ESE 406/505 & MEAM 513 - SPRING 2011
HOMEWORK #7
DUE 23-Mar-2011 (Monday, 28-March with late pass)

1. Work problem 4.7 in the textbook. In addition to parts (a), (b), & (c) in the text, consider the following additional questions, assuming that $k_t' = 1$, $K' = 4$, and $\tau_m = 2$.

   a. What is the crossover frequency of the loop transfer function? How far is the phase from -180 degrees at this frequency? What does this mean? Submit a bode plot for the loop transfer function and show how to determine the value of K_v from the plot.

   b. What is the bandwidth of the system, using the textbook's definition that bandwidth is the frequency at which the gain of the closed-loop response to commands is -3dB?

   Answers:

   a. $K' = \frac{K_p K K_m}{k}$, $k_t' = \frac{k k_t}{K_p}$

   b. Type 1 & $K_v = \frac{k K_m}{(1 + k K_m k_t)}$

   c. Decrease (k_t makes steady-state errors to ramp inputs larger).

   d. You can get the necessary bode plot using the following Matlab commands. The rest is up to you.

   ```
   Gp = tf([4],conv([1 0],[2 1]));
   H = tf([1 1],[1]);
   G = Gp*H;
   bode(G); grid on;
   ```

   e. You can get the necessary bode plot using the following additional Matlab commands. The rest is up to you.

   ```
   T = Gp/(1+Gp*H);
   bode(T); grid on;
   ```

2. Work problem 4.14 in the textbook, parts (a) and (b) only. Also work the following revised version of part (d): make a bode plot of the loop transfer function including the given sensor dynamics and identify on the plot the value of Kv and the amount by which the phase is above -180 degrees.

   Answers:

   a. Yes & Kv = 10.67

b. No. Recall from lecture that perfect rejection of steady-state disturbances at the input requires integral feedback.

3. Work problem 4.23 in the textbook. Ignore part (a) of the problem, which is strange because it doesn't match the transfer function given in part (b). Also add the following question:

   (e) For the integral feedback you found in part (c), make a bode plot of the ratio of closed-loop response to road grade divided by the open-loop response to road grade. At what frequency is the ratio greater than 1 (0dB)? If the car is cruising at 25 m/s (about 60mph), what is the minimum distance between peaks of rolling hills for which the integral feedback controller will reduce the speed variations, compared to a simple "constant throttle" controller?

   Answers:

   b. $k_p > 0.08$
   c. Integral feedback assures zero steady error for a constant grade.
   d. $k_I = 0.0001$
   e. Because the disturbance can be scaled to have the same transfer function as the input, the disturbance is equivalent to a disturbance at the input. Thus, the ratio described is the sensitivity function, 1/(1+G). The rest is up to you.