ME 132 Dynamic Systems and Feedback
Summer 2025 George Anwar

HW6

Due: Monday, August 4 at 11:59 pm

- Homework 6 is a written assignment; **Please read Nise Chp. 9 and 10** (Skip Nyquist Criterion).
- For coding questions, attach a screenshot of the script and output (Simulink!)
- Please write neatly and legibly, because if *we can't read it, we can't evaluate it.* **Box** your final answer.
- In all of the questions, **show your work**, not just the final answer. Unless we explicitly state otherwise, you may expect full credit only if you explain your work succinctly, but clearly and convincingly.
- If you are asked to provide a "sketch," it refers to a *hand-drawn* sketch, well-labeled to indicate all the salient features—not a plot generated by a computing device.
- If you have a confirmed disability that precludes you from complying fully with these instructions or with any other parameter associated with this problem set, please alert us immediately about reasonable accommodations afforded to you by the DSP Office on campus.
- **Start early. Some of the material is prerequisite material not covered in lecture; you are responsible for finding resources to understand it.**

Deliverables Submit a PDF of your homework to the Gradescope assignment entitled "{Your Name} HW1". You may typeset your homework in LaTeX or any word-processing application (submit PDF format, not .doc/.docx format) or submit neatly handwritten and scanned solutions.

1 Honor Code

I will adhere to the Berkeley Honor Code: specifically, as a member of the UC Berkeley community, I act with honesty, integrity, and respect for others. Failure to comply with these guidelines can be considered an academic integrity violation. Please email Professor Anwar ganwar@berkeley.edu or post on Ed if you have any questions!

- **List all collaborators. If you worked alone, then you must explicitly state so.**
- **Declare and sign the following statement**:
  "I certify that all solutions in this document are entirely my own and that I have not looked at anyone else's solution. I have given credit to all external sources I consulted."

  Signature : ______________________ *Date* : ______________________

  While discussions are encouraged, *everything* in your solution must be your (and only your) creation. Furthermore, all external material (i.e., *anything* outside lectures and assigned readings, including figures and pictures) should be cited properly. We wish to remind you that consequences of academic misconduct are *particularly severe*!

- Violation of the Code of Conduct will result in a **zero** on this assignment and may also result in disciplinary action.

2 Questions

1. Consider the unity feedback system shown in Figure P9.1, where

$$G(s) = \frac{K}{s(s+3)(s+6)}$$

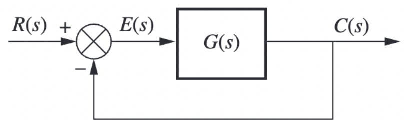

FIGURE P9.1

a. Design a PI controller to drive the ramp response error to zero for any K that yields stability.

b. Use MATLAB to simulate your design for $K = 1$. Show both the input ramp and the output response on the same plot.

2. Consider the unity feedback system shown in Figure P9.1 with

$$G(s) = \frac{K}{(s+3)(s+5)(s+7)}$$

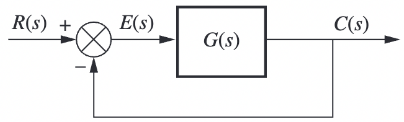

FIGURE P9.1

a. Design a compensator that will yield $K_p = 20$ without appreciably changing the dominant pole location that yields a 10% overshoot for the uncompensated system.

b. Use MATLAB or any other computer program to simulate the uncompensated and compensated systems.

c. Use MATLAB or any other computer program to determine how much time it takes the slow response of the lag compensator to bring the output to within 2% of its final compensated value.

