Experiment 2: Resistor Networks for 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, you will use resistors to control the speed of each motor on your car. You are going to do this in a fairly direct, brute-force, manner by placing resistance between the battery supply and the motors to limit the current supplied to each. Because the battery is capable of supply high power to the resistors (in excess of their ¼-watt rating), we will use "networks" of resistors such that the effective rating of the resistance created by the combination of resistance is higher than that of a single resistor.

Place the following items in a stack on the center table in 1005 ECEB and return to 1001 ECEB *before* the TAs begin laboratory Exercise #2:

1. The Prelab and the MATLAB plot, stapled.
2. The Laboratory Exercise #2 Summary page (last page of this document only, ***not*** the entire document)
3. Your prelab hardware circuit.

Learning Objectives

- Learn to pulse wheels for control of motor speed and car direction.
- Investigate power rating and equivalent resistance to implement a simple method of motor speed control.
- Measure the equivalent resistance of resistors in parallel to determine a descriptive formula for equivalent resistance.

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

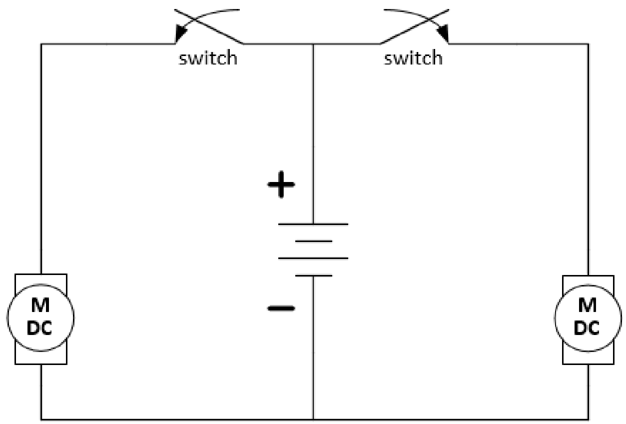
When we transition from 1005 to 1001 ECEB, we will first meet (in two groups) at the center tables. Generally, this first "breakout" session is where students will discuss and perfect their prelab assignments which often involve a circuit built at home

Notes:

or other group discussion. Today, you will work with the snap-action switches. Start by placing the wheels on your car if you did not in the previous lab session.

Breakout Session

On your car's breadboard, build the switched circuit of Figure 1 and Figure 3. It is very much like your prelab circuit, but replaces the resistor/LED combinations with the car motors and the buttons with the snap-action switches.



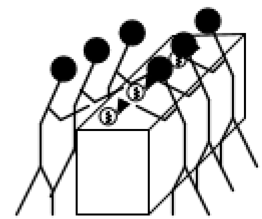


Figure 1: *Circuit schematic for switching motors.*

Figure 2: *The snap-action (lever) switch. The second wire on the switch should be the "normally-open" (**NO**) connector which connects to the common (**COM**) when the switch is pressed. The other is "normally closed" (**NC**).*

