EE 475 Final Exam, Fall 2010

Name:___________________

1. Given $M(t) = \begin{bmatrix} 2e^{-t} - e^{-2t} & e^{-t} - e^{-2t} \\ -2e^{-t} + 2e^{-2t} & 2e^{-2t} - e^{-t} \end{bmatrix}$. Is M(t) a state transition matrix? If it is, find A such that M(t) = exp(At); if not, explain why not.

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

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

$$y = \begin{bmatrix} -1 & 0 & -2 & 0 & -3 \end{bmatrix} x$$

Determine if the system is asymptotically stable, BIBO stable, completely controllable, and completely observable.

3. In a root locus based controller design, the plant TF is type 1 with numerator coefficient vector ng and denominator coefficient dg. A lead controller has been designed with z_lead, p_lead, and K computed. It has also been determined that a lag controller is needed to reduce the “ess to ramp” to <= ess2ramp_des. Write a few lines of Matlab code that will a) compute the ess2ramp when the lead controller has been used, b) compute the parameters of the lag controller (z_lag, p_lag, K_lag), c) compute and display the overall controller TF C, and d) compute and display the closed-loop unit step response.

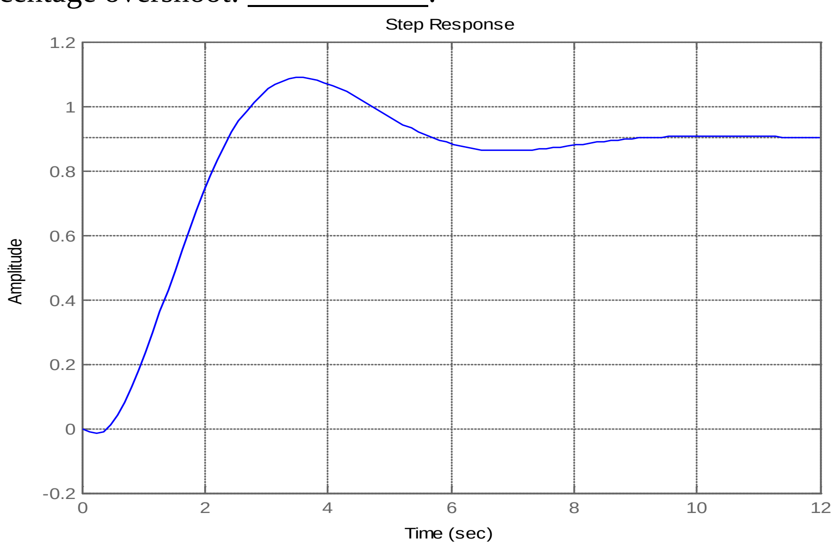
4. In a Bode plot based controller design, it has been determined that a lead controller is needed to achieve closed-loop step-response overshoot <= Mp_des % and rise time tr <= 1 sec. It has also been determined that a lag controller is needed to reduce ess. The plant TF is defined in Gp. Write a few lines of Matlab code for the lead controller design part.

5. An LTI system has characteristic polynomial $d(s) = s^4 + Ks^3 + (K+3)s^2 + 4Ks + 4K - 4$.
   A) find conditions on K such the system is asymptotically stable, B) find the value of K such that the system will have sustained oscillation, and C) find the oscillation frequency.

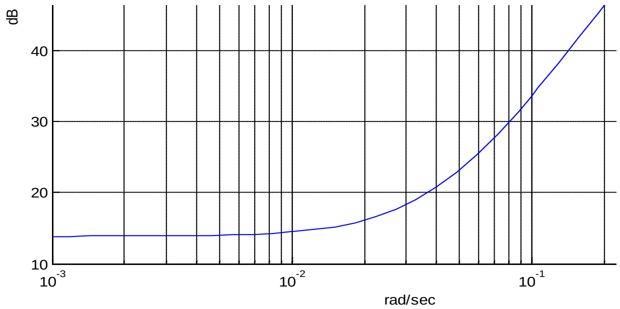
6. The open-loop Bode plot of a unity feedback system is given when the controller gain K=1. The plant TF is rational, stable and minimum phase. The Bode plot has uniquely defined w_gc, w_pc, GM>0, and PM>0. With the controller gain denoted as a symbol K, the closed-loop characteristic polynomial is obtained and a Routh table is constructed for it. A) if K=1, how many sign changes are there in the first column of the Routh table? B) for what value(s) of K will a whole row of the Routh table become zero? C) with K as in part B), what can you say about the roots of the associated auxiliary equation?

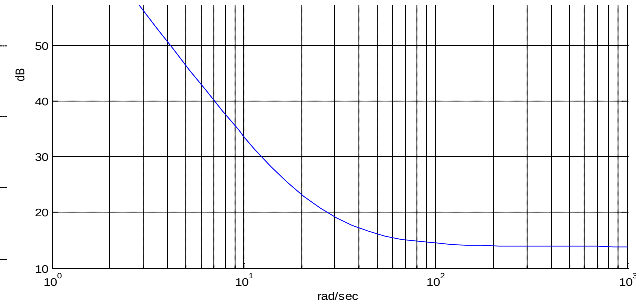
7. Hand sketch the root locus for $1 + K(s+1)/\{(s+6)(s+4)(s^2+2s+4)\} = 0$ as $K = 0$ to ∞. Compute the asymptote information, any break away points, departure/arrival angles at any complex poles/zeros, and the jw-axis crossing points, if applicable. Determine the phase cross-over frequency in the Bode plot of $(s+1)/\{(s+6)(s+4)(s^2+2s+4)\}$.

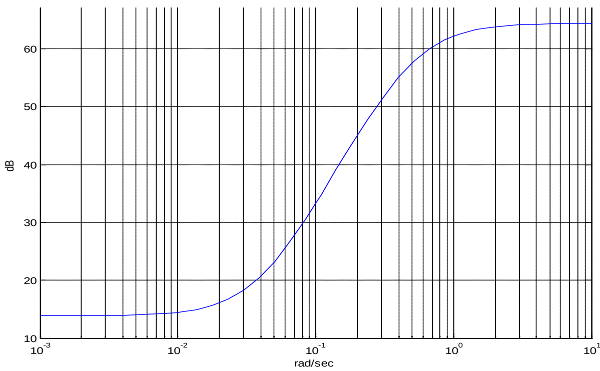
8. A closed-loop system has step response given below.
   a) Is this system a prototype second order system?_______
   b) This system has one zero, do you think it is in the left or right half plane?_____
   c) Is the system BIBO stable or unstable? ________
   d) The rise time = ________________, The delay time = ________________.
   e) The peak time = _______________, The 2% settling time = ___________.
   f) The percentage overshoot: _____________.

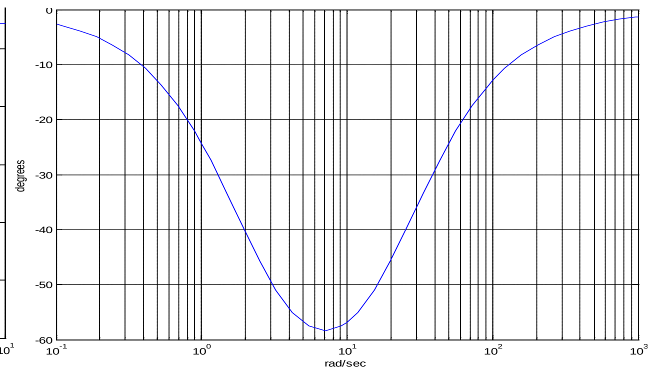


