Lab 1 - Motor Spin Down Test

PRE-LAB

The angular speed ω of a motor is governed by the first order differential equation

$$I\dot{\omega} \; + \; b\omega \; = \; 0$$

where I is the moment of inertia of the motor and attachments about the motor's axis and b is the linear viscous damping constant.

a. The rate of the exponential decay of $\omega(t)$ is determined by the *time constant* T_c defined as the quantity associated with a solution of the form $e^{-\frac{t}{T_c}}$. Determine T_c.
   **Result:**

$$T_c \; = \; \frac{I}{b}$$

b. A motor is spinning with $\omega = 1000$ rad/sec. The power is then cut off and the motor spins down. The resulting spin rate can be modeled as a system governed by the first order equation shown above. When $t = T_c$, what is the ratio $\frac{\omega(t)}{\omega(0)}$? Suppose that time constant of the motor is measured as $T_c = 1$ second. What is the angular speed of the motor after 1 second? After 3 seconds? Using Matlab or by hand calculations, plot $\omega(t)$ for the first four seconds after the power is cut off.
   Result:

$$\omega(1) = 367.9 \text{ rad/sec} \qquad \omega(3) = 49.8 \text{ rad/sec}$$
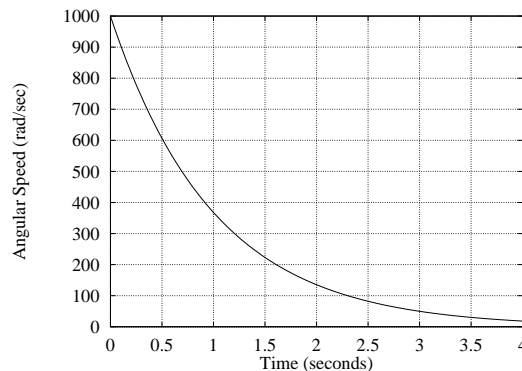
LAB

The purpose of this lab is to get you acquainted with the lab and the equipment, and to give you a real-life example of a first order system. In this lab, you will measure the response of a motor to an initial angular velocity, then use the measured time constant to determine the viscous damping of the system. Please bring a PC-formatted or reformatable floppy disk with you to the lab. In the lab, you will find:

- A DC motor (just like the ones you will find in your haptic paddle kit) mounted on a stand, with an extra mass attached to the rotor
- An oscilloscope with a scope probe
- A variable power supply
- Some alligator clips
- A PC with an A/D (Analog to Digital) card

Hook up the motor to the power supply with the alligator clips. Ground (black wire) goes to the `COM` plug, and signal (red wire) goes to `+18V` plug. Turn on the power and turn up the voltage to about 2V using the knob on the left. Avoid going higher than 6V, the rating for the motor. Now hook up the leads of the motor to the oscilloscope using the scope probe. You may have to play around with the trigger and the level settings to see the signal. Looking at the oscilloscope with the motor running, you will see the voltage applied to the motor. If you disconnect the power supply, you will see the *Back EMF* (Electro Motive Force) of the motor. Back EMF is proportional to the speed of the motor by a factor K_v called the *speed constant* or *voltage constant*. For this motor, the constant is 900 rpm (revolutions per minute) per volt. If you disconnect one of the alligator clips powering the motor, you can see the Back EMF (and thus the speed) decaying on the oscilloscope.

Now we will record this decay using the computer and A/D card. Unhook the oscilloscope and hook up the A/D screw terminal board. Again, use the red and black wires for signal and ground. On the computer, do `cd c:\me161\lab1` and run the data acquisition program by typing `lab1` at the prompt. Get the motor running again, with an input voltage of around 6V. Hit the `t` key to start taking data, and immediately remove one of the power connectors to the motor. (Note that removing the connector and turning off the power supply are *not* the same thing.) When the motor has stopped spinning, hit any key to stop taking data. Your data has been saved in a MATLAB script file called `lab1data.m`. Copy it onto a floppy disk using the `DOS` command `copy labdata1.m a:` to take with you (Macs will be able to read it).

The `lab1` program has recorded the time and the speed in the file `lab1data.m`. (Actually, it read the voltage from the A/D card then multiplied it by K_v to get the speed). Using the `DOS` command `edit`, you should to look at the numbers in the file to see if they make sense before leaving the lab. You should get time going from 0 to several seconds and speed going from about 5000 to 0 rpm.

Questions:

1. Provide a MATLAB plot of your spin down test, with time on the x-axis and speed on the y-axis. In MATLAB run the `lab1data.m` script to get the variables `time` and `speed` into the workspace. Plot using the command `plot(time,speed)`. Please zoom in on the relevant part of the plot using the MATLAB command `zoom`.

2. On the plot, indicate the point at the time constant $t = T_c$. What are T_c (don't forget to subtract the time before you cut the power) and $\omega(T_c)$? Hint: use the ratio $\frac{\omega(t)}{\omega(0)}$ from the Pre-Lab problem in the homework).

3. The inertia of the mass added to the motor is about 22 g-cm^2 and the inertia of the rotor is 8.6 g-cm^2. What is the viscous damping in the system?