Prelab	Participation	Lab
$\surd+$ $\surd$ $\surd-$ 0	$\surd+$ $\surd$ $\surd-$ 0	$\surd+$ $\surd$ $\surd-$ 0

Name: ______________________

1 Lab: Motor Spin Down Test

1.1 Introduction to Dynamic Systems lab

Each laboratory experiment consists of a PreLab, Inlab, and Postlab.

- The PreLab is to be done individually **before** coming to lab. The PreLab is checked for completion by your TA **immediately upon your arrival** at your lab section.
- The InLab is held in Peterson 108. Experiments are done in small groups during your regularly scheduled lab section.
- The Postlab is due at the same time as the homework. Submit the PostLab (lab handout and graphs) **separately** from the homework.

1.2 PreLab: Motor spin-down (analytical and Working Model)

1. Do the following two homework problems (from the book):
   System identification for a 1^{st}-order dynamic system (Coulomb friction).
   System identification for a 1^{st}-order dynamic system (viscous damping).
2. Download and install Working Model (demo version) from the class website:
   `http://www.stanford.edu/class/me161`
   Note: Working Model runs on Windows/PC (not Macintosh). Please find a colleague with a PC.
   Go through the Working Model tutorial.
   - Start Menu→Programs→Working Model→WMIntroduction
   - Double click the WMInstructoryTutorial.pdf file
   - Become comfortable with Working Model as you will use it in several labs.
3. Download and run the following Working Model simulations from the class website:
   MotorSpinDownTest.wm2d
   MotorSpinDownTestGuess.wm2d
   Record results on the Working Model1 PreLab (see back of textbook).

1.3 Experiment: Motor spin down

This section acquaints you with lab hardware and real motors. By measuring the angular speed of a freely spinning motor you will be able to determine numerical values for the viscous damping and/or Coulomb friction in the motors.

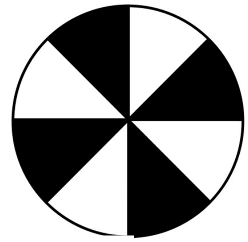
Each lab station has the following equipment:

DC motor	Wooden rod	HEDS 9100 encoder
Stopwatch	Variable voltage supply	Motor driver/Arduino Interface board
Oscilloscope	Arduino UNO board	DS275 RS-232 Transceiver Chip

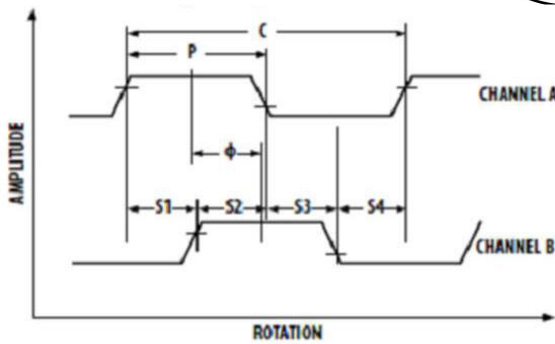
We use several pieces of equipment to measure and record the motor's angular speed, namely, we use an encoder, an Arduino microprocessor, a transceiver, and a computer.[1] This equipment is described below (if you fully understand it, you are a superstar).

[1]Most motors do not come attached to a rotary encoder and assembled with a encoder, microprocessor, transceiver, and computer. It is still possible (without an encoder, etc.) to make rough estimates of the viscous damping or Coulomb friction in a motor.

- **Encoder:**
  Our optical quadrature encoder determines our motor's rotational speed by detecting alternating light and dark patterns on a disk. For example, the encoder on the right shows 8 transitions (from light to dark or vice-versa). A quadrature encoder has the ability to detect both angular speed **and** direction. Our encoder has 1000 transitions (500 black sections and 500 white sections) and counts 1000 $\frac{\text{tics}}{\text{rev}}$.

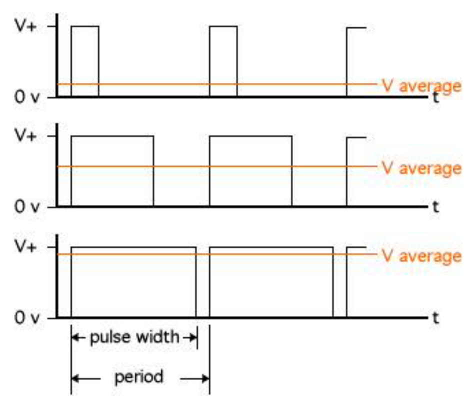


  Shown to the right is the output signal from the encoder to the Arduino microprocessor.



