ESE 406/505 & MEAM 513 - SPRING 2012
HOMEWORK #7
DUE by Friday 2-Mar-2012 by 2PM @ 320 Towne (NO LATE PASSES)

1. Work problem 5.12 in the textbook. You should try to "sketch" the locus by hand, but you may use Matlab to confirm your hand sketch and find the gain to achieve the desired pole locations.

   Answer: K ~ 15 for damping ratio 0.5.

2. Work problem 5.14 in the textbook. Do the block-diagram algebra by hand so that you can express the closed-loop denominator in the form a(s)+Kb(s). Then use a root locus to find the value of K that gives the required damping ratio.

   Answer: $a(s)=s^2+s+10$, $b(s)=10s$, K=0.22.

3. Repeat the analysis of yaw-rate feedback on the 747 from the last homework, but this time let MATLAB generate the root locus for you. Submit the root locus plot with the closed-loop pole location corresponding to K=1.5 clearly identified.

   HINT: First, convert the state-space model to a transfer function using MATLAB's `ss2tf` function. The get the loop transfer function including the low-pass and high-pass filter. Then you can use the `rlocus` and `rlocfind` commands.

4. **ESE 406 ONLY**: Work problem 5.31 but instead of the given compensator, use $H(s)=K\dfrac{s+1}{s+4}$. (The 2-to-1 lead ratio in the given compensator is very weak and doesn't provide much stabilization, so we will try a 4-1 lead compensator.) For part (b), find the gain that results in neutral stability. The ratio of the gain for neutral stability to the nominal gain is called the "gain margin" and is something we will talk about a lot after spring break.

   Answers: (a) the root locus shows the roots are in the left-half plane for all K>0.

   (b) K ~ 8 for damping ratio ~ 0.32. K~36 for neutral stability, so the gain margin is about 4.5.

   ESE 505 / MEAM 513 ONLY: Work problem 5.29 in the textbook.

   Answers: (a) $m\ddot{x} = 20x + 0.5i - mg.$

   (b) $V_o = 0.392.$

   (c) $\frac{E}{U} = \frac{2500}{s^2 - 1000}$. (Note that the governing equations are all linear, so that linearization effectively just removes the gravity and Vo terms. You don't need to bother with the formal state-space methods here, but you should be sure that you could if you needed to.)

(d) The poles come together at the origin and then go along the imaginary axis. Proportional feedback cannot stabilize the system.

(e) This is an open-ended question. Here is a suggestion: start with PD control and try for a natural frequency of about 30 (this is roughly the magnitude of the open-loop unstable root), with a damping ratio of maybe 0.7. Now low-pass filter the derivative feedback. This will decrease the damping ratio of the closed-loop pole, as discussed in class. Find a filter time constant that will give a closed-loop damping ratio of 0.5. Convert your proportional plus filtered derivative feedback into the form requested. These are just suggestions. The point is for you to play around with this enough to feel comfortable with lead compensation.