Due at 1700, Fri. Mar. 3 in homework box under stairs, first floor Cory .
Note: up to 2 students may turn in a single writeup. Reading Nise 8, 9
Midterm: Thurs. Mar. 9, Location: 277 Cory, 0810-0930 am.

1. (22 pts) Root locus (Nise 8.7)
Given the unity gain feedback system in Fig. 1, where

$$G(s) = \frac{K(s+15)(s+40)}{(s+30)(s^2-20s+200)}$$

`[11 pts]` a) Find and approximately hand sketch the root locus using RL rules 1-8.
`[4 pts]` b) Find the range of K which makes the system stable.
`[5 pts]` c) Using the second order approximation (assuming dominant 2nd order poles) find the value of K that gives $\zeta = 0.5$ and $T_s \approx 0.2$ for the system's dominant closed-loop poles.
`[2 pts]` e) Use MATLAB to plot the step response for c) and compare to approximation estimate.

2. (25 pts) Root locus (Nise 8.6, 8.9)
Consider the unity gain feedback system in Fig. 1 with $G(s) = \frac{k(s-10)(s-5)}{(s+20)(s+10)(s+2)}$. Here $-\infty < k < \infty$
`[13 pts]` a) Apply root locus rules: specify real axis segments, break-away and break-in locations on real axis, and angle of departure from complex poles.
`[6 pts]` b) Find the $j\omega$ crossing using Routh-Hurwitz.
`[4 pts]` c) Hand sketch the closed-loop root locus for positive and negative k.
`[2 pts]` d) Find the range of k for stability.

3. (26 pts) PI compensation (Nise 9.2)
Consider open loop plant

$$G(s) = \frac{2000K}{(s+10)^2(s+20)}$$

and unity feedback.
`[5 pts]` a) find K such that overshoot is 20%.
`[11 pts]` b) Design a PI controller with the same 20% overshoot such that steady state error is 0, with $T_s \leq 1$ sec. (Hint: PS4-1)
`[6 pts]` c) Hand sketch the root locus for the original system and the system with a **PI** compensator, and verify with Matlab.
`[2 pts]` d) Use Matlab to compare the step response for the closed-loop compensated and uncompensated systems, transient and steady state response.
`[2 pts]` e) Find the steady state error for a step for both systems.

4. (27 pts) PD compensation (Nise 9.3)
Consider open loop plant

$$G(s) = \frac{144K}{s(s+4)(s+12)^2}$$

and unity feedback.
`[5 pts]` a) find K such that overshoot is 20%.
`[12 pts]` b) Design a PD controller (i.e. find zero location) such that $T_p \approx 0.8$ sec, with the same 20% overshoot.
`[6 pts]` c) Hand sketch the root locus for the original system and the system with a **PD** compensator, and verify with Matlab.
`[2 pts]` d) Use Matlab to compare the step response for the closed-loop compensated and uncompensated systems, transient and steady state response.
`[2 pts]` e) Find the steady state error for a step for both systems.

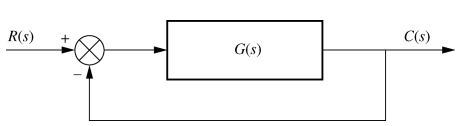

Fig. 1. Unity Gain Feedback.