Experiment 3: Switched-Resistor Speed Control

Name:

NetID:

Today's bench partner:

Section AB/BB:

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
8	**9**	**A**	**B**	**C**	**D**	**E**	**F**

Laboratory Outline

This week, 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 are actually using a time-varying circuit. The tool of choice for analyzing time-varying signals is the *oscilloscope*. Also, we have a tool called the *function generator* that will enable us to generate time-varying voltage signals for test-and-analysis. We'll save the function generator for next week.

Learning Objectives

- Learn to pulse wheels for *fine-tuned* control of motor speed and car direction.
- Investigate and confirm Kirchhoff's laws for DC analysis of our car.
- Gain an introduction to benchtop equipment designed for time-varying signals; the function generator and oscilloscope.

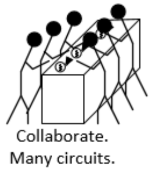
Introduction…Meet in 1005 ECEB

Drop off your Prelab (and the Summary Sheet for today) in 1001 ECEB at a center table. One TA will check that you have completed your prelab assignment while the other will answer any questions you may have about last week's lab or today's prelab in 1005 ECEB. You will also receive a quick rundown of what is planned for today.

In the Lab…Move into 1001 ECEB

When instructed, move into the breakout session of the lab. Today, you will compete in navigating a straight line, but with small adjustments in the motor speed.

Breakout Session



Set up two rows of blocks at one can's length from each other and about 1 meter in length. Using the longer wires provided by your TA, take turns racing your car through the setup using the snap-action switches as controllers for the two wheels. If you knock down a figurine, you are eliminated. In lab 2, the car wheels would start and stop. Now, you will just be causing them to change speeds.

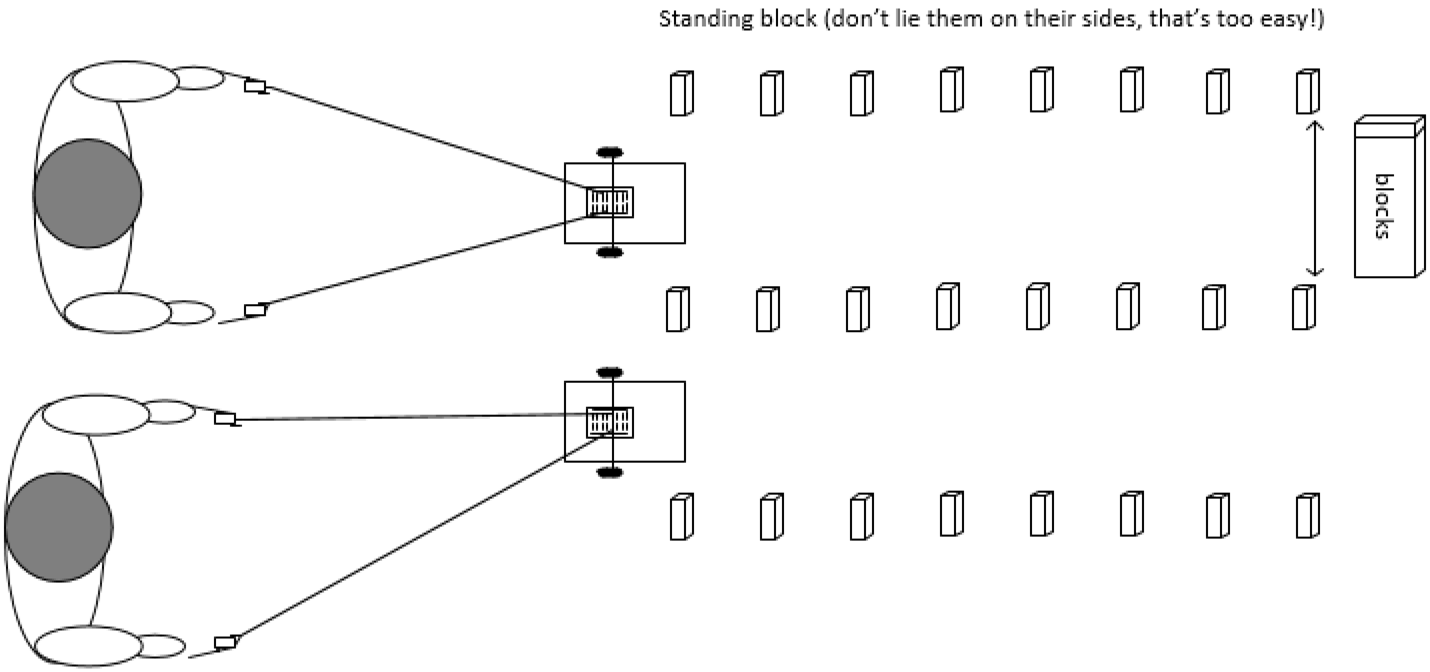
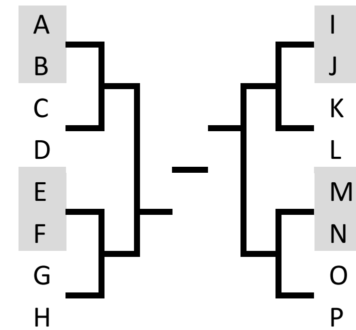


