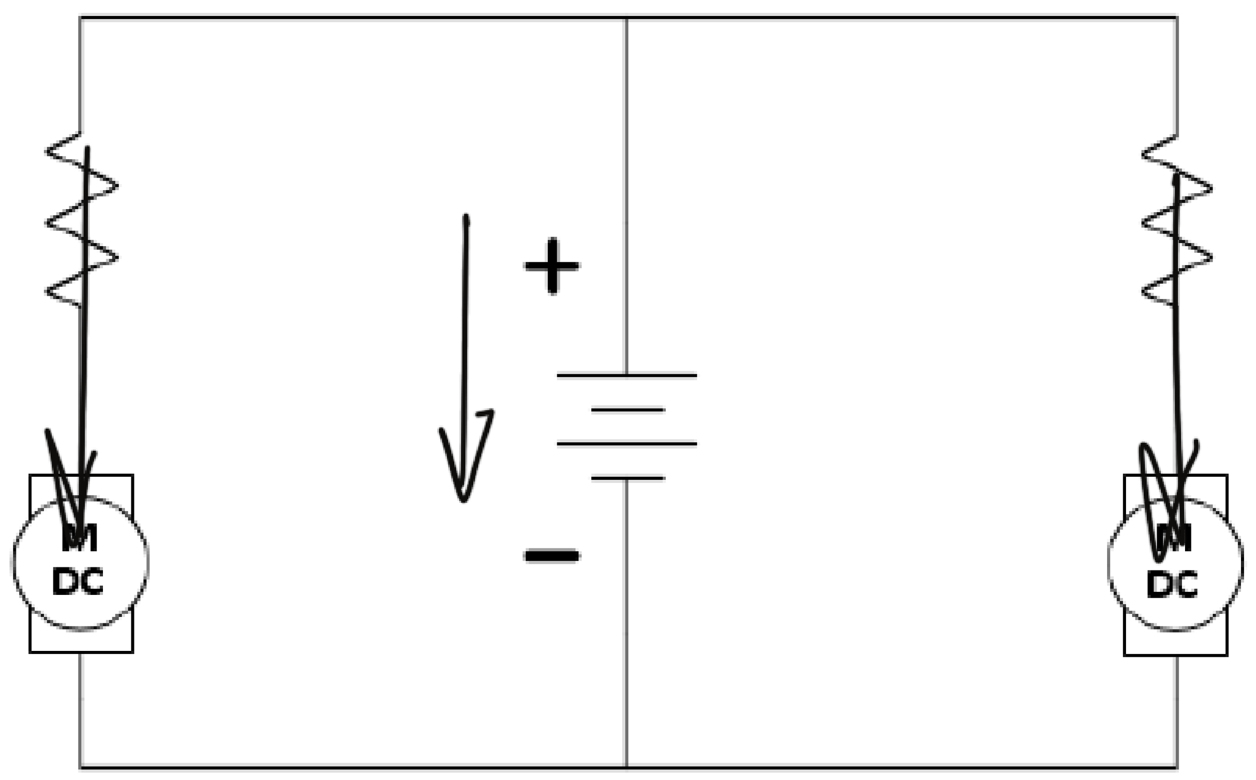


Figure 9: Please circle your node and label the currents.

Let's use the ammeter to measure the current flowing through your motors. Note the change in the location of the red wire on the figure below.

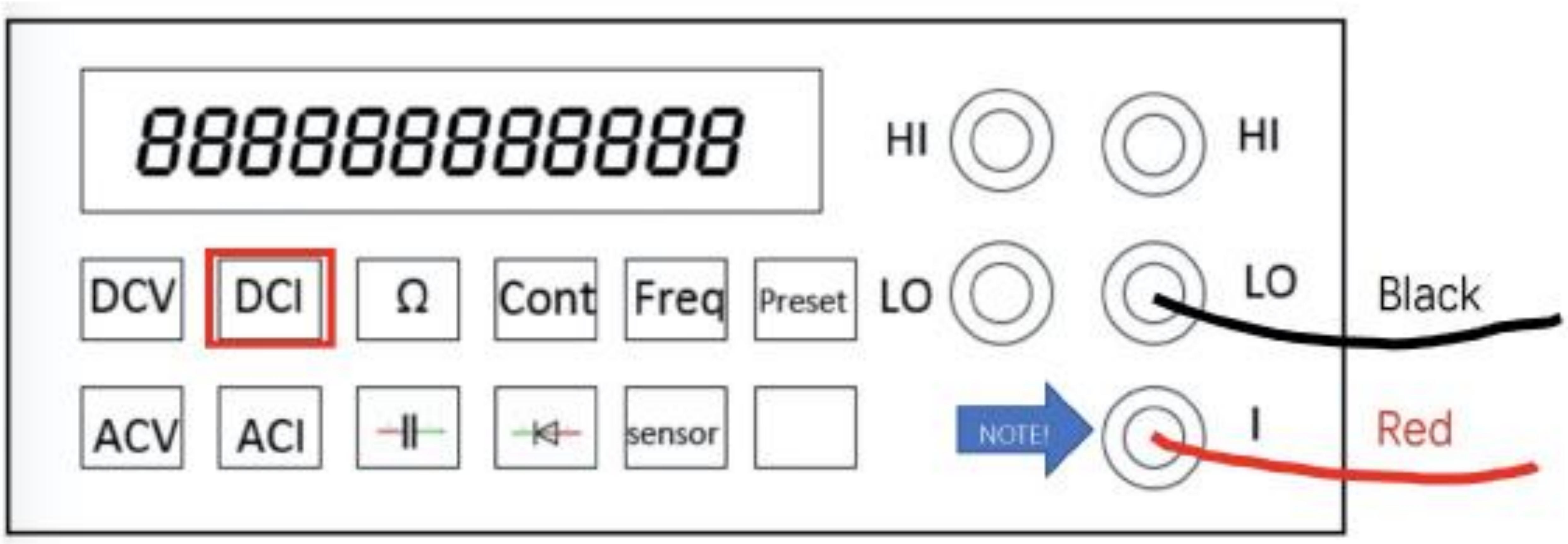


Figure 10: Using DCI to measure DC current. Plug the red banana cable in the I port.