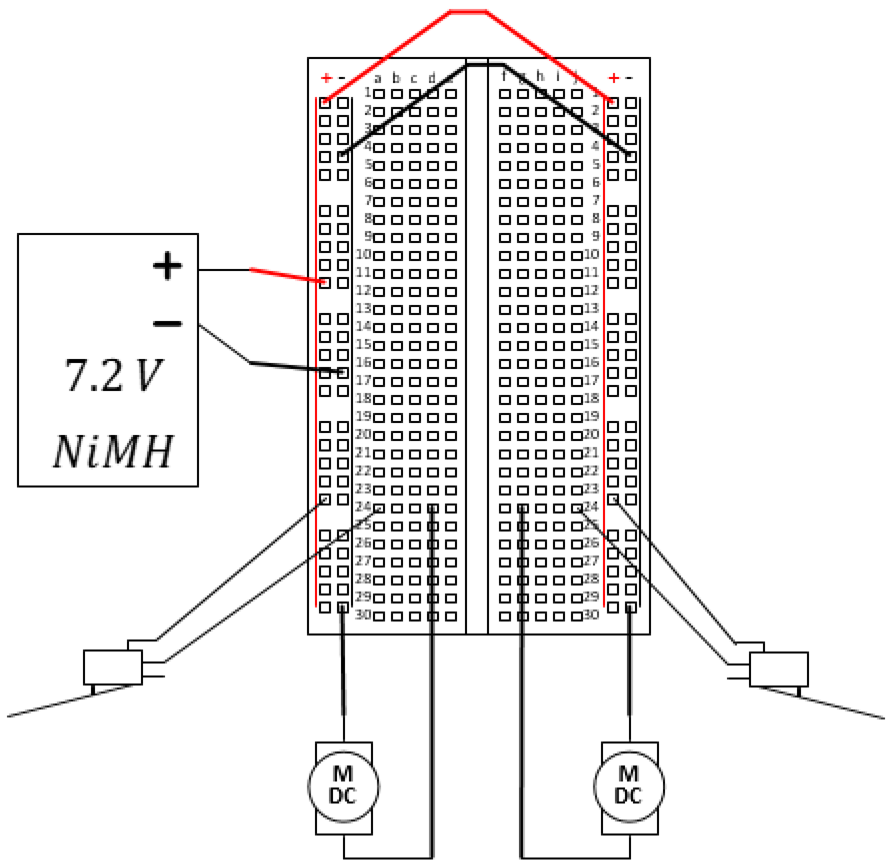


Figure 3: *Example physical diagram for switching motors using the snap-action switch.*

Set up three rows of wooden blocks to make a track wide enough for one Jenga can to easily fit and about 1 meter in length. Using the longer wires provided by your TA, have head-to-head competitions racing your car through the setup using the snap-action switches as controllers (see Figure 4). If you knock down a figurine or use force on your wires to steer, you are eliminated. A bracket is provided, but watch your time! The entire class should finish this exercise before 45 minutes of lab time has expired. If you run out of time, just call an end to the Breakout Session without finishing the bracket…sorry, no winner!

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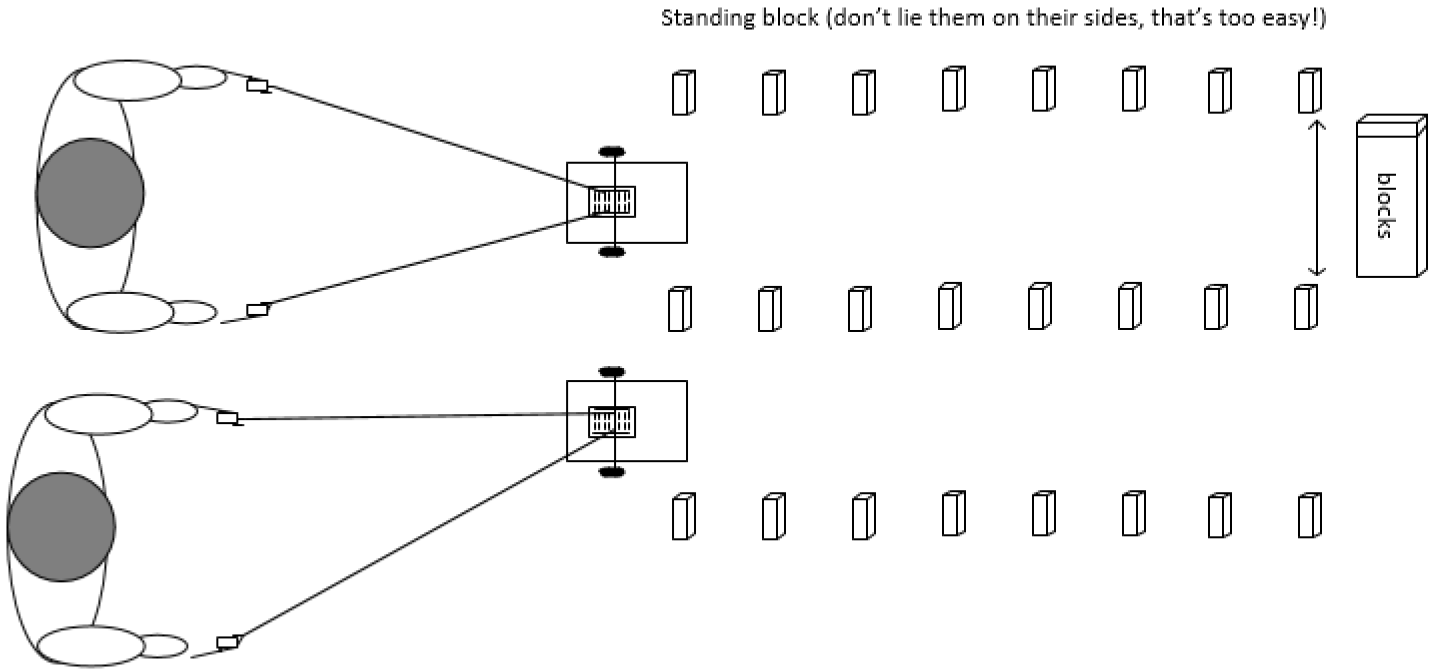
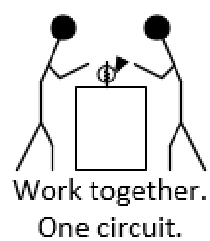


Figure 4: Car race using snap-action switches for wheel-control races (not to scale).