- **Computer:**
  The computer connects to the Arduino microprocessor via a USB cable (Serial Communication). Computer bits (ones and zeros) are transferred between the computer and Arduino microprocessor. You will use the compiled Arduino-specific executable file (Lab1.ino) to communicate between the computer and motor. When you run Lab1.ino, you will be prompted to select whether or not to use an encoder (choose the appropriate selection for the associated lab question).

- **Arduino UNO microprocessor (the interface between the computer and motor):**
  In this lab, the Arduino will use PWM (Pulse Width Modulation)[2] to vary the average voltage delivered to the motor.

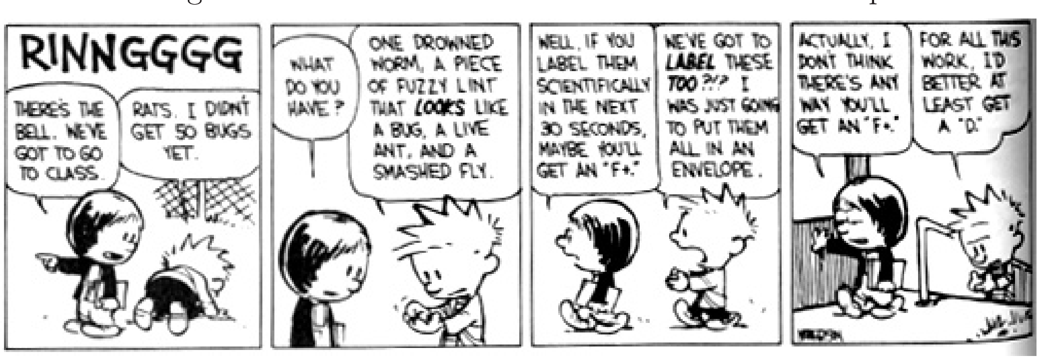


  The frequency of this PWM signal is 30 KHZ.

  For questions involving the encoder, the Arduino receives the digital signal from the encoder and counts the transitions from "high" (5 Volts) to "low" (0 Volts) of the signal in 5 milliSecond intervals.

  The on-screen data is in units of $\frac{1 \text{ tic}}{5 \text{ milliSecond}}$.

- **Motor driver/Arduino Interface Board:**
  The motor driver circuit receives the PWM signal from the Arduino microprocessor and controls the voltage delivered to the motor via the 12 Volt wall adapter.



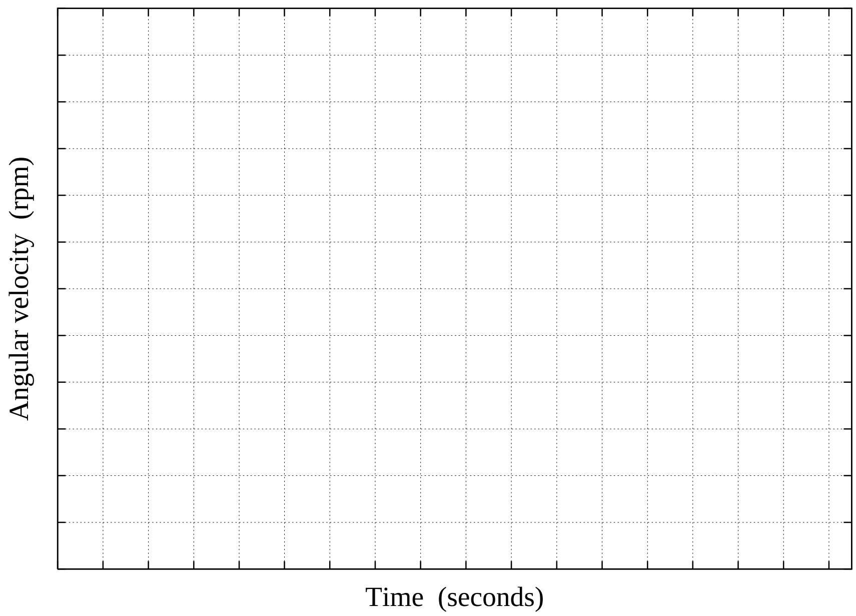
[2] A PWM signal is on (designated by a "high-bit" 1) or off (designated by a "low-bit" 0) for different intervals.

