Due at 1700, Fri. Nov. 2 in bcourses.

Note: up to 2 students may turn in a single writeup. Reading Nise 10, 11, 12.2

1. (20 pts) Time Delay (Nise 10.12)
Given a unity feedback system with forward path transfer function
\[ G(s) = \frac{8000}{(s + 20)^3} \]
Assume a total delay in the feedback path for example from camera frame rate limit of \( \Delta T \).
[2pts] a) Draw a block diagram for the system, including \( \Delta T \) propagation delay for error \( e(t) \) to reach the controller/plant \( G(s) \).
[8pts] b) Draw Bode diagrams for the system without delay, and estimate gain and phase margin. Determine \( \Delta T \) for a 20° reduction in phase margin for the system with delay.
[6pts] c) Estimate overshoot and settling time from second order approximation for both cases.
[4pts] d) Use Matlab to plot the step response for the closed loop system with and without delay and compare to the estimate from part c. (Use \( G_{\text{delay}}=\text{tf}(\text{num}, \text{den}, '\text{InputDelay}', \Delta T) \) to include time delay in the system.)

2. (25 pts) Lag Compensation (Nise 11.3)
Given unity feedback system with OLTf:
\[ G(s) = \frac{K(s + 4)}{(s + 2)(s + 6)(s + 8)} \]
[7pts] a) Sketch by hand the Bode plot for \( G(j\omega) \).
[15pts] b) Design a lag compensator (using methods of Ch 11) such that the phase margin is at least 45°, and the static error constant = 100 and sketch the Bode plot for the compensated OLTf.
[3pts] c) Use Matlab to plot the closed-loop step response for the compensated and uncompensated system, and compare steady state error. Also use \texttt{margin} to check design spec is met.

3. (25 pts) Lead Compensation (Nise 11.4)
Given unity feedback system with OLTf:
\[ G(s) = \frac{K}{s(s + 5)(s + 20)} \]
[7pts] a) Sketch by hand the Bode plot for \( G(j\omega) \).
[15pts] b) Design a lead compensator using frequency domain techniques (of Ch 11) , such that per cent overshoot is approximately 10% or less, with \( T_p \approx 0.5 \text{sec} \) and \( k_v \approx 10 \), and sketch the Bode plot for the compensated OLTf.
[3pts] c) Use Matlab to plot the closed-loop ramp response for the compensated and uncompensated system, and compare steady state error and settling time. Also use \texttt{margin} to check design spec is met.

4. (30 pts) State Feedback/Pole placement (Nise 12.2)
Consider the plant, where \( G(s) = \frac{Y(s)}{U(s)} \):
\[ G(s) = \frac{100}{(s + 1)^4} \]
[8pts] a. Draw the signal graph in phase variable form and write the corresponding state equations.
[12pts] b. Find \( K = [k_1 \ k_2 \ k_3 \ k_4] \) such that feedback \( u = r - Kx \) yields an equivalent second order step response with \( \zeta = 0.5 \) and \( \omega_n = 10 \). (Place third and fourth pole 5 times further from \( j\omega \) axis as the dominant pole pair).
[10pts] c. With zero initial conditions, use Matlab to plot the step response \( y(t) \) and also \( u(t) \), and each individual component \( k_1x_1(t), k_2x_2(t), k_3x_3(t), k_4x_4(t) \). Which state contributes most to \( u(t) \)?