Name:______________________ UIN: ☐☐☐☐☐☐☐☐☐ Section AB/BB: ☐

Experiment 6: An Improved Motor Model

Laboratory Outline:

Up until this point we've used devices that can be treated as ideal for most practical purposes. Yet, even non-ideal devices are very practical in many applications and these will prove useful in your final design challenge as well as a host of projects you might take on after ECE 110. Motors and batteries are two such devices. As engineers, we must recognize non-ideal behavior and ask pertinent questions…Does a motor behave like a resistor? No, clearly our oscilloscope measurements revealed behaviors that are clearly not Ohmic. What is a better model? Can our battery provide enough current to drive two motors and the rest of the circuitry for any extended amount of time? You'll now understand some of the limitations of these devices when used in a circuit.

The DC power supply on your bench can be treated as an ideal voltage source for a great deal of its voltage range with typical circuits used in class. This is not the case with batteries. In the prelab, you characterized how our battery pack behaved under a load and you used a simple linear approximation of a battery that allows us to analyze this non-ideal device by modelling with a perfectly-linear IV curve.

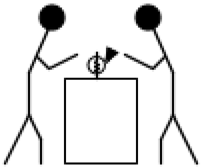
Motors convert electrical energy into kinetic energy. Today we'll characterize the chassis motor by varying the voltage that is applied to the motor terminals. In addition, we'll develop a linear model that approximates the motor's behavior over a range of input voltages. This will simplify analysis for the motor-drive circuit.

Notes:

Breakout Session…Sorry, no breakout today. Go directly to your benches.

At Your Bench

Motor Characterization through IV



Work together.
One circuit.

Today we'll look at the voltage-current relationship of a DC motor and see how it differs from resistors and develop a simplified linear model of the motor that we can use for basic circuit analysis.

Connect the circuit as shown in **Figure 3, using the power (voltage) supply and one of the drive motors on your car**.

- ✓ Make sure that the output on the power supply is set to "off" when you are constructing or making changes to your circuit. Use the + and − ports of the **+6V supply** on the HP3631A DC power supply.
- ✓ The DC motor in the diagram is one of the drive motors on your car chassis (not the extra DC motor in your ECE110 electronics kit). You do not need to remove the motor from the chassis. Instead, use the small wooden block as a "car lift" to keep the wheels off the ground.

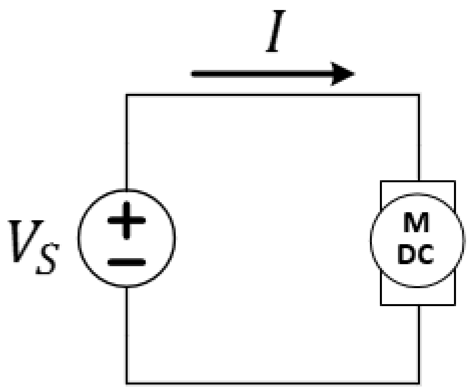


Figure 3: *Circuit schematic of the variable voltage source motor drive method.*

Run your motor at 6 volts for 2 minutes to warm it up. This should help you get more consistent results in your measurements.

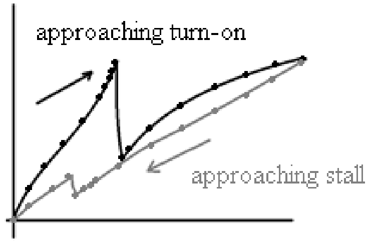
Before we begin taking measurements using our motor, let's quickly sweep the voltage to find the point at which the motor begins to turn. You will find that when the supply voltage is too low, the motor will remain stopped due largely to static friction and inertia. When the voltage is increased enough, the motor will turn on. Once the motor is moving and the voltage is decreased, the motor will not necessarily stop (stall) at the same turn-on voltage level because of the different *kinetic* friction and inertia. Kinetic friction of the motor is less than the static friction. The inductance of the motor windings may also play a role in keeping the motor rotating.

Starting from $0\ V$, the motor will fight internal friction. To find the turn-on voltage it is important that you always collect your data in with increasing voltage. If you need to go back and collect a certain data point, you need to start over from a voltage that produces a stalled position. Likewise, the stall voltage can only be found by starting from a higher voltage where the wheel is moving and reducing the voltage until the stall occurs.

Question 1: Starting at zero volts, sweep the voltage of the power supply up to 6V and make note of the approximate "turn-on" voltage at which the motor begins to spin. Once you have hit 6V, sweep the voltage back

Notes:

Warning: Do not apply more than 10 volts to your motor or you will risk permanent damage to it.