3. Consider the unity feedback system shown in Figure P9.1 with

$$G(s) = \frac{K(s+6)}{(s+3)(s+4)(s+7)(s+9)}$$

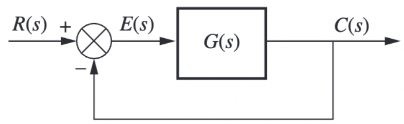

FIGURE P9.1

a. Sketch the root locus. Use MATLAB.

b. Find the coordinates of the dominant poles for which $\zeta = 0.8$.

c. Find the gain for which $\zeta = 0.8$ analytically. Use MATLAB to check your answer.

d. If the system is to be cascade-compensated so that $T_s = 1$ second and $\zeta = 0.8$, find the compensator pole if the compensator zero is at -4.5.

e. Discuss the validity of your second-order approximation.

f. Use MATLAB or any other computer program to simulate the compensated and uncompensated systems and compare the results to those expected.

4. An X-4 quadrotor flyer is designed as a small-sized unmanned autonomous vehicle (UAV) that flies mainly indoors and can help in search and recognizance missions. To minimize mechanical problems and for simplicity, this aircraft uses fixed pitch rotors with specially designed blades. Therefore, for thrust it is necessary to add a fifth propeller. A simplified design of the thrust control design can be modeled as in Figure P9.1 with $G(s) = G_c(s)P(s)$ where

$$P(s) = \frac{1.90978(\frac{s}{0.43} + 1)}{(\frac{s}{9.6} + 1)(\frac{s}{0.54} + 1)}$$

represents the dynamics of the thruster rotor gain, the motor, and the battery dynamics. Initially, the system is designed using a proportional compensator given by $G_c(s) = 3$ (*Pounds, 2009*).

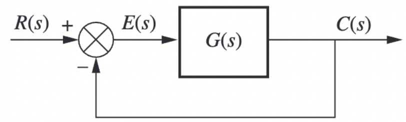

FIGURE P9.1

a. Calculate the resulting steady-state error for a unit step input.

b. Design a lag compensator to yield half the steady-state error of the proportional compensator, without appreciably affecting the system's transient response.

c. Use MATLAB to simulate the original design and the lag compensated design. Verify your results.

5. Find analytical expressions for the magnitude and phase response for each $G(s)$ below.

   a. $G(s) = \frac{1}{s(s+2)(s+4)}$

   b. $G(s) = \frac{(s+5)}{(s+2)(s+4)}$

c. $G(s) = \frac{(s+3)(s+5)}{s(s+2)(s+4)}$

6. For each function in the previous problem, make a plot of the log-magnitude and the phase, using log-frequency in rad/s as the ordinate. Do not use approximations.

7. For each closed-loop system with the following performance characteristics, find the closed-loop bandwidth:

   a. $\zeta = 0.2$, $T_s = 3$ seconds

   b. $\zeta = 0.2$, $T_p = 3$ seconds

c. $T_s = 4$ seconds, $T_p = 2$ seconds

d. $\zeta = 0.3$, $T_r = 4$ seconds

8. Using Bode plots, estimate the transient response of the systems in Figure P10.6.

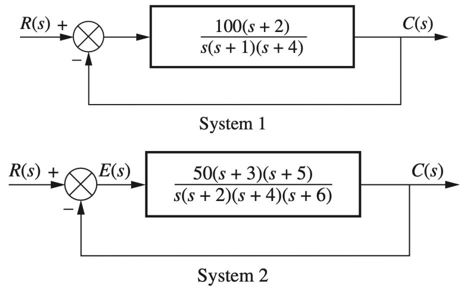

FIGURE P10.6

More space for above question.

9. Write a program in MATLAB that will use an open-loop transfer function, $G(s)$, to do the following:

    a. Make a Bode plot.

    b. Use frequency response methods to estimate the percent overshoot, settling time, and peak time.

    c. Plot the closed-loop step response.

    Test your program by comparing the results to those obtained for the systems in Figure P10.6.

Insert your code here for the above question.

10. The open-loop dynamics from DC voltage armature to angular position of a robotic manipulator joint is given by $P(s) = \frac{48500}{s^2+2.89s}$ (*Low, 2005*).

    a. Draw by hand a Bode plot using asymptotic approximations for magnitude and phase.

    b. Use MATLAB to plot the exact Bode plot and compare with your sketch from Part a.