At your Bench

While it was fun to control your car and make it move in a straight line, it should also be possible to build a type of "cruise control" to make your car go in a straight line as well. To do so, we might consider placing a resistor in series with each motor in order to limit the current flow and slow the motors. To match wheel speeds (compensating for differences in the motors due to loose specifications), a different resistance would be necessary for each wheel. See Figure 5.



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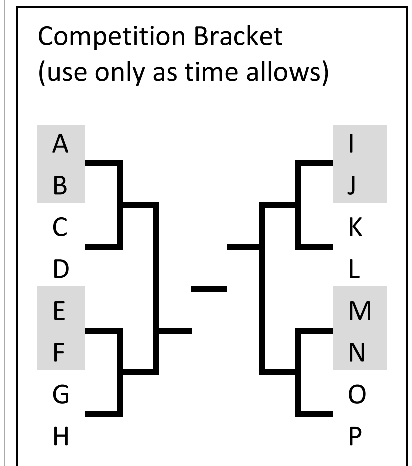

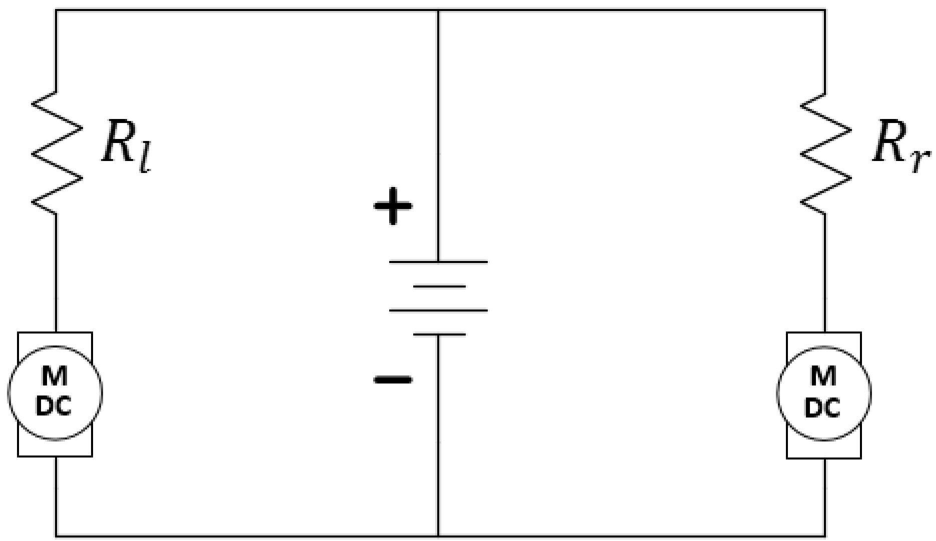

***Figure 5**: A grand idea! Use two different resistances to make the speeds of the left and right motors match.*

The problem with this plan is that the resistors in our pack are only rated at ¼ -watt. Let's crunch some numbers and see why this is an issue.

Question 1: When modeling your wheel as an Ohmic device (a resistor) last week, what value did you determine would represent it? $R_m =$ _______________ (reference Lab 1 Question 9)

Question 2: Assuming you want most of the battery voltage to appear across the motor (so it doesn't stall), R_l and R_r should be no larger than the resistance of the motor. Again, measure the open circuit voltage of your rechargeable battery (you may have a different battery than last time). Now, assuming we choose $R_l = R_r = R_m$, estimate how much current might flow through each resistor and, therefore, each motor?

$V_{\text{battery,oc}} =$ _______________ $I_m =$ _________________

Question 3: Again, continuing with this model for the motors, how much power will be dissipated by each of the resistors and each of the motors? $P_R \approx$ _____________

Notes:

Don't forget to include your units with your answers!

Notes:

But the resistors are only rated at ¼ -Watt! Therefore, we have established that simple resistors used in this manner are attempting to dissipate power well beyond their rated values and bound to 1) get hot, 2) burn your fingers when you touch them, and 3) eventually fail. What can we do? Let's use your understanding of cylindrical conductors to think about this…

Question 4: If a $20\ \Omega$ resistor is dissipating $1\ \mathrm{W}$, how much power would be dissipated by each of five $100\ \Omega$ resistors used in parallel to replace the single $20\ \Omega$ resistor?

