Due at 1700, Fri. Apr. 3 in homework box under stairs, first floor Cory .
Note: up to 2 students may turn in a single writeup. Reading Nise 10.10-10.12, 11

1. (15 pts) Time Delay (Nise 10.12)
Consider a telesurgery robot system, where the remote tool is modelled as a mass-damper system. The input to the system is commanded position, and output is actual position of the remote tool. The remote tool is located 3000 km from the master controller (10 ms delay in each direction, total 20 ms delay). The open-loop plant plus controller is given by:

$$G(s) = \frac{3000}{s(s + b/m)}$$

where $m = 1kg$, and $b/m = 70s^{-1}$. The closed-loop system is unity feedback.
a) Draw a block diagram for the system, including 10 ms propagation delay for the sensed position to the controller, and 10 ms delay for the commanded force to reach the actuator.
b) Draw Bode diagrams for the system with and without delay, and estimate gain and phase margin for both systems.
c) Use Matlab to plot the step response for the closed loop system with and without delay. Use `Gdelay=tf(num,den,'InputDelay',0.02)` to include time delay in the system.

2. (20 pts) Gain Adjustment (Nise 11.2)
Given unity feedback system with OLTF:

$$G(s) = \frac{K(s + 20)(s + 25)}{s(s + 6)(s + 9)(s + 14)}$$

a) Sketch by hand the Bode plot for $G(j\omega)$.
b) Estimate the value of K such that the phase margin $\Phi_m = 30°$.
c) Use Matlab to plot the step response for this value of K and compare ζ from this step response with estimate from phase margin.

3. (20 pts) Lag Compensation (Nise 11.3)
Design a lag compensator for a unity feedback system with OLTF

$$G(s) = \frac{K(s + 4)}{(s + 2)(s + 6)(s + 8)}$$

such that the system operates with a 40° phase margin and static error constant of 100. Provide Bode plot in Matlab showing compensated OLTF.

4. (20 pts) Lead Compensation (Nise 11.4)
Design a lead compensator for the unity feedback system with OLTF

$$G(s) = \frac{K}{s(s + 3)(s + 15)(s + 20)}$$

to yield $K_v = 4$ and a phase margin of 40°. Provide Bode plot in Matlab showing compensated OLTF.

5. (25 pts) PI control
Design a PI control for the unity feedback system with OLTF

$$G(s) = \frac{100K}{s(s + 36)(s + 100)}$$

that will yield a zero steady-state error for a ramp input, and 9.5% overshoot for a step input. (Matlab OK). Use Matlab to plot step response of closed loop system. Provide Bode plot in Matlab showing compensated OLTF.