Figure 1: Car race using snap-action switches for wheel control (not to scale).

Notes:

Competition Bracket
(only as time allows)



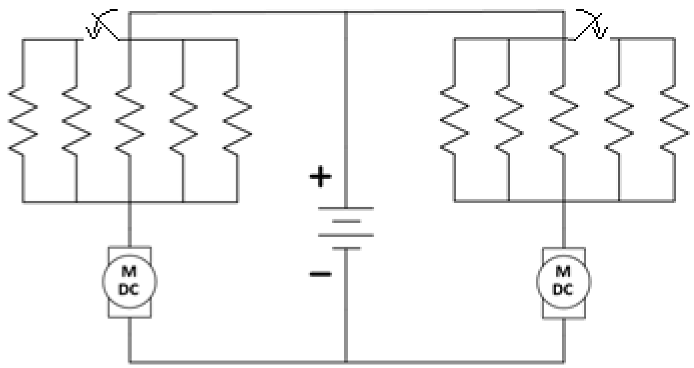
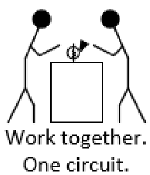


***Figure 2**: Example circuit using snap-action switches to fine tune the wheel speed without stopping. Figure is intended only as a conceptual idea, not to suggest numbers and orientation of resistors.*

At your Bench



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.

Notes:

Notes:

Oscilloscope Viewing of Time-Varying Signals

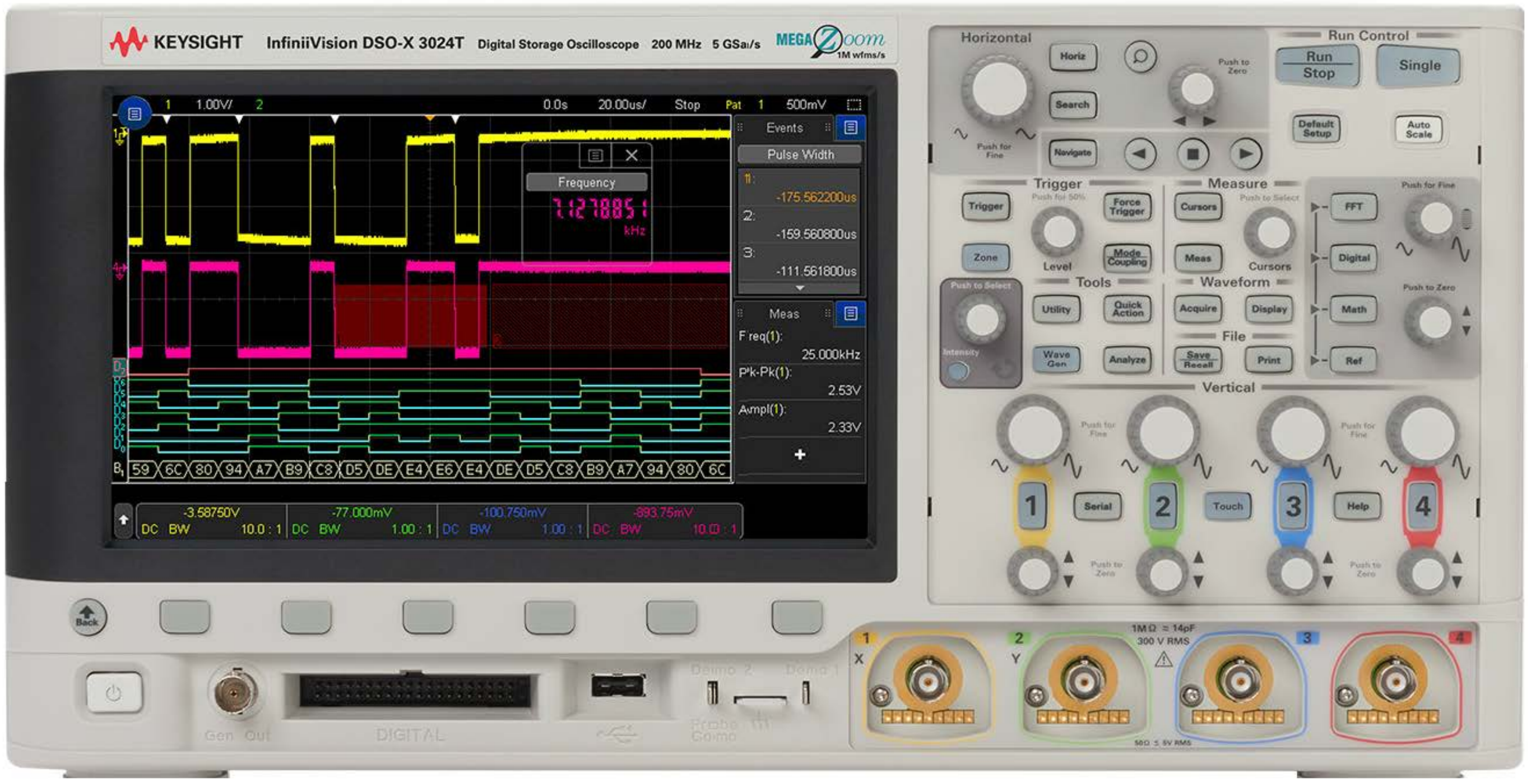


Figure 3: *A KEYSIGHT Technologies oscilloscope similar to that used in the lab. Image Source: KEYSIGHT*

We will learn about the oscilloscope in parts. Today, we will investigate just a few settings and understand that it produces a view of the voltage signal as a function of time, but not worry about *how* it does so. Power on your oscilloscope by pressing the power button in the lower-left corner of the instrument.

When the instrument has finished powering up, press the Default Setup button near the upper-right corner of the instrument. This button will remove any unusual settings done by the previous user and put us into a known state.

Figure 4: The oscilloscope's Default Setting.

Next, connect a coaxial-to-banana cable to the Channel 1 input.

