ENGR 105: Feedback Control Design

Final Exam, Winter Quarter 2012

Monday, March 19, 2012, 8:30-11:30 am, Room 420-40

Name: ____

Exam Policies

- Allow one empty seat between yourself and the next person.
- No calculators, cell phones, or other electronic devices. Please leave these items in your bag or pocket throughout the exam. There is a clock in the room.
- The exam is closed book and closed notes, except you may use four sheets of paper with notes (writing on front and back is permitted).
- Simplify answers as fully as possible, box your answers, and show all work for full credit.

Stanford Honor Code

1. The Honor Code is an undertaking of the students, individually and collectively:
   a. that they will not give or receive aid in examinations; that they will not give or receive unpermitted aid in class work, in the preparation of reports, or in any other work that is to be used by the instructor as the basis of grading;
   b. that they will do their share and take an active part in seeing to it that others as well as themselves uphold the spirit and letter of the Honor Code.
2. The faculty on its part manifests its confidence in the honor of its students by refraining from proctoring examinations and from taking unusual and unreasonable precautions to prevent the forms of dishonesty mentioned above. The faculty will also avoid, as far as practicable, academic procedures that create temptations to violate the Honor Code.
3. While the faculty alone has the right and obligation to set academic requirements, the students and faculty will work together to establish optimal conditions for honorable academic work.

I acknowledge and accept the Honor Code on this exam and all other work associated with this class.

____

signature

Problem	Score
1 (10 pts.)	
2 (15 pts.)	
3 (20 pts.)	
4 (15 pts.)	
5 (20 pts.)	
6 (20 pts.)	
Total (100 pts.)	

Problem 1. (10 pts.)

Mark the following True (T) or False (F):

______ a. (1 pt.) A pure time delay has no effect on the magnitude of the open-loop transfer function.

______ b. (1 pt.) For an equation to be in root-locus form, the polynomial $a(s)$ must be of lower degree than $b(s)$.

______ c. (1 pt.) Stability margins can be found from the Bode plot of any system.

______ d. (1 pt.) As the poles of a system move further away from the origin of the real-imaginary plane, the system response gets faster.

______ e. (1 pt.) Lead compensation resembles a PI controller.

______ f. (1 pt.) A lead compensator can be implemented as an analog circuit.

______ g. (1 pt.) A magnitude of 1000 is equivalent to 60 decibels.

Provide a short narrative answer to each of the following questions:

h. (1 pt.) What is a physical interpretation of the poles of a guitar?

i. (1 pt.) Why might you want to determine stability from a Nyquist plot rather a Routh Array?

j. (1 pt.) For the Phantom Omni robots/haptic devices shown in class, name two assumptions we made about the system dynamics to permit use of the analysis techniques learned in this course.

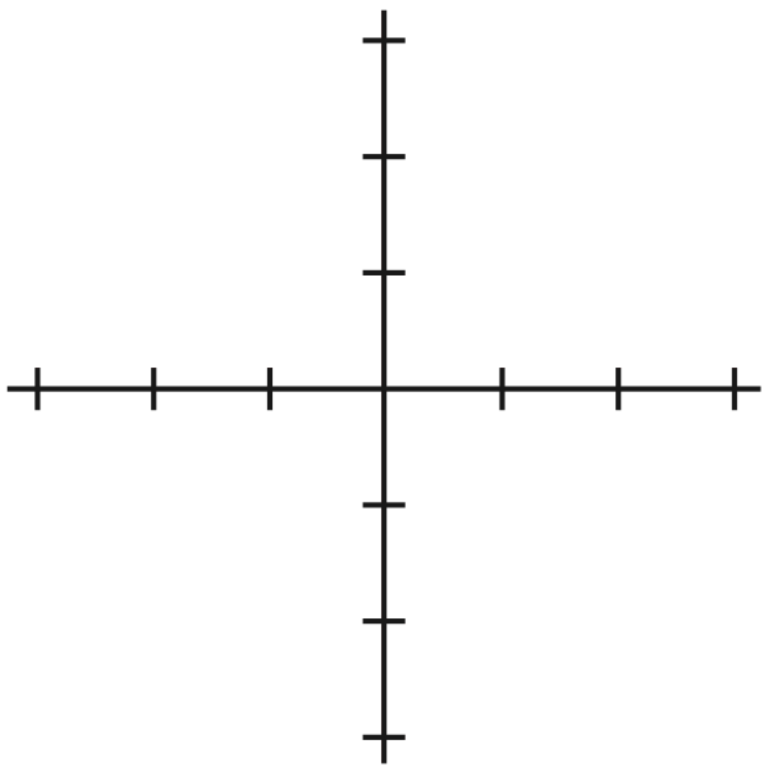
Problem 2. (15 pts.)

