1. Sketch the root locus for the feedback system below with \( P(s) = \frac{s+1}{s^2(s+3.6)} \) and \( K(s) = k, k > 0 \).

![Root Locus Diagram]

Is it possible to find a gain \( k \) such that all of the CL poles have a real part less than -1.2?

2. **OPTIONAL** Suppose you are given a system \( P(s) = \frac{s-1}{(s-1.5)(s+2)} \). Is it possible to stabilize the feedback system with a stable controller?

3. Consider the inverted pendulum problem of homework #1 (problem #4). The transfer function from the actuating force \( f \) to the angle of rotation \( \theta \) is given as

\[
P(s) = \frac{1/M\ell}{s^2 - \frac{M+m}{M\ell} g} = \frac{\dot{\theta}(s)}{f(s)}.
\]

Assume \( M = 10, m = 2, \ell = 5, g \approx 10 \) (in a compatible system of units). Consider now, the feedback system below

![Inverted Pendulum Diagram]

a) Use Root locus arguments to show that a proportional controller does not stabilize the system.

b) What controller \( K(s) \) can we use to stabilize the system and also to provide CL poles with damping ratio \( \zeta \geq 0.707 \) and real part less than -3?

![Inverted Pendulum Diagram]

4. Consider the unity feedback system below with \( P(s) = \frac{1}{(s+2)(s+3)}, K(s) = \frac{k+z}{s+p}, k \geq 0 \). Find a triplet \((k, z, p)\) such that the closed loop is stable and there is a pair of complex CL poles at \( s = -1 \pm j \). Where is the other CL pole?

![Unity Feedback Diagram]

5. Space vehicles, such as the space shuttle, using wings to maneuver while reentering the earth’s atmosphere present an interesting control problem. The figure below illustrates a conceptual design of such a system and indicates the block diagram of the pitch-rate control system.
(a) Set $k_1 = 0$ and draw the root-locus (you may use MATLAB) as $k_2$ varies over the positive real numbers. Is the system stable for all $k_2$? Can the system follow a unit step command with 0 steady state error?

(b) Select $k_1 = 1$ and draw the new root-locus (you may use MATLAB). Is the system stable for all $k_2$? Can the system follow a unit step command with 0 steady state error?

(c) Select the values of $k_1$ and $k_2$ which will result in a step response with settling time less than 10 secs and as minimal overshoot and rise time you can.