Notes:

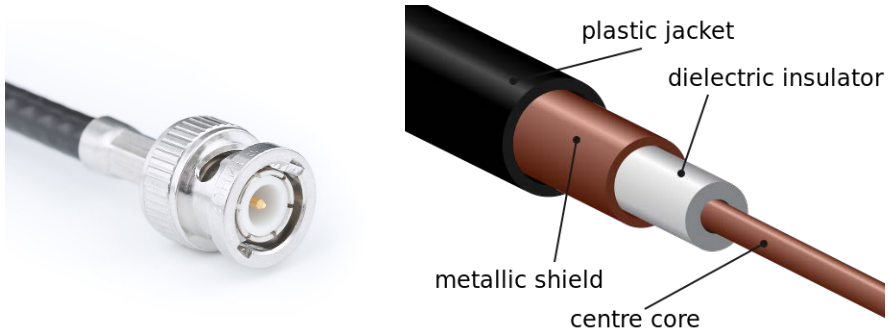


Figure 5: *A coaxial cable with a BNC connector appropriate for use with the KEYSIGHT oscilloscope. Note that although the cable on the left would seem to be a single wire, the actual construction has two conductors, a core and a shield. Image Source: Wikipedia*

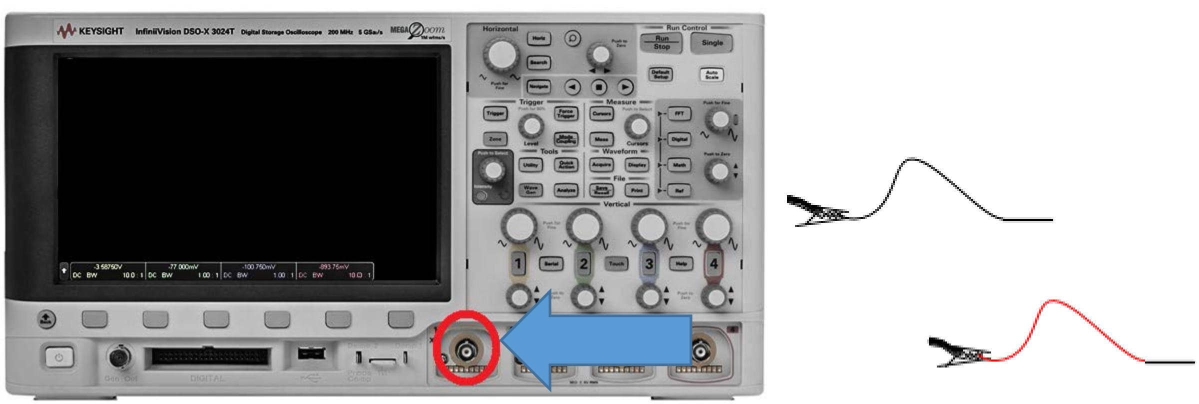


Figure 6: *The oscilloscope's Channel 1 input.*

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.

Notes:

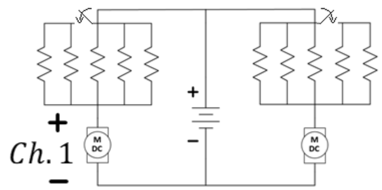


__Figure 7:__ Using the oscilloscope to monitor the voltage on the left motor.

Very quickly, toggle your left motor's speed using the snap action switch. You will primarily use two controls on the oscilloscope to improve your view…the vertical scale adjust and the horizontal scale adjust. If the display appears to be "untriggered" (ie. scrolling past), try turning the triggering threshold knob (Figure 9), first counter-clockwise, until the horizontal triggering line *slices* through the signal.

