

2.003 Modeling, Dynamics, and Control I  
MIT  
Department of Mechanical Engineering  
Spring 2005  
Lab 6

Week of April 4, 2005

## 1 Laboratory

With the lab apparatus, use your fingers to apply torque, first to the flywheel shaft and second to the motor shaft. Imagine that you didn't know about the gears and you had to estimate the magnitude of the inertia attached to each of the two shafts. Would you estimate them to be the same. If not, which would you say was larger? By a little or a lot? Explain what is going on relative to the analysis in your prelab.

## 2 Time constant with motor

Move all magnets along the baseplate away from the flywheel so that they supply no damping. Use a square wave from the signal generator to measure the step response in velocity. Be sure to choose an appropriate amplitude to avoid saturation (power supply "clicks"). Compare your results with part 2b) of the prelab. Include appropriate data in your lab report.

## 3 Time constant with magnets in place

Now put all three magnets in place on the flywheel and measure the square wave response. Use your analysis from part 2c) of the prelab to estimate the model damping  $B$  that you actually have (the value in the prelab is not necessarily accurate). Again, you'll need to choose an appropriate drive signal level.

## 4 Frequency response

Now we want you to measure the sinusoidal response. For linear time invariant (LTI) systems, if the input is  $\sin(\omega t)$ , the output will be  $M \sin(\omega t + \phi)$ , where  $M$  and  $\phi$  are functions of  $\omega$ . That is,  $M$  is the ratio of the output to the input amplitude and  $\phi$  is the relative phase shift of the output with respect to the input.

- (a) Convince yourself (and us) that if  $\Delta t$  is the time advance of the output relative to the input, then

$$\phi = \frac{\Delta t}{T} 2\pi \text{ [rad]}$$

where  $T = 2\pi/\omega$  is the period of the waveform.

- (b) Measure and plot  $M(\omega)$  and  $\phi(\omega)$  versus  $\omega$  on linear coordinates over an interesting set of at least 10 frequency points. Use the system with 3 magnets in place. Can you develop an analysis which predicts the observed behavior? Show us the details of your analysis.

## 5 Extra Credit

Plot  $M(\omega)$  and  $\phi(\omega)$  on log-log and semi-log coordinates. Use the Matlab bode command to overlay measured with model data and compare.