ENGR 105: Feedback Control Design
Midterm Exam, Winter Quarter 2012
Friday, Feb. 17, 2012, 9:00-9:50 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 bring two 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.
- There are 4 questions worth a total of 50 points. (Note that the exam lasts 50 minutes – one point per minute!)

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 (5 pts.)	
2 (15 pts.)	
3 (15 pts.)	
4 (15 pts.)	
Total (50 pts.)	

Problem 1. (5 pts.)

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

_____ a. (1 pt.) The time-domain performance specification of maximum overshoot that we defined in class for a system's response to a step input is only exact when the system transfer function can be written in the form:

$$\frac{a}{s^2 + bs + c}$$

where a, b, and c are real constants.

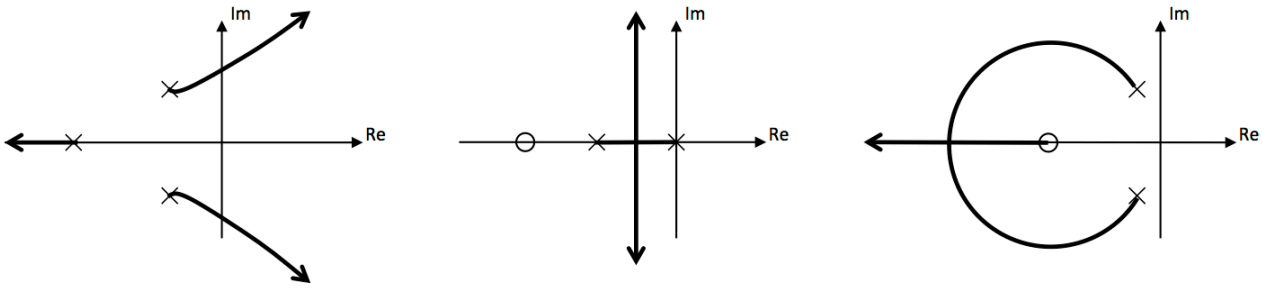
_____ b. (1 pt.) Exact derivative control is impossible to implement on a real system.

_____ c. (1 pt.) A system with the following transfer function is stable for a positive real number a.

$$\frac{1}{s^2 + as}$$

Circle the correct answer for the following questions:

d. (1 pt.) Which of the following cannot be a valid root locus? (Arrows indicate lines going to infinity.)



e. (1 pt.) Which of the following statements is *not* true?

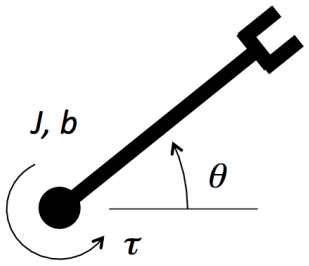
The Laplace transform is a nonlinear transformation.

The Laplace transform can be used to transform a system described by a differential equation into a system described by an algebraic equation.

Multiplication in the s-domain is equivalent to convolution in the time domain.

Problem 2. (15 pts.)

Consider the one-degree-of-freedom robot arm shown below. It has inertia J and torsional damping b. A motor (whose dynamics you can ignore) applies a torque τ at the center of rotation. The angle of the arm is given by θ.



a. (3 pts.) Develop the equation of motion for this plant.

b. (3 pts.) Obtain the transfer function from torque input to angle output. Assume zero initial conditions.

c. (3 pts.) You want to design a feedback control system that will cause the arm angle to track a reference input. Draw the block diagram for the entire system, using unity feedback and a proportional gain K.

d. (3 pts.) Find the closed-loop transfer function from reference input to angle output for the closed-loop system.

e. (3 pts.) For what values of K is this system stable?

Problem 3. (15 pts.)

a. (5 pts.) Find the impulse response $y_1(t)$ for a system with a transfer function given below, and sketch the response versus time.

$$\frac{Y_1(s)}{U(s)} = \frac{1}{s(s+1)}$$

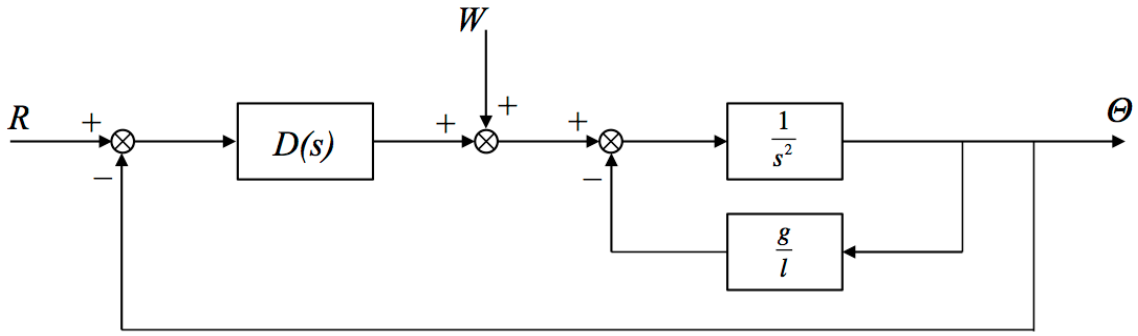
b. (5 pts.) Now consider the system below, which is the same except for the addition of a zero. Find the impulse response $y_2(t)$ for this new system and sketch is versus time.

$$\frac{Y_2(s)}{U(s)} = \frac{s+2}{s(s+1)}$$

c. (5 pts.) Explain the effect of the addition of the zero.

Problem 4. (15 pts.)

Consider the system shown below, which represents control of the angle of a pendulum that has no damping. In this linearized model of a pendulum under the influence of gravity, g is the gravitational acceleration and l is the length of the pendulum. Both are positive real numbers.



a. (5 pts.) What condition must $D(s)$ satisfy so that the system is of Type 1 with respect to reference input?

b. (5 pts.) Let $D(s)$ be a PID controller. What PID controller gains will result in a stable closed-loop system?

c. (5 pts.) Find the class of disturbances $w(t)$ that the system can reject with zero steady-state error.