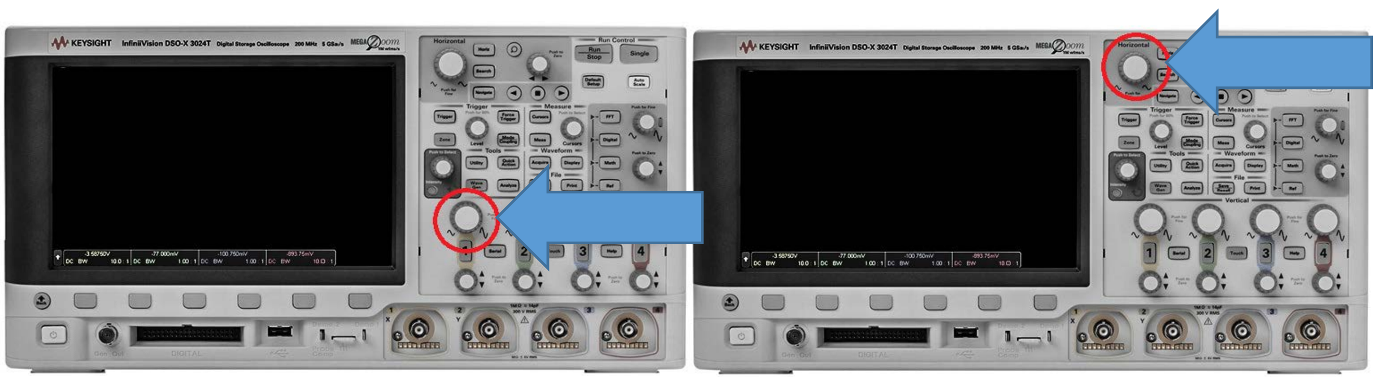


__Figure 8:__ Adjust the view using the vertical scale adjust (visible height of the signal) and the horizontal scale adjust (amount of time shown on the screen).

Notes:

Notes:

Figure 9: *Adjust the trigger such that the horizontal trigger line that appears sits between the two voltage values across the motor.*

Question 1: Briefly discuss the function of each the vertical scale and the horizontal scale adjustments.

Question 2: Adjust the time scale to estimate the maximum frequency at which you are able to vary between the two motor speeds. Record below the rate (or the *period*) at which you can toggle between the two speeds and discuss any challenges you had in determining this measurement.

Notes:

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.

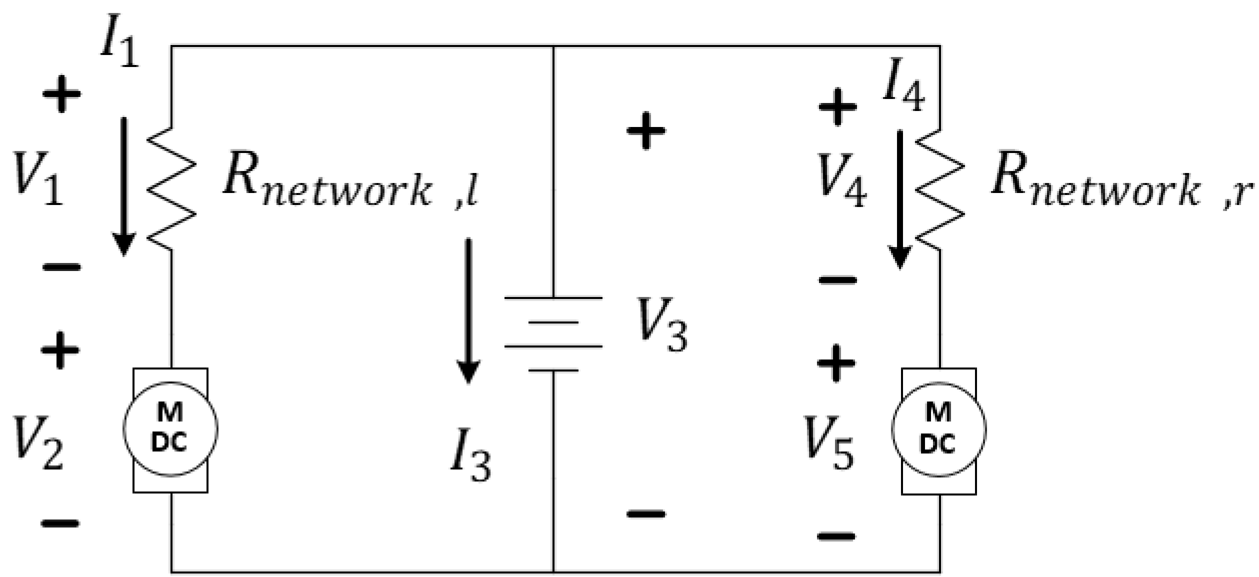


***Figure 10**: Voltage measurements to be recorded. Note that the – symbol represents the location of the black (COM) wire of the multimeter and the + symbol the location of the red ($V - \Omega$) wire for each measurement.*

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.