Let's not use a single ¼-watt resistor for R_l and R_r, but rather use a network of parallel resistors to build an equivalent resistance with an effective higher power rating. Please follow the following procedures carefully…

With your battery turned OFF, construct the circuit of Figure 3. Note how we are using the "power rail" of the breadboard to facilitate the placement of multiple resistors. Use $100\ \Omega$ for each resistor. Five such resistors in parallel will provide the equivalent of around $20\ \Omega$, but with a higher power rating. Carefully trim the wires of each $100\ \Omega$ resistor so that there is less chance of creating a "short circuit" across the desired resistive network. Leave space for more resistors to be added. Don't miss adding the two "jumper" wires that connect one side of the board to the other.

Make sure your battery is initially OFF.

We don't want current flowing through our circuit until we are confident it can handle it!

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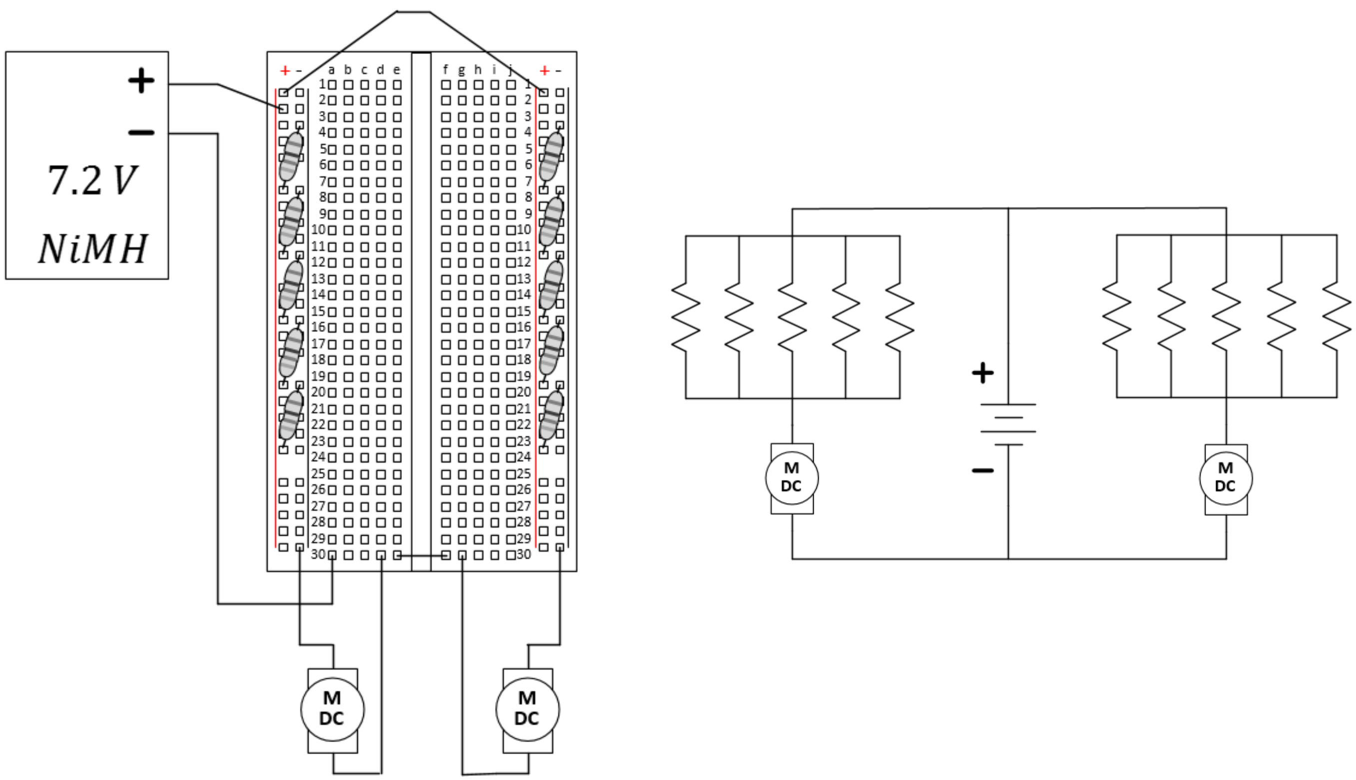


(a) (b)

Figure 3*: The breadboard circuit you are to build (a) the physical diagram and (b) the schematic of the same circuit.*

Now, with your car sitting on a wooden block (so it doesn't run away from you), turn on the battery. Both wheels should spin, but you might note that one wheel is faster than the other. Attempt to speed a slow wheel by adding another resistor in parallel with the network on that side of the car. Alternately, attempt to slow a wheel by removing a resistor. BUT DO NOT USE LESS THAN **FIVE** RESISTORS PER NETWORK or you may go beyond the power rating and burn your fingers!

