EE 302: Assignment

1. Consider the unity feedback system shown in Figure 1, with

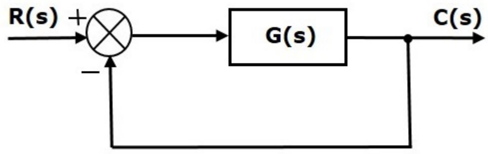

Figure 1: A unity feedback system

$$G(s) = \frac{K}{(s+3)(s+5)}$$

   (a) Show that the system cannot operate with a settling time of $\frac{2}{3}$ seconds and a percent overshoot of 1.5% with a single gain adjustment.

   (b) Design a controller/lead compensator so that the system meets the transient response characteristics of part (a). Specify the controller/compensator's pole, zero and the required gain.

2. Consider a simple mass, spring, damper system as shown in Figure 2 with $m = 1\ kg$, $b = 10\ Ns/m$, $k = 20\ N/m$, F=1 N.

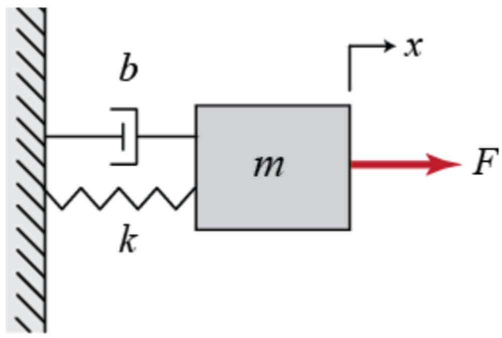

Figure 2: A mass, spring damper system

   (a) Find the transfer function between force and displacement for the above system. Also find the unit step response and time domain specifications of the system.

   (b) Design a proportional controller such that the new steady state error is within 0.05%. Also comment on variation in overshoot, rise time and settling time with respect to proportional gain.

   (c) Design a P-D controller with P taken in part (b) such that the peak overshoot is within 15%. Comment on variation rise time, settling time and steady state error with respect to P-D gains.

   (d) Design a P-I-D controller such that the steady state error reduces to zero, overshoot is less than 15% and rise time less than 0.15 sec. Keep P and D constant and vary I.

   (e) Modify the above P-I-D controller such that the steady state error reduces to zero, no overshoot and rise time less than 0.2 sec. Keep P constant and vary I and D.

3. The transfer function for an F-16 aircraft relating angle of attack $\alpha(t)$ to elevator deflection $\delta_e(t)$ is given by

$$G(s) = \frac{\alpha(s)}{\delta_e(s)} = 0.072\frac{(s+23)(s^2+0.05s+0.04)}{(s-0.7)(s+1.7)(s^2+0.08s+0.04)}$$

   Design a cascade compensator to yield zero steady-state error, a settling time of about 0.05 sec, and a percent overshoot not greater than 20%.

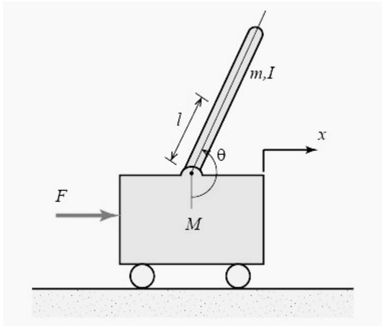

Figure 3: An inverted pendulum mounted to a motorized cart

4. Consider the system shown in Figure 3 consisting of an inverted pendulum mounted to a motorized cart.To prevent the pendulum from falling over, one must move the cart horizontally with an external force F, which is the control input. Design a controller for the inverted pendulum system using the root locus design technique such that the controller attempts to maintain the pendulum vertically upward when the cart is subject to a 1 N-sec impulse. The controller must meet the following design criteria:

   (a) Settling time of less than 2 sec.

   (b) Pendulum does not move more than 10^o away from the vertical.

   Assume that
   Mass of the cart $(M) = 0.5\ kg$,
   Mass of the pendulum $(m) = 0.2\ kg$,
   Coefficient of friction for cart $(b) = 0.1\ N/m/sec$,
   Length to pendulum's center of mass $(l) = 0.3\ m$,
   Moment of inertia of the pendulum $(I) = 0.006\ kg.m^2$.

5. The controlled process of a dc motor control system with unity feedback has the transfer function

$$G(s) = \frac{6.087 \times 10^{10}}{s(s^3 + 423.42s^2 + 2.6667 \times 10^6 s + 4.2342 \times 10^8)}$$

   Due to the compliance in the motor shaft, the process transfer function contains two lightly damped poles, which will cause oscillations in the output response. The following performance criteria are to be satisfied.

   (a) Maximum overshoot less than 1%,

   (b) Rise time less than 0.15 seconds,

   (c) Settling time less than 0.15 seconds.

   Design a lead compensator such that all the step-response attributes are satisfied.