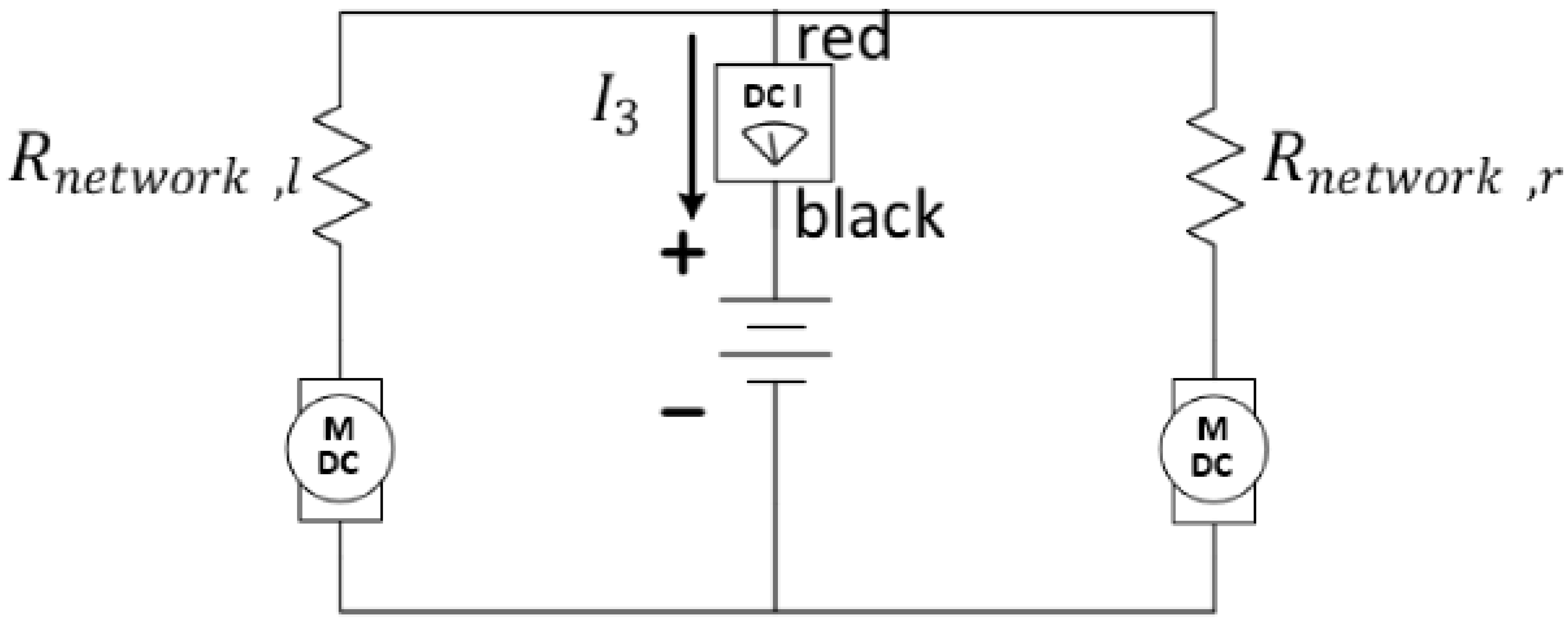


Figure 11: Insert the ammeter to measure the current supplied by the battery (I_3). The connections of the physical ammeter are shown in the previous figure.

Question 10: Measure I_3 using the ammeter and compare to the calculation using KCL done earlier.

$I_{3\,measure} = 0.259A$

I_3 measure $\approx$ I_3 calculation

Any equipment used in the lab to analyze a circuit should have a minimal effect on the circuit's behavior. For instance, the use of a voltmeter should not alter the voltage it was intended to measure. An ammeter (current meter) should have minimal effect on the current it is to measure.

Question 11: The voltmeter is placed in parallel with a circuit component to measure the voltage potential across it. What must be true about the effective resistance of the voltmeter?

The effective resistance of the voltmeter should be as big as possible

Question 12: An ammeter is placed in series with the branch for which current is to be measured. What must be true about the effective resistance of the ammeter?

The effective resistance of the ammeter should be as small as possible

Question 13: Discuss: Do you feel that the incremental change in wheel speed is better or worse than turning the motors fully on and off like we did last week? Explain.

better

we can change the wheels' speed in both or other side to control the car's speed and driving direction.

Explore More! Modules

The Instructor will provide you with their preferences for this week's ***Explore More! Modules***. Continue with below **with your choice. Rememb**er, at the end of the semester, you will earn points towards your total semester lab score by having completed a minimum of 6 modules. If you wish to be eligible for a Course Aide position in the future, please consider doing more and impressing us with your command of the material and your ability to aid your classmates.