Due at 1700, Fri. Mar. 24 in homework box under stairs, first floor Cory.

1. (20 pts) Time Delay (Nise 10.12)
Given a unity feedback system with forward path transfer function

\[ G(s) = \frac{10000}{(s + 10)^2(s + 30)} \]

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 10° 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 \( G_{\text{delay}} = \text{tf}(\text{num, den, 'InputDelay', deltaT}) \) to include time delay in the system.)

2. (15 pts) TF from Bode (Nise 10.10, 10.13)
The Bode plot for a stable closed-loop system \( T(s) = \frac{G(s)}{1+G(s)} \) is shown to the right.

[10pts] a) Estimate \( T(s) \) from the Bode plot.

[5pts] b) Estimate the open loop transfer function \( G(s) \).

3. (15 pts) Gain Adjustment (Nise 11.2)
Given unity feedback system with OLT:

\[ G(s) = \frac{K(s + 2)(s + 20)}{s(s + 10)^3(s + 15)} \]

[8pts] a) Sketch by hand the Bode plot for \( G(j\omega) \).

[4pts] b) Estimate the value of \( K \) and phase margin such that the step response has an approximate 15% overshoot.

[3pts] c) Use Matlab to plot the step response for this value of \( K \) and compare \( \zeta \) from this step response with estimate from part b). Also use the \texttt{margin} command to check estimates from hand drawn bode plot.

4. (25 pts) Lag Compensation (Nise 11.3)
Given unity feedback system with OLT:

\[ G(s) = \frac{81(s + 10)}{(s + 0.03)(s + 3)^2(s + 30)} \]

[7pts] a) Sketch by hand the Bode plot for \( G(j\omega) \).

[15pts] b) Design a lag compensator such that the phase margin is at least 45°, and the DC gain of the system is increased by 10dB, and sketch the Bode plot for the compensated OLT.

[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.

5. (25 pts) Lead Compensation (Nise 11.4)
Given unity feedback system with OLT:

\[ G(s) = \frac{400000(s + 5)^2}{(s + 2)^2(s + 30)^2(s + 100)} \]

[7pts] a) Sketch by hand the Bode plot for \( G(j\omega) \).

[15pts] b) Design a lead compensator such that the phase margin is 40°, and the DC gain of the system is unchanged, and sketch the Bode plot for the compensated OLT.

[3pts] c) Use Matlab to plot the closed-loop step 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.