EE 475 Final Exam, Fall 2011

Name:___________________

1. For a prototype 2nd order system with under-damped poles, use one of the choices to fill in the blank. (6 points)

   ______Most directly affects the percentage overshoot

   ______Most directly affects the rise time

   ______Most directly affects the settling time

   ______Most directly affects the oscillation frequency

   ______Most directly affects the peak time

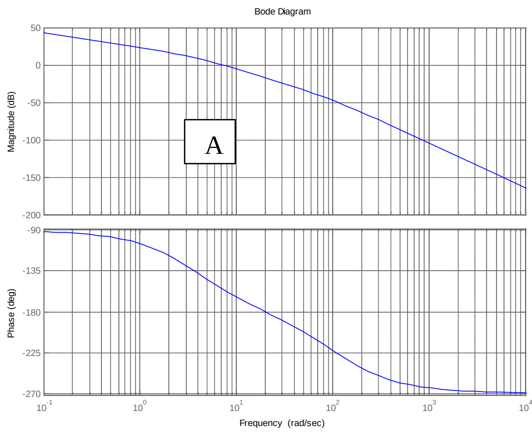
   ______Most directly affects steady state tracking error to a ramp input

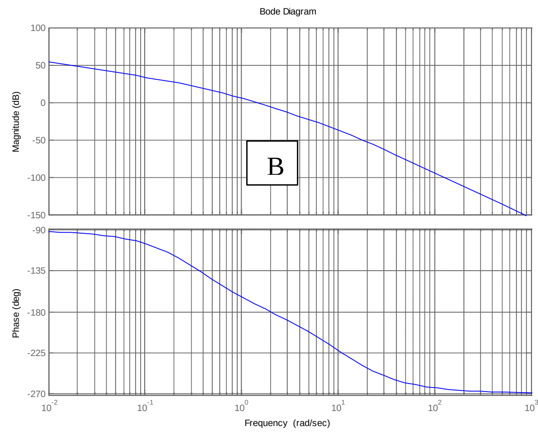
   a. Un-damped natural frequency
   b. Imaginary part of the pole
   c. Real part of the pole
   d. Damping ratio
   e. Something else

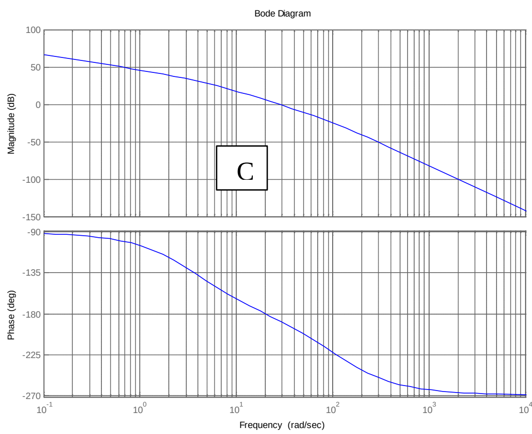
2. Match the following controller transfer functions with the correct names. (8 points)

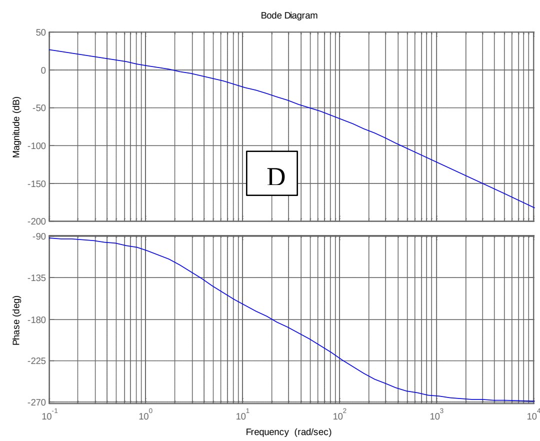
a. 10	______1. Lead
b. s+10	______2. Lag
c. (s+10)/s	______3. lead-lag
d. (s+10)/(s+1)	______4. P (proportional)
e. 10 (s+1)/(s+10)	______5. PD (proportional plus derivative)
f. (s+1)(s+10)/s	______6. PI (proportional plus integral)
g. (s+1)(s+100)/(s+10)^2	______7. PID (prop. plus int. plus derivative)
h. 10/(s+10)	______8. None of the above