Example motor IV data without curve fits. Your figure may look quite a bit different.

Notes:

down and make another note of the approximate voltage at which the motor stops or "stalls". Record your approximate turn-on and stall voltages here. These two numbers should be somewhat different.

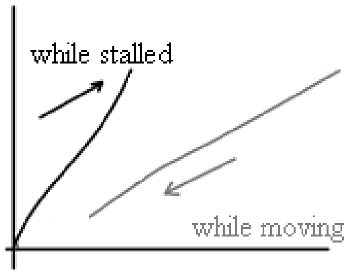
Voltage (V)	**Current**	**Notes:**

Table 2: *Current flow for the motor for* ***increasing, then decreasing,*** *DC voltage with comments.*

Question 2: Use MATLAB or BenchVue to generate an automated sweep of the power supply. Start at zero volts and sweep the voltage of the power supply up to 6V.

Question 3: Use MATLAB or Python to generate a graph of IV data.

Question 4: Perform a linear curve-fit to the "while moving" portion of this data (labeled on the image to the right). You may use a straight edge to draw your linear curve-fit on your printout. Alternately, in MATLAB, you might use the *polyfit* command to do a first-order (*n=1*) fit to that data.



Example motor IV data showing the two portions where you should perform curve fits.

Question 5: Determine a linear equation (slope-intercept form) corresponding to the linear curve-fit generated. Explain how you found the missing values below.

While Moving: $I = \_\_\_\_\_\_\_\_\_ V + \_\_\_\_\_\_\_\_\_\_$

Question 6: Using this equation, determine a Thevenin-equivalent circuit for your motor to model it when it's moving.

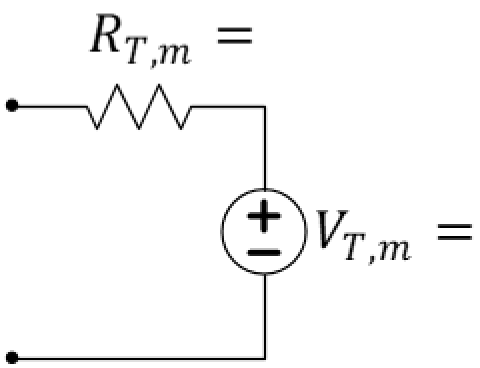


***Figure 4:** Record your estimates of $R_{T,m}$ and $V_{T,m}$ for **the Thevenin model of the moving motor** in the figure above.*

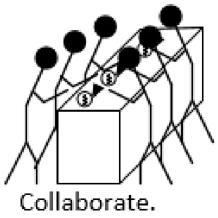
Mini-Project Modules

Mini-Project 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.

This week, we highly recommend the following ***Mini-Project modules:***

***Mini-Project* 6D: Using the Arduino to Drive Vehicle**	***Mini-Project* 7B: Interfacing Resistive Sensors Digitally**	***Mini-Project* The Burglar Alarm** ***Mini-Project* 100: IV Characteristics**

Breakout Discussion Session



When called back to the breakout, work in teams of 8 to answer the Lab Summary questions.

Notes:

Notes:

Learning Objectives

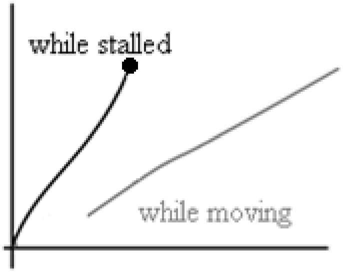
- Measure, analyze, and model the IV characteristics of the motor, noting that hysteresis (different behaviors in two different stimulus directions) requires two Thevenin models.
- Make note of the current drawn by the motor in normal operation and at a stall point.
- Estimate the waste power (large percentage!) for an inefficient voltage-divider-style motor speed controller.

You should now know how to think about circuits that include both batteries and motors as you now understand several limitations of these devices when used in a circuit. You have seen that models can help us produce accurate estimates of the actual performance of these devices. Motors and batteries are a central part of our future experiments and will be necessary for the final design project.

Notes:

Lab 6 Summary

Question 7: How much power is drawn from the power supply just below the turn-on voltage (while still stalled)? See the operating point suggested in the image below, but use the data you collected.



The stall point will draw a large amount of power from the battery that is wasted!

Question 8: When stalled, all energy from the battery is wasted. How long will your battery last if it were to sit continuously *just below* the turn-on state? Recall that the battery is rated at 1900 mAh. You measured the current drawn just below turn-on!