Guidelines:

1. Complete the pre-project task 1 before Project Day 1 on Wednesday, January 19
2. Work in assigned teams to complete tasks 2 through 4 on Project Day 1
3. Complete the post-project task 5 on your own (with appropriate help from your teammates) before the due date
4. Each student will turn in their own work
5. The objective is to determine the physical parameters of the provided DC motor

Project Description:

In lab, you will see two DC motors with a belt attached from one shaft to the other. One motor will be driven by a voltage source to vary the speed. The other motor will be driven by the belt, and will generate a voltage proportional to its speed. Each motor has an attached encoder that outputs a square wave which cycles 48 times for every full revolution of the shaft. The motor's encoder will be output to the oscilloscope through the Encoder ports. You will use a selection of DC motor tests during class time, then use the results of these tests to calculate physical constants for the motor.

Tasks:

1. Find the transfer function for the system
   a. We derived the equations of motion in class for an unloaded DC motor. Here is what we got, expressed in Laplace form.
   - $(Js^2 + bs)\Theta_m(s) = KI_a(s)$
   - $(L_a s + R_a)I_a(s) = E_{in}(s) - K_b s\Theta_m(s)$

   a. Find the transfer function from input voltage $\left(E_{in}(s)\right)$ to output shaft speed $\left(\Omega(s) = s\Theta_m(s)\right)$. In other words, algebraically solve the two equations to find: $T(s) = \frac{s\Theta_m(s)}{E_{in}(s)} = \frac{\Omega(s)}{E_{in}(s)}$

b. In task 1a, you should have gotten something algebraically equivalent to the equation below. If you did not, see if you can find your mistake, then get help if you cannot.

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

c. List the physical constants we will need before we can use this transfer function.

d. Do some online searching to find an experiment that might work to find J or b (your choice) for a DC motor. Describe the gist of the experiment you found, and list your source.

2. Measure the internal armature resistance of the driven motor by switching your multi-meter to an Ohm setting. Is the resistance different at different shaft rotation orientations? How much does it change when the shaft is rotating quickly between orientations? Use the portable battery powered meter to measure the inductance. Hook the leads across the Generator ports and push the button. Check with other teams to see what values they are measuring for resistance and inductance. How much do these parameters vary by?
    a. R_a:
    b. Describe what you learned about resistance variation:
    c. L_a:

3. Also, calculate the armature resistance of the driving motor using an alternate method. By stalling the motor, you can ensure that the only voltage drop in the loop occurs across the resistor. Turn on the motor using the voltage source set to a relatively slow motor speed. Then stall the motor by using your finger to increase the belt tension. (*Don't do this if the belt is spinning very fast!*) Use the voltage source meter to measure the voltage supplied and the supplied current. (Note that we could get a more accurate measurement with other meters, but this will be sufficient for our purposes). Calculate the armature resistance from $R_a = \frac{V_{mot}}{I_{mot}}$
    a. V_{mot}:
    b. I_{mot}:
    c. R_a:
    d. Do these two methods match? If not, which do you trust more and why?

4. Calculate the back-emf constant for the generator. This driven motor will have no applied voltage, which will allow you to measure the back emf directly. At the same time, you can observe the speed on the oscilloscope. The motor encoder will output a square wave pulse 48 times per complete revolution. You should convert this to rad/s. Do this for four different motor shaft speeds. For at least one of these speeds, use the external tachometer to confirm the measured speed.
    a. Record data in the table below

Back emf (V)	Pulse Speed (Hz)	Shaft Speed (Hz)	Shaft Speed (rad/s)	Tach. Speed (rpm)	Tach. Speed (rad/s)

5. Interpret the results of Task 6 using Matlab. Note that this task should be done individually. Sharing concepts, function names, or coding strategies with your group members is appropriate group work. Sharing code electronically, or copying somebody else's code would not be appropriate group work.
    a. Make a plot in Matlab to show how shaft speed changes the back-emf for your DC motor.
    b. How close is this graph to the expected straight-line relationship passing through the origin?
    c. Estimate a representative back-emf constant, K_b, in $\frac{V}{\frac{rad}{s}}$ from the slope of your graph