

Guidelines:

1. Work in your assigned teams to complete tasks 1 through 3 in lab today
2. Complete tasks 4-7 on your own (with appropriate help from your teammates)
3. Each student will turn in their own work
4. The objective is to determine the remaining physical parameters of the provided DC motor

Project Description:

At your station you will see an unloaded DC motor driven by a voltage source. A multimeter will measure the supplied current. An oscilloscope will measure the encoder pulse frequency (48 pulses per revolution).

Tasks:

1. Review our results from project assignment 1. Recall that the relevant equations of motion are:

- a. $(Js^2 + bs)\Theta_m(s) = KI_a(s)$

- b. $(L_a s + R_a)I_a(s) = E_{in}(s) - K_b s\Theta_m(s)$

And the resulting transfer function should have been:

- c. $\frac{\Omega(s)}{E_{in}(s)} = \frac{K}{(Js+b)(L_a s + R_a) + KK_b}$

The measured and calculated parameters should have been close to the following (but use your own numbers):

$R_a = 9.2\Omega$	$L_a = 0.21 \text{ mH}$	$K_b = 0.014 \frac{V s}{rad}$	$K = 0.014 \frac{N m}{A}$
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2. Estimate the damping coefficient of this system based on the current.
 - a. Run the DC motor with an input voltage of approximately 5.0 V. Record the steady-state speed of the pulse signal from the oscilloscope, then convert to rad/s of the shaft:
 - b. Make sure the multimeter is set to DC current measurement. Record the current here:
 - c. Calculate the damping coefficient using the equation, $b = \frac{Ki_a}{\omega}$:
 - d. Derive the equation for b starting from equation 1a (I will show you how to do this on the board, but reproduce the key steps here)

3. Estimate the moment of inertia based on the coasting behavior:
- Based on equation 1a, find a transfer function for just the mechanical part of the DC motor system. Use the armature current as the input, and the shaft speed as the output. This should result in a first order transfer function. Write this transfer function in the form $G(s) = \frac{con_1}{s+con_2}$
 - The time constant of this system is $T = \frac{1}{con_2}$. Write down an equation for T calculated from physical constants of the motor.
 - Look at your work from Task 2a, and write down the measured encoder frequency in Hz:
 - If you were to suddenly disrupt the supply current through the motor, the first order model predicts that the speed would decay exponentially to zero. Calculate the expected encoder frequency after one time constant. ($f(t = T) = e^{-1}f_0$)
 - Measure the time constant of the physical system using a stopwatch. You will need to physically pull the motor leads to remove the input current quickly. As a team find the best way to measure the time from pulling motor leads until the one time-constant speed is reached. *It will not be easy to get an accurate measurement, but do your best.* Write your best measurement here.

- f. As a class, we will repeat this experiment using Matlab to capture data in a more controlled way. Write the time we found below.
- g. Calculate the moment of inertia using your time constant from task 3f, and the equation from task 3b:

Individual Portion

4. Analyze the uncontrolled response of a DC motor's speed
 - a. Using your numerical values for all physical parameters, write the transfer function from task 1
 - b. Find the 2 poles for this system
 - c. What would you expect the overshoot of this system to be?
 - d. What would you expect the settling time of this system to be?
 - e. Using the final value theorem, find the final speed for a unit step voltage input
5. Analyze the step response in Matlab
 - a. Declare your measured motor parameter values and make the transfer function for the motor
 - b. Graph the response of the motor to a 5 V step input (you can use $\text{step}(5*G)$ to do this since it is a linear system)
 - c. Compare this graph to the step up portion at the beginning of the Matlab data we collected in class (I will add this graph and data to Brightspace)
 - i. Do they both settle on the same speed?
 - ii. Do they both have the same rise time?
 - iii. Do they both look similarly exponential?
 - iv. Do these results build or shrink your confidence in your model?
 - v. Answer these four questions as a paragraph in the comments of your Matlab code

6. Analyze the time constant decay in Matlab
 - a. Make the current transfer function from Task 3a in Matlab
 - b. Use *lsim* to simulate the response of this system to a sudden stop in current
 - i. Set *Istart* equal to the current you measured in Task 2b
 - ii. Create a time vector such as $t = 0:0.01:10$;
 - iii. Create a vector of current inputs that stays at *Istart* for long enough to come to steady-state, then drops to zero
 - iv. $I_in = Istart * ones(size(t))$;
 - v. $I_in(t > 5) = 0$;
 - vi. $lsim(Gcur, I_in, t)$
 - c. Compare this graph to the step down portion of the Matlab data we collected in class
 - i. These will not and should not start at the same value because one used voltage for the y axis, and the other used current for the y axis
 - ii. Do they have the same time constant?
 - iii. Do they look similarly exponential?
 - iv. Do these results build or shrink your confidence in your model?
 - v. Answer these three questions as a paragraph in the comments of your Matlab code.
7. Print a published version of your Matlab code and attach it to this worksheet.
 - a. Also include a paragraph evaluating the usefulness and achievability of this lab