1.3.1 Estimation without an Encoder

The purpose of this section is to use a stop-watch and variable power supply to estimate the shape of the spin-down angular speed for a DC motor with a wooden rod attached to the shaft. Note: The motor's no-load speed is 5984 rpm at 24 volts and the no-load speed is **directly proportional** to the input voltage (assume the rod does not contribute a significant load).

- If necessary, login to the lab computer. Username: me161student
  Password: 1euler1. Ensure the domain is ENGR
- Ensure the wall power-adapter is plugged into both the Arduino microprocessor and the wall. (the power-adapter reduces the 120 Volts from the PG&E to 12 Volts).
- Double-click on the file Lab1/Lab1.ino
- When the Arduino graphics window appears on-screen, click the on-screen logo for the serial-monitor. Ensure the USB communication port (Tools ⇒ Ports) is not COM1, COM2, or COM3.
- Ensure the USB cable connects the computer to the Arduino microprocessor.
- To start the program, type **1** and enter a voltage between 1 and 5.
- Wait for the motor to spin-up to full speed.
- Type **s** to stop electrical current from flowing to the motor (the motor's will slow-down).
- Simultaneously to typing **s**, start timing with a stop-watch.
- Stop timing when the motor stops spinning

Complete the graph of the time-history of motor angular speed (below).
Please label the scale on your axes!
How many data points do you need to determine if the motor's speed decreases linearly or exponentially? ___.



1.3.2 Estimation with an Encoder

Complete the following equation which converts from the units displayed on the computer screen to the motor's angular speed in RPM. (Note: This is important for determining x-axis tic-mark values for your graph).

$$\frac{1\ \_\_\_}{1\ \_\_\_\_\_\_} * \frac{1 \text{ interval}}{5 \text{ ms}} * \frac{1000 \text{ ms}}{1 \text{ second}} * \frac{60 \text{ sec}}{1 \text{ minute}} * \frac{1 \text{ rev}}{\_\_\_\_\ \text{tics}} = \frac{12 \text{ rev}}{1 \text{ minute}}$$

You will collect data three times. The 1^{st} time, collect data without attaching the rod to the end of the motor. The 2^{nd} and 3^{rd} time, collect data with the rod attached, at a low voltage and high voltage. Ensure no wires or hands are in the way of the spinning rod!
To collect data using the computer setup:

1. Create a folder on the desktop for your lab group (put all your files in it each week)
2. Return to the Arduino's program's main-menu by typing **r**
3. Type **2** to start the program for these questions
4. Select a motor voltage between 1 and 6
5. The Arduino will stop reporting data when the motor has stopped.
6. Save the data into a file in your folder on the desktop.
7. Enter another voltage to get an additional set of data.
8. Repeat this process to get three sets of data as described above.
9. Plot the data file (e.g., using Microsoft Excel, MATLAB®, or PlotGenesis).
   Note: Before plotting, delete the menu (first couple of lines) at the top of the file.
   Think about converting the encoder data (counts) into rpm and what to use for the time scale.
10. Email the data files and/or graphs to yourself and your group members.
11. For each set of data, print out a graph of angular speed (rpm) vs. time (s) of the motor to hand in with your lab handout. Label the axes and title the graphs!
12. Ensure the power to the board is off and the setup is neat for the next lab section.

1.3.3 Questions

For the no-load condition **without** the rod:

- The motor's speed appears to decrease **linearly/exponentially** (circle one)
- It behaves like this because **Coulomb friction/viscous damping in the motor/air-resistance** (circle one) dominates the response
- Determine the value of the quantity that dominates the motor spin-down, i.e., the **either** Coulomb friction constant **or** the time constant τ ________.

Now **add the rod** to the motor shaft and take another set of data.[3]

- The motor's speed appears to decrease **linearly/exponentially** (circle one)
- It behaves like this because **Coulomb friction/viscous damping in the motor/air-resistance** (circle one) dominates the response
- Determine the value of the quantity that dominates the motor spin-down, i.e., the **either** Coulomb friction constant **or** the time constant τ ________.

† **Challenge question**: Knowing that data from a motor that decays purely exponentially allows you to calculate the time constant τ, what would you do to find numerical values for both the damping constant b and moment of inertia I in the motor's ODE: $I\,\dot{\omega} + b\,\omega = 0$

[3] The rod's moment of inertia can be estimated as $I_{rod} = \frac{1}{12}\,m\,L^2$