Make final adjustments by setting your car on the floor until it runs straight. If you have time, set up again the two rows of blocks and see if your car can clear them now *without* any physical control!

Analysis…

As an aspiring engineer, we would like to not only follow a procedure, but to also analyze the results and consider alternatives to our design. Let's spend a little time decomposing the circuit we just built. Carefully follow these instructions.

Remove the battery, the motors, and the two "jumper wires" from your circuit leaving ONLY the two resistor networks on either side.

Question 5: Beginning with the left resistor network circuit, attach the Ohmmeter to the two rails and record the resistance. Continue to remove resistors and record the measurement until all resistors have been removed from the left-side resistor network.

Number of resistors	Resistance (measured, in Ω)	Comments:
		With all resistors, this is R_l.

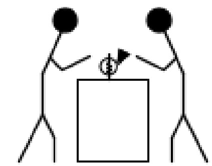
***Table 1**: Left-side resistor network decomposition*

Question 6: Repeat this procedure with the right-side resistor network.

Number of resistors	Resistance (measured, in Ω)	Comments:
		With all resistors, this is R_r.

***Table 2**: Right-side resistor network decomposition*

Notes:



Work together.
One circuit.

Think about it…

While ECE110 doesn't require a "professional" lab notebook, you should learn to start good habits now. Never erase mistakes or remove "bad" data. Cross out mistakes with a simple line and make the correction nearby. If you can explain an "outlying" data point, do so, but never arbitrarily choose to remove an outlier to improve your data set.

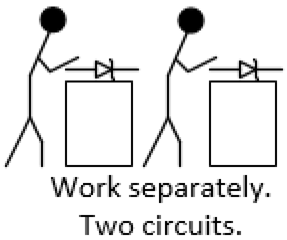
Notes:

Question 7: Provide a formula for the resistance of n $100\ \Omega$ resistors in parallel.

Question 8: Using your resistive model, R_m, for both motors and the resistor networks you designed above, predict how long a NiMH rechargeable battery rated at $1900\ \mathrm{mAh}$ would operate both wheels of the car continuously before going dead (depleting its charge). Show your work.

The TA will provide you with their preferences for this week's ***Explore More! Modules.*** Continue with below with your choice. Remember, at the end of the semester, you will earn points towards your total semester lab score by having completed a minimum of 10 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.

Explore More! Modules



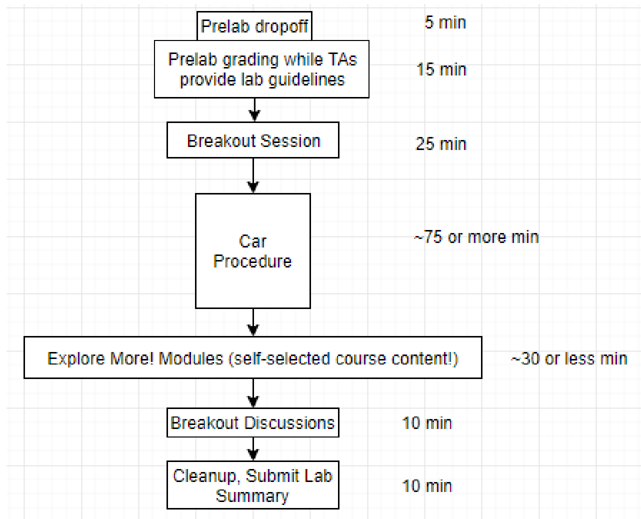


Figure 9: *Explore More! Modules provide students with options to investigate new concepts! As time allows, do one or more of the modules before returning to the laboratory's core procedure.*

Breakout Session Discussion

Discuss the lab summary at the center benches with your lab mates. Answer the questions and submit your summary sheet and modules before cleaning up for the day.

Notes:

Lab 2 Summary (To be submitted at the end of the laboratory session)

Question 9: Explain in your own words why we needed a resistive network instead of a single resistor to slow the wheels.

Question 10: What is the equivalent power rating of your left-side resistive network?

Question 11: Did this seem to be an effective method of wheel-speed control? What pros and what cons do you see in this method?

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:

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(circle one)

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