A certain system has dynamics dominated by a complex pair of poles and no finite zeros. The time-domain specifications are:

$$t_r \leq 1.2 \text{ sec}$$
$$M_p \leq 17\%$$
$$t_s \leq 4.6 \text{ sec (estimate)}$$

a. (10 pts.) Sketch the region in the s-plane where the poles could be placed so the system will meet these specifications. Use the axes given below.

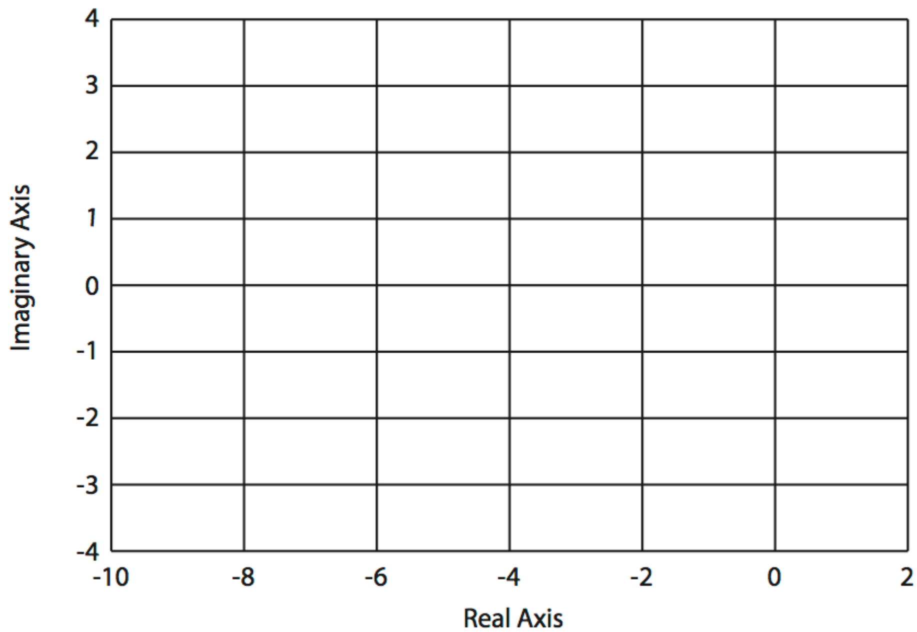
b. (5 pts.) Indicate on your sketch the specific locations that will have the *smallest rise time* and also meet the settling time estimate exactly.



Problem 3. (20 pts.)

Consider the transfer function $G(s) = \frac{s^2+4s+5}{s(s+1)(s+2)(s^2+9)}$

a. (3 pts.) Enter the poles and zeros of $G(s)$ on the s-plane below.



b. (12 pts.) Calculate the following guidelines for sketching the root locus $1 + KG(s)$.

The angles of the asymptotes are: ______________________________

The center of the asymptotes is: ______________________________

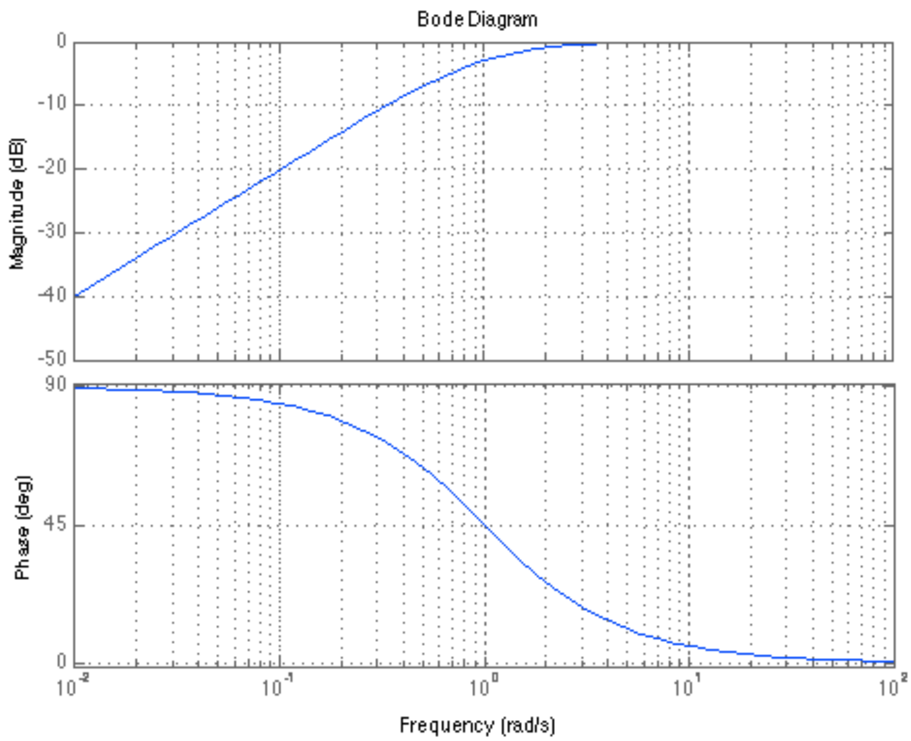
The arrival angles at the complex zeros are: ______________________

The departure angles from the complex poles are: __________________

c. (5 pts.) Sketch the root locus on the s-plane above.

Problem 4. (15 pts.)

The Bode plot shown below was determined from a transfer function $G(s)$.

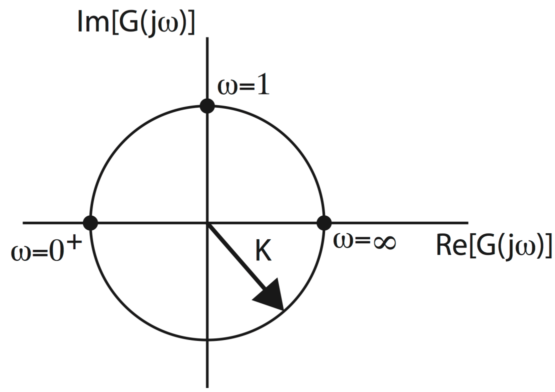


a. (8 pts.) Find the simplest $G(s)$ that could result in this Bode plot.

b. (7 pts.) Solve for the response of $G(s)$ to a unit step input, assuming zero initial conditions, and sketch the response versus time. Explain how this result is intuitive, given the zero and pole locations.

Problem 5. (20 pts.)

Consider the Nyquist plot shown below.



a. (7 pts.) Sketch the corresponding Bode plot (magnitude and phase).

b. (7 pts.) Suppose you know the transfer function is of the form $G(s) = A\frac{s+z}{s+p}$.

Find values for A, z, and p that correspond to the given Nyquist plot.

A = __________

z = __________

p = __________

c. (3 pts.) For what values of K will the corresponding unity feedback system be stable?

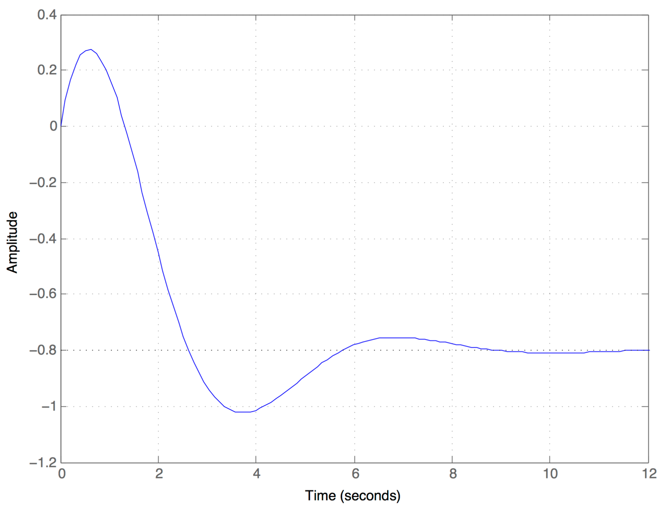
d. (3 pts.) Is the transfer function of part b unique in corresponding to the given Nyquist diagram? Explain.

Problem 6. (20 pts.)

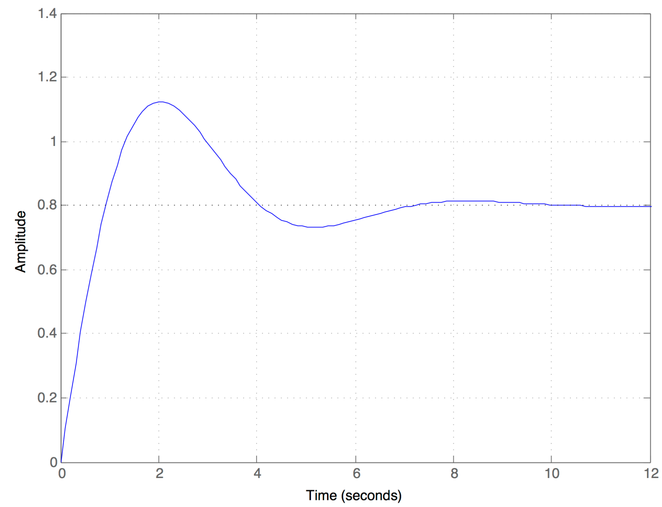
Plots of four time responses to a unit step (a, b, c, d), four s-plane plots of open-loop poles and zeros (i, ii, iii, iv), and four Nyquist plots (i, ii, iii, iv) are shown below and on the next page. Match them up on the page after the next, and give reasons for your choice in each case.

Step responses:

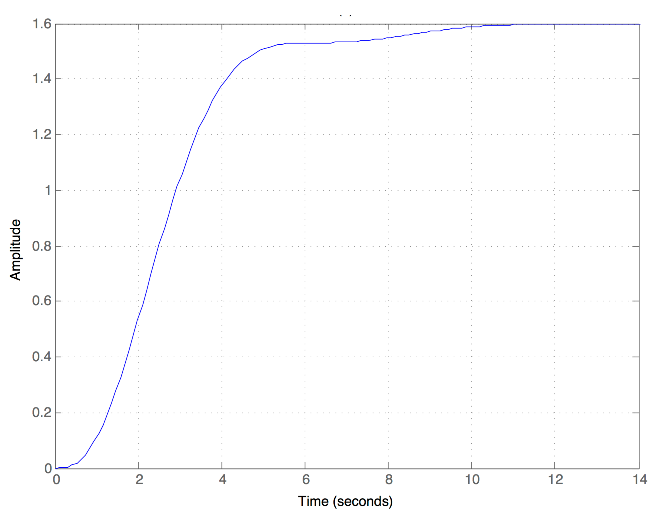
(a)



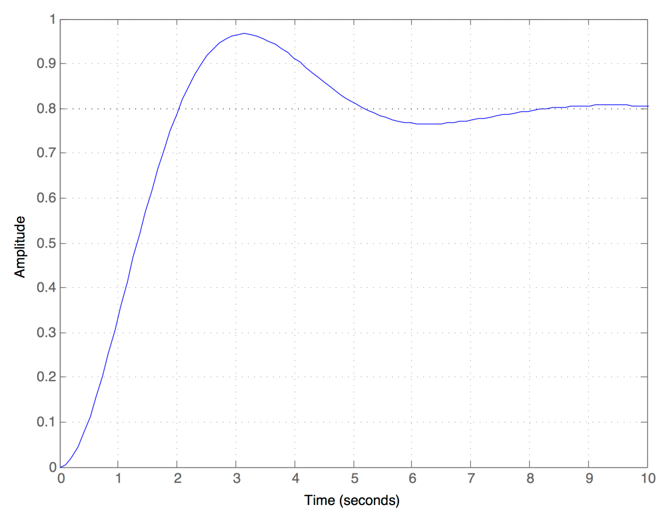
(b)



(c)

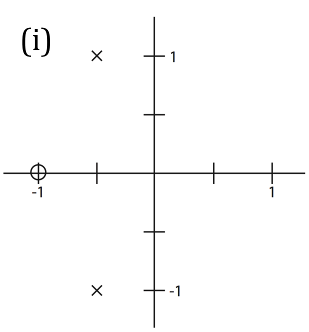


(d)

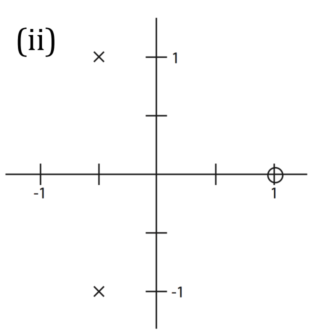


S-plane plots:

(i)



(ii)



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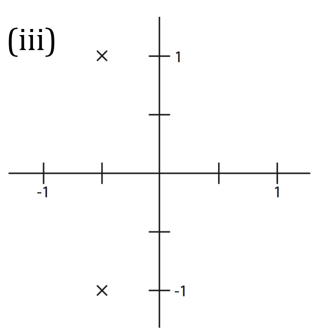
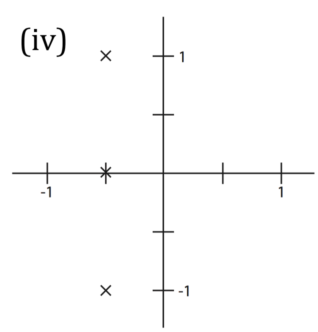
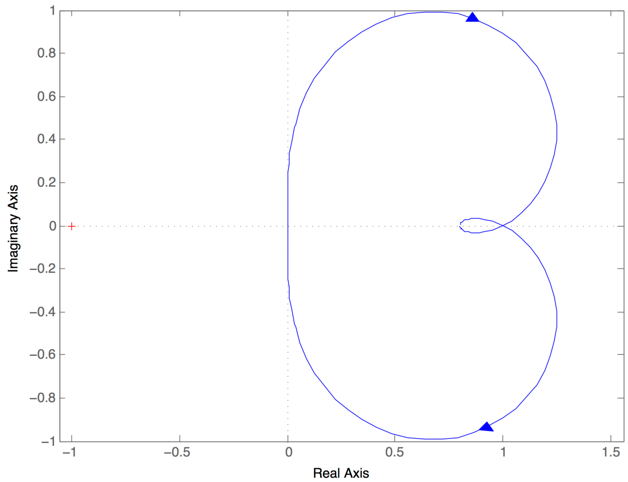


(iv)

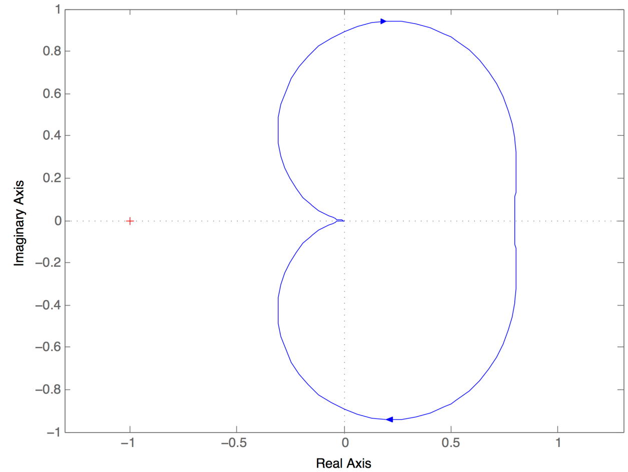


Nyquist Plots

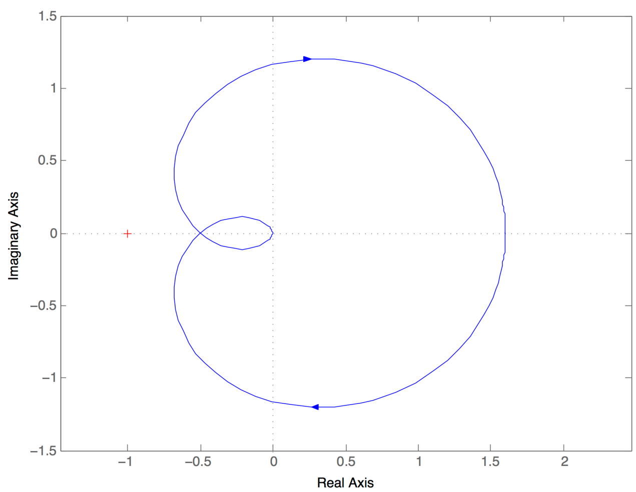
(i)



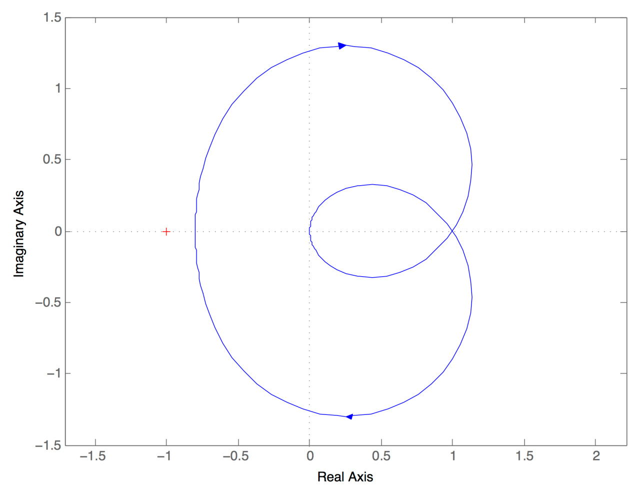
(ii)



(iii)



(iv)



a. For step response (a), the corresponding s-plane is _____ and the Nyquist plot is _____.

   Rationale:

b. For step response (b), the corresponding s-plane is _____ and the Nyquist plot is _____.

   Rationale:

c. For step response (c), the corresponding s-plane is _____ and the Nyquist plot is _____.

   Rationale:

d. For step response (d), the corresponding s-plane is _____ and the Nyquist plot is _____.

   Rationale: