Sample Final

ENGR 4220/5220, Control Systems

Professor Hill

University of Detroit Mercy, Winter 2014

Name: ______________________________

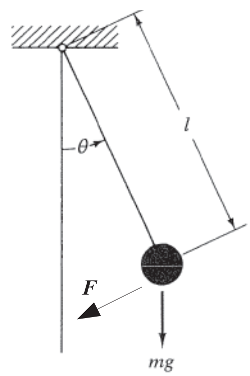
Date: ______________________________

Scores:	Problem 1	________	20 points
	Problem 2	________	20 points
	Problem 3	________	20 points
	Problem 4	________	20 points
	Problem 5	________	20 points
	total	________	100 points

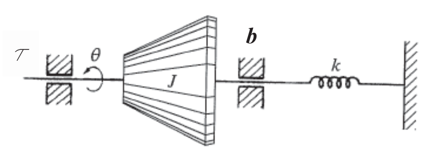
The exam is closed book and closed notes. One sheet of notes (8.5×11), two sides, and a calculator are allowed. A Laplace transform sheet consisting of pages 18 and 20 from Ogata will be provided on the exam. Solutions to this sample exam will be posted on the course website.

1. (20 points) For each of the systems given in the sketches below, find the transfer functions.

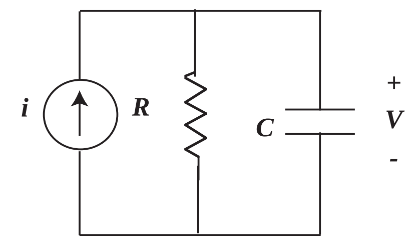
(a) Input $= F$, output $= \theta$.
(you may assume small θ)



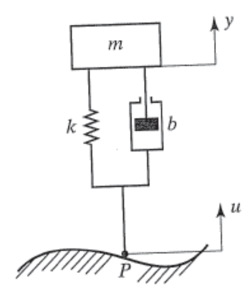
(b) Input $= \tau$, output $= \theta$.



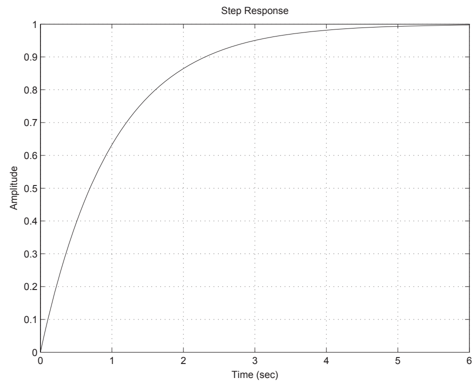
(c) Input $= i$, output $= V$.

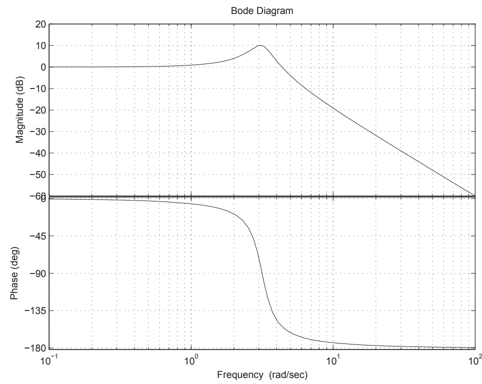


(d) Input $= u$, output $= y$.

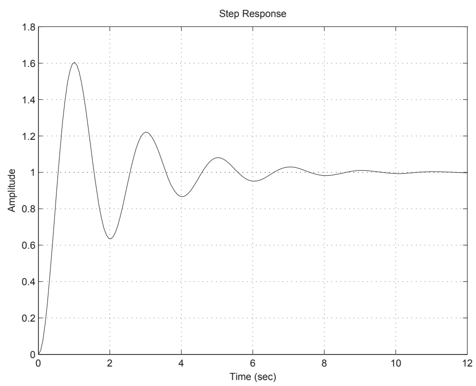


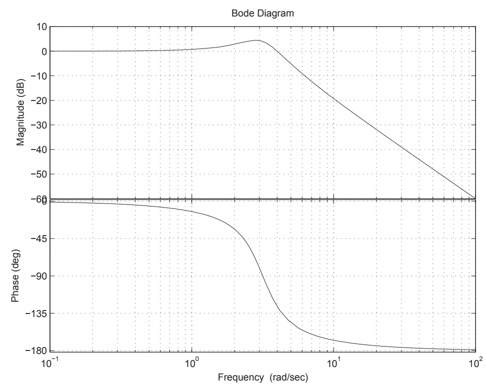
2. (20 points) Match the step responses on the left with the Bode plots on the right.



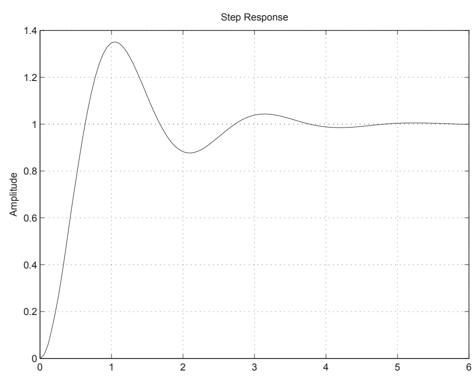


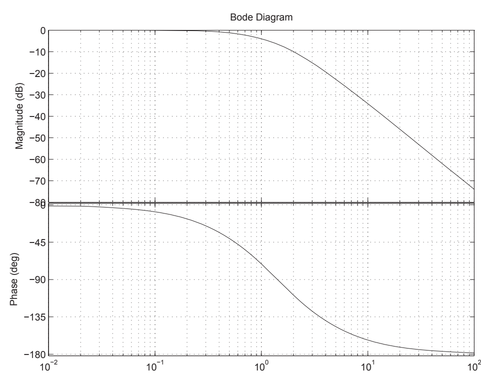
A __________



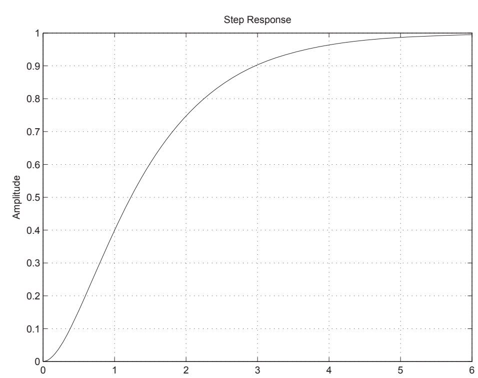


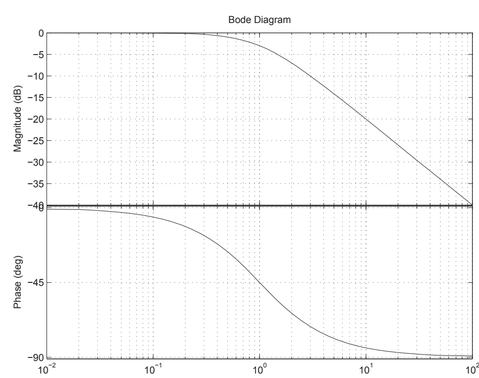
B __________





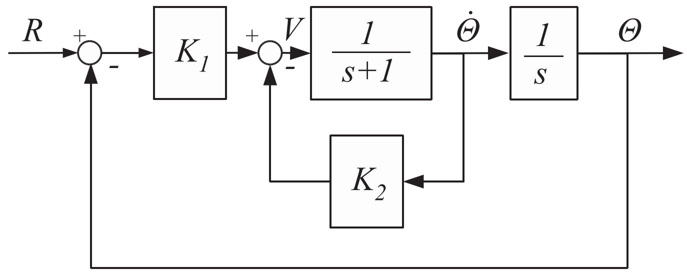
C __________





D __________

3. (25 points) Consider a DC motor that has a voltage input $V(t)$ and angular position output $\theta(t)$, with a transfer function of $\frac{\Theta(s)}{V(s)} = \frac{1}{s(s+1)}$. We want to control the motor to achieve (for a step reference input) a settling time of 4 seconds and a maximum overshoot of 10%. To achieve this control, we will use both tachometer (velocity) and encoder (position) feedback, as shown in the block diagram below.



(a) Plot the line in the complex plane that corresponds to a maximum overshoot of 10% and the line that corresponds to a settling time of 4 seconds. Then determine the pair of closed-loop poles that satisfies both requirements.

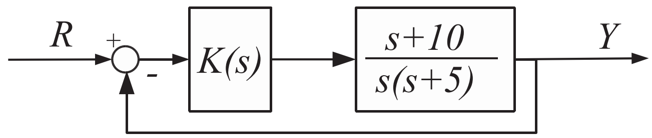
(b) Find the closed-loop transfer function in terms of K_1 and K_2.

(c) Find K_1 and K_2 such that the closed-loop poles are placed at the locations found in part (a).

(d) Do you expect the resulting closed-loop step response to exhibit the desired overshoot and settling time? Explain. What is the advantage of employing a pole placement technique (as was done here) as compared to using a frequency response design technique?

(e) For the K_1 and K_2 found in Part (c) determine the steady state error resulting from a ramp reference.

4. (20 points) Consider the unity feedback system shown below.



(a) Draw the root-locus for the given system under proportional control $K(s) = K$.

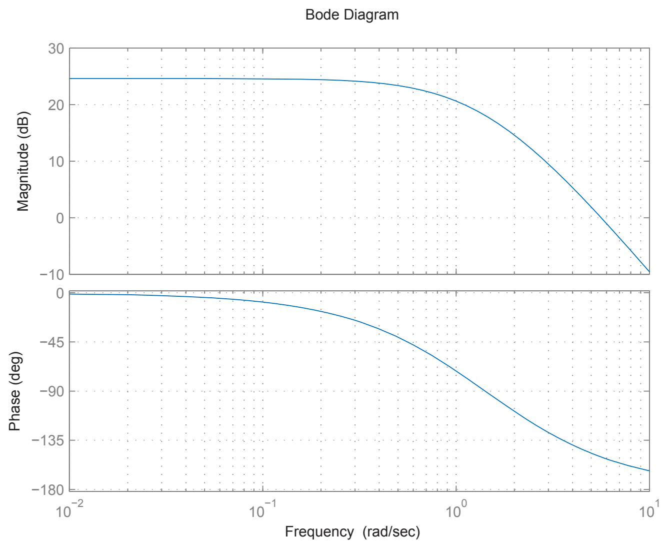
(b) Mark on the root locus drawn in Part (a) where the closed-loop poles must be located to provide the minimum settling time possible under proportional control.

(c) Find the gain K that places the closed-loop poles at $-5 \pm 5j$. Also, what is the settling time predicted by these poles for a canonical second order system?

(d) Find the actual closed-loop transfer function using the K you found in Part (c). You may assume $K = 5$ if you were unable to perform Part (c).

(e) Using your solution from Part (d) find the time response of the closed-loop system for a unit step reference. How does the settle time for this time response compare to the predicted answer in Part (c)?

5. (20 points) Consider the Bode plot of an open-loop plant given below.

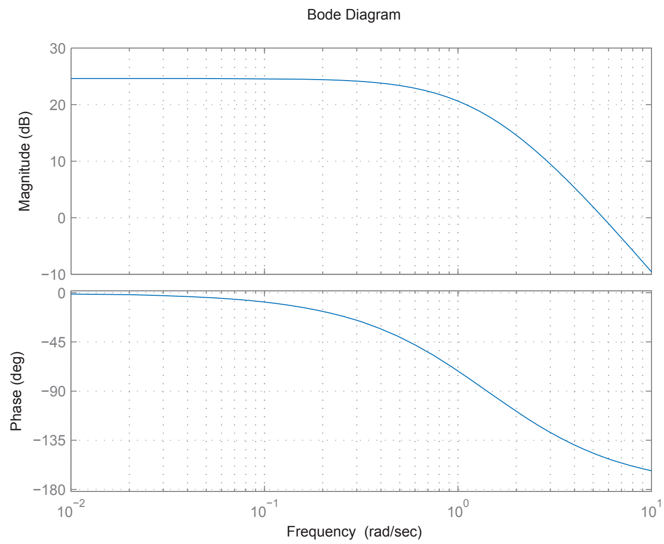


(a) Determine the gain and phase margins for the uncontrolled plant. Note that the phase plot approaches (but never reaches) -180° as ω becomes large.

(b) Based on the above bode plot, estimate the system type and the number of poles in the plant transfer function.

(c) It is desired to control the given plant with the lag compensator $0.3\frac{s+0.4}{s+0.1}$. Sketch the straight line approximation of the Bode plot for the Lag compensator below.

(d) Below is repeated the Bode plot of the open-loop plant. Sketch on the same set of axes the Bode plot of the open-loop system if the Lag compensator from part (c) is added in series with the plant.



(e) Based on your answer to Part (c), what is the effect of adding the Lag compensator on the closed-loop performance of the system as compared to the closed-loop system without the Lag compensator.

(f) What is the benefit of using the frequency response approach to designing a lag compensator as opposed to using the root locus approach?