Notes:

Voltage Symbol	Voltage (measured, in V)	Comments:
V_1		
V_2		
V_3		
V_4		
V_5		

***Table 1**: Voltage measurements of Figure 3.*

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 10).

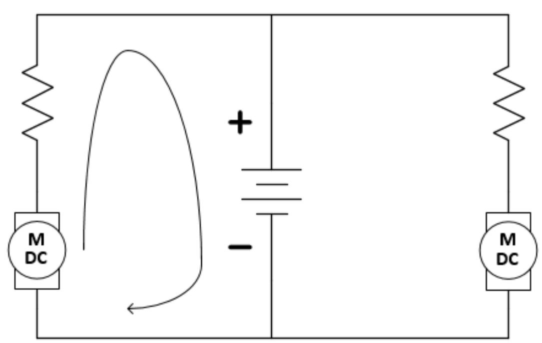


***Figure 11:** Loop 1.*

Notes:

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.

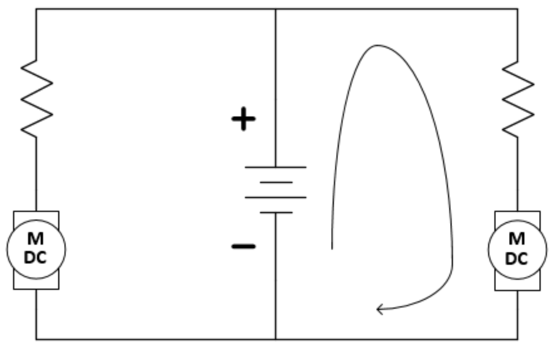


Figure 12: *Loop 2.*

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.

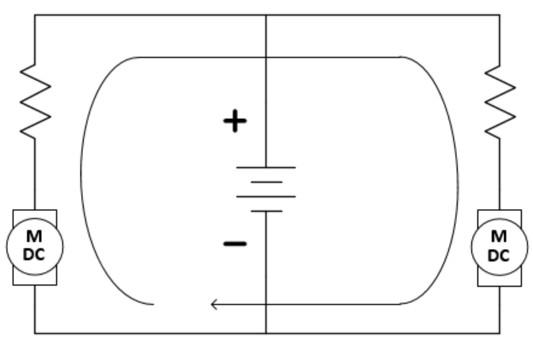


Figure 13: *Loop 3.*

Notes:

Question 7: The resistance of each resistive networks were measured last time (if they were unchanged). Reference the previous lab and report them here. Alternately, remove the battery and motors and measure each again using the ohmmeter. $R_{network,l}$ = ____________, $R_{network,r}$ = ____________

Question 8: Use Ohm's Law and your measurements to determine the values of I_1 and I_4 (ref Figure 10).

Question 9: Use Kirchhoff's Current Law to determine the value of I_3 (ref Figure 10). Start by circling the node being evaluated in the circuit below and drawing your current labels and assumed polarities (see Figure 3) on the schematic. Show your work. Briefly explain why I_3 takes on a negative value.

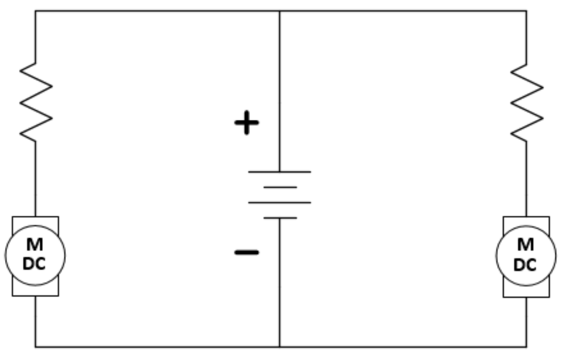


Figure 14: *Please circle your node and label the currents.*

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.

With nearly 450 students using the lab, you might want to **check the fuse** on your ammeter. To do so, use a banana cable from the HI to the LO ports and make sure the multimeter makes a sound in CONTinuity mode.

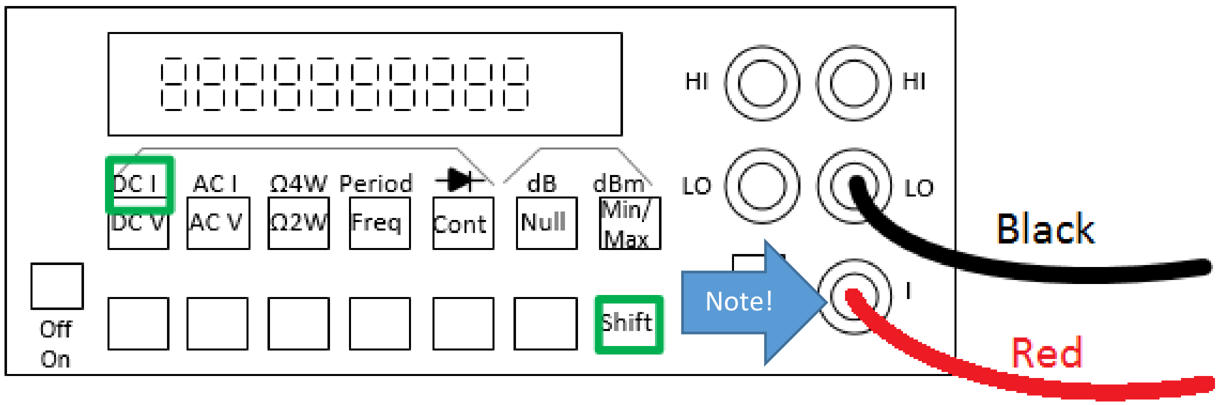


Figure 13: *Use Shift-DCI to measure DC current. Plug the red banana cable in the I port.*

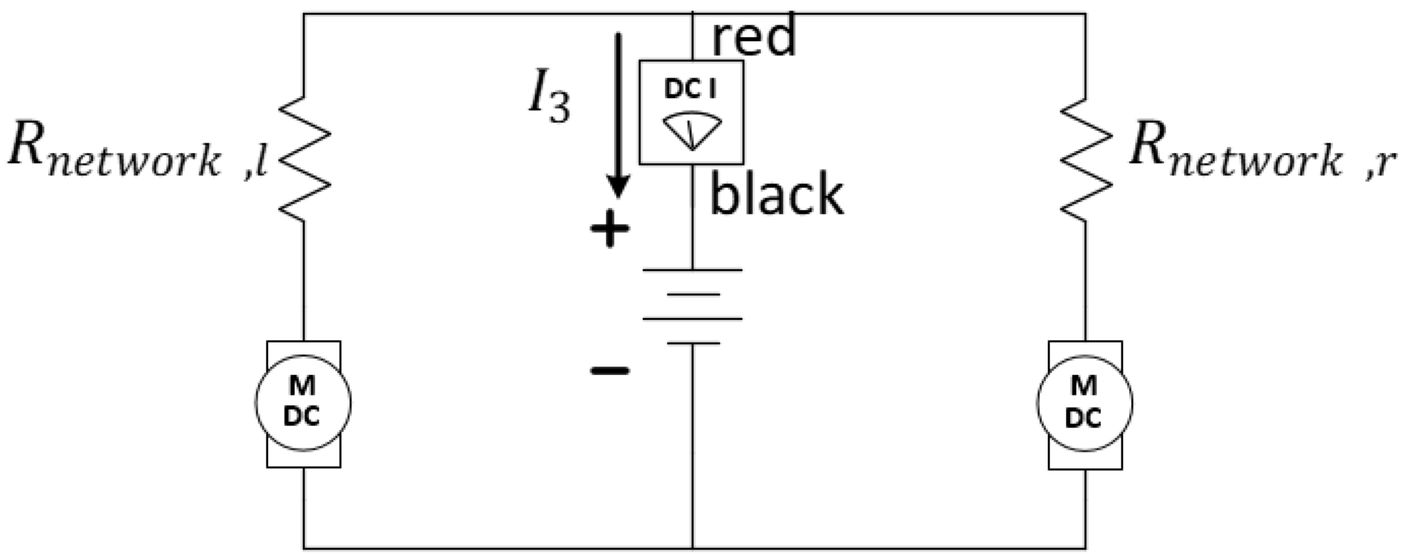


Figure 14: *Insert the ammeter to measure the current supplied* by *the battery,* I_3*. The connections of the physical ammeter are shown in the previous figure.*

Notes:

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

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.

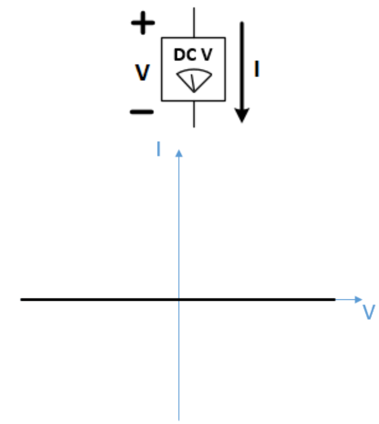
Question 11: The voltmeter is placed in parallel with a circuit component to measure the voltage potential across it. What must be true about the effective resistance of the voltmeter?

Think about what the oscilloscope measures and how channel 1 of the oscilloscope was inserted into the circuit.

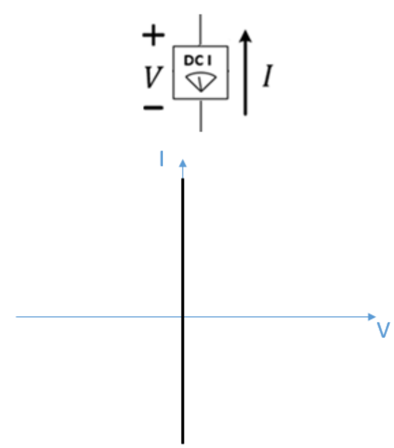
Question 12: What must be true about the effective resistance of the oscilloscope's Channel 1?

Question 13: 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?

Notes:



The ideal voltmeter carries no current regardless of the voltage it measures.

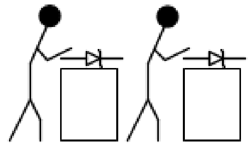


An ideal ammeter incurs no voltage drop across its terminals regardless of the current flowing through it.

Notes:

You may return your car to your locker, then continue with ***Explore More!* Modules**.

Explore More! Modules



Explore More! Modules provide students with options to investigate new concepts! As time allows, do one or more of the recommended modules before returning to the laboratory's core procedure.

Lab 3 Summary (To be submitted at the end of the laboratory session)

Question 14: 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.

Question 15: What did the oscilloscope offer that the voltmeter did not?

Question 16: What is always an important requirement of the equipment we use to measure voltage and current?

For TA use only:

- Prelab Check: full/half/zero credit TA initials: __________________
- Student was engaged throughout the lab, not distracted by phone, homework, etc. TA initials: __________________

Lab grade (reasons for deductions and/or total points awarded): ______________/6

Notes:

Name:

NetID:

Section AB/BB:

0 1 2 3 4 5 6 7

8 9 A B C D E F

(circle one)

Bench:

A B C D E F G H I J K L M N O P

(circle one)

Return your borrowed equipment, clean up your benchtop, and submit your lab summary before leaving for the day. Thank you!