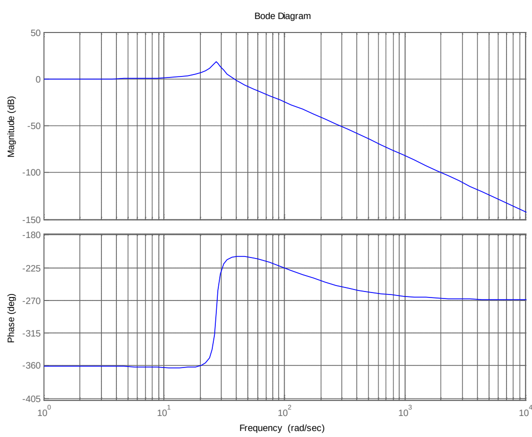
3. Four unity feedback control systems' open-loop Bode plots, closed-loop Bode plots, and closed-loop step response plots are given. Match each system's plots by placing A, B, C, or D on the closed-loop Bode and step response plots. (8pts)

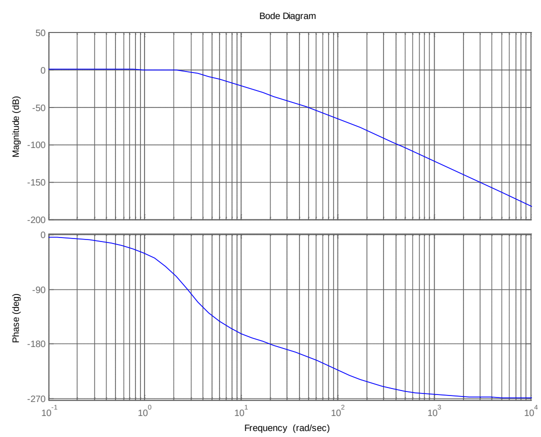


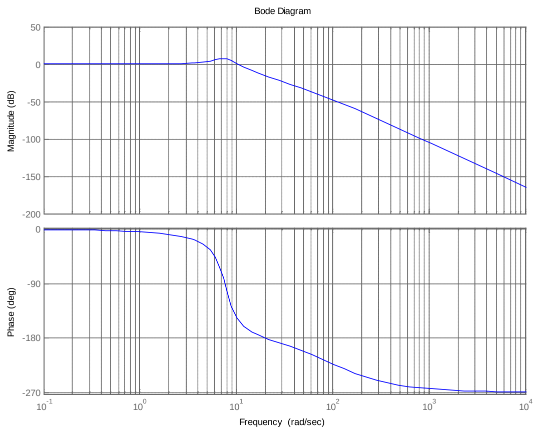


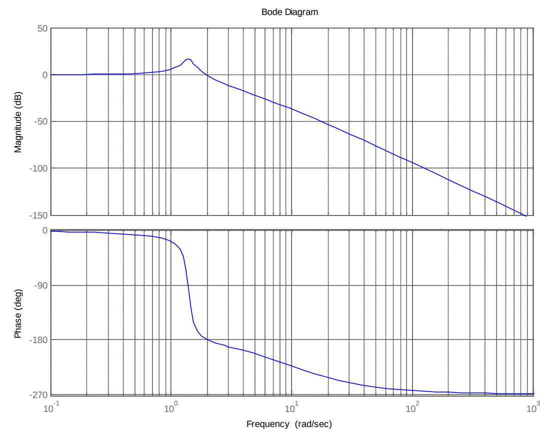


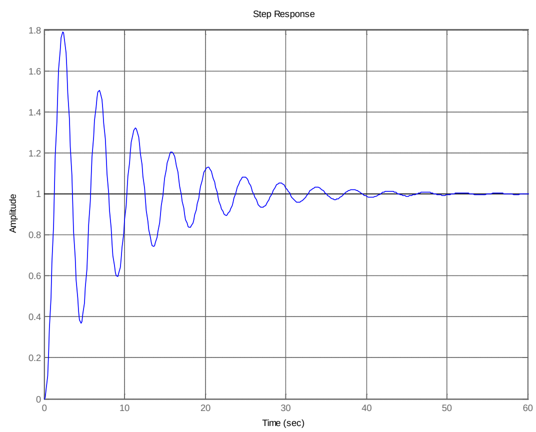


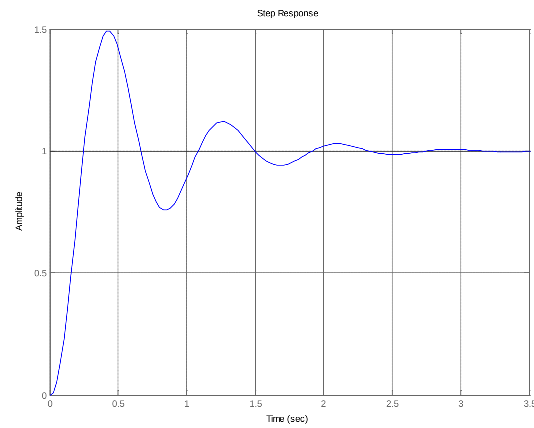


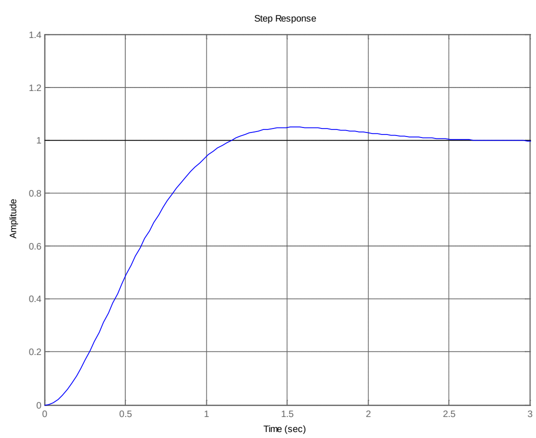


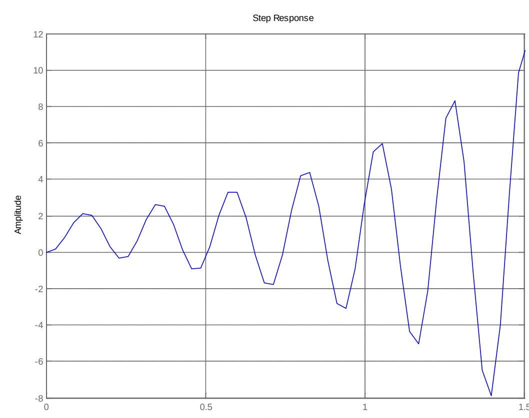

Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/sec)


Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/sec)


Step Response
Amplitude
Time (sec)


Step Response
Amplitude
Time (sec)


Step Response
Amplitude
Time (sec)


Step Response
Amplitude
Time (sec)

4. Which one of the following can NOT be used to reduce overshoot? (2pts)
   a. P, b. I, c. D, d. PID, e. lead-lag

5. Which one of the following is used to eliminate nonzero steady-state error? (2pts)
   a. P, b. PI, c. PD, d. lead, e. lag

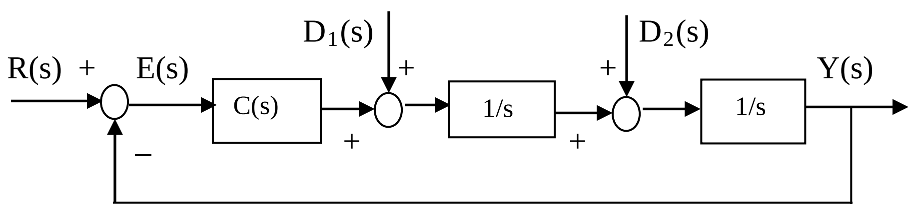
6. Which one of the following has the most similar use to a PD? (2pts)
   a. P, b. PI, c. lead, d. lag, e. lead-lag

7. Which TWO of the following are known to typically cause sluggish settling? (2pts)
   a. P, b. PI, c. PD, d. lead, e. lag

8. If the root locus does not pass through the region for the desired closed-loop poles, which TWO of the following could be useful? (2pts)
   a. P, b. PI, c. PD, d. lead, e. lag

9. If the signal to the controller is noisy, which one of the following should NOT be used? (2pts)
   a. P, b. PI, c. PD, d. lead, e. lag

10. Consider a control system given in the following block diagram:



where C(s) = K(s + z)/(s + p), and K, z, p > 0.

a. What is the system type with respect to R? (2 points)__________________

b. What is the system type with respect to D_1? (2 points)_________________

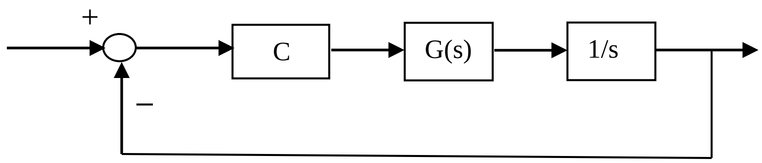
c. What is the system type with respect to D_2? (2 points)_________________

d. What condition must K, z and p satisfy to guarantee closed-loop stability? (2 points)

e. Find the acceleration error constant K_a with respect to the reference R(s). (2 points)

f. Find the steady state tracking error if input R is a unit acceleration signal. (2 points)

11. Consider the control design problem with the following standard block diagram:

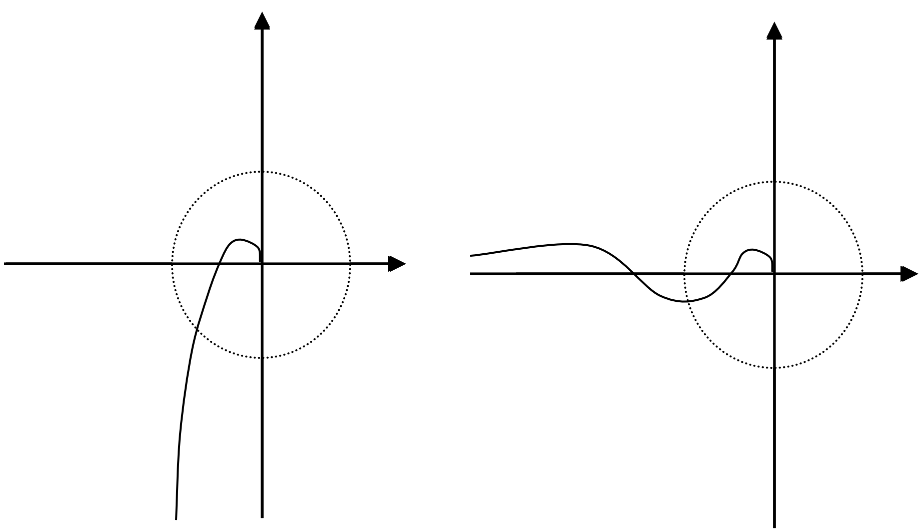


where G(s) = 100/{(s+1)(s+9)}.

a. Design a controller C(s) that satisfies Mp ~=16%, and ts ~= 0.5s (for +- 1% tolerance). Limit C(s) order to be 1 and num deg – den deg <=1. (4 points)

b. With the correct controller, find the gain cross-over frequency and phase margin of the compensated Bode plot. (4 points)

12. Given the Nyquist plots of G(s). Assume G is a strictly proper open-loop TF of a unity negative feedback system and G has no unstable poles. 1) Use the Nyquist criteria to determine the number of unstable poles of the closed-loop system. 2) Determine the gain margin and phase margin. (The unit circle is shown.) (6 points)



13. In a unity feedback set-up, the open-loop transfer function G(s) is stable and minimum phase with all real coefficients. The Bode plot of G(s) is given on the next page.

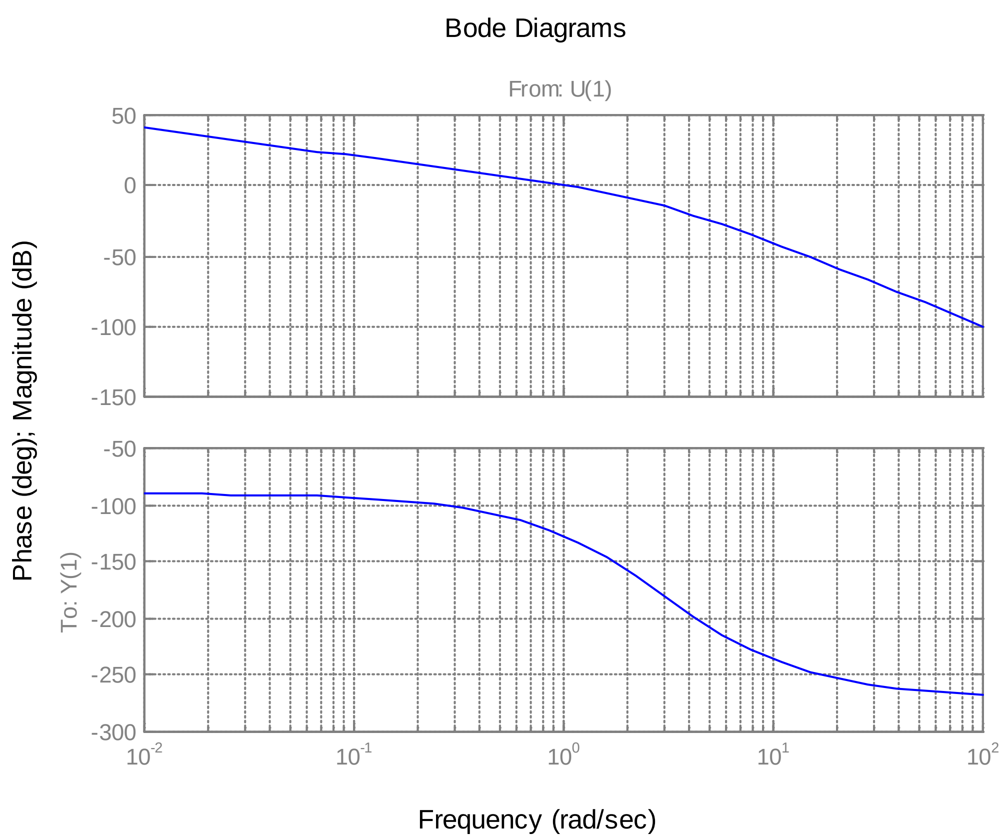
   a. Find the gain crossover frequency, phase crossover frequency, gain margin, and phase margin. (2 pts)________________________________

   b. Determine the closed loop stability. (1 pts)_____________________

   c. Estimate the percentage overshoot and rise time in the closed-loop unit step response. (2 pts) __________________________________

   d. Determine the system type and estimate the steady state tracking error in the closed loop unit ramp response. (2 points)________________________________

   e. If the overall system gain is increase by 10 times, what happens to the closed- loop stability? (1 pts)_____________________________________



14. Given $M(t) = \begin{pmatrix} e^{-2t} & te^{-2t} & t^2e^{-2t}/2 \\ 0 & e^{-2t} & te^{-2t} \\ 0 & 0 & e^{-2t} \end{pmatrix}$. Is M(t) a state transition matrix? If it is, find A such that M(t) = exp(At); if not, explain why not. (8 points)

15. Consider a linear control system given by the following state space model.

$$\dot{x} = \begin{bmatrix} -2 & 1 & 0 & 0 & 0 \\ 0 & -2 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & +1 \end{bmatrix} x + \begin{bmatrix} 0 & 1 \\ 1 & 0 \\ 0 & 2 \\ 2 & 0 \\ 0 & 3 \end{bmatrix} u$$

$$y = \begin{bmatrix} -1 & 0 & -2 & 0 & 0 \end{bmatrix} x$$

Determine if the system is asymptotically stable, BIBO stable, completely controllable, and completely observable. (8 points)

16. In a root locus based controller design, the plant TF is already entered in Gp. The root locus of Gp is already drawn. The desired region for the closed-loop dominant pole has been drawn on the same graph as the root locus. It has been determined that the dominant part of the root locus does not pass through the desired region, but not too far away. It is hence determined to use a lead controller to bring the root locus into the region. Write a few lines of Matlab code that will a) prompt the user to choose desired dominant pole; b) compute the angle deficiency at the desired pole; c) use the bisector method to the parameters of the lead controller (z_lead, p_lead, K), d) compute and display the overall open-loop TF; and e) compute and display the closed-loop unit step response. (8 points)

17. In a Bode plot based controller design problem with a type 1 plant TF, it is required to achieve closed-loop step-response overshoot to be <= Mp_des % and steady state tracking error to a unit ramp input to be <= ess_rd. Since there is no speed or bandwidth requirement, it has been determined that a lag controller is needed to reduce ess. The plant TF is defined in Gp. Write a few lines of Matlab code for the lag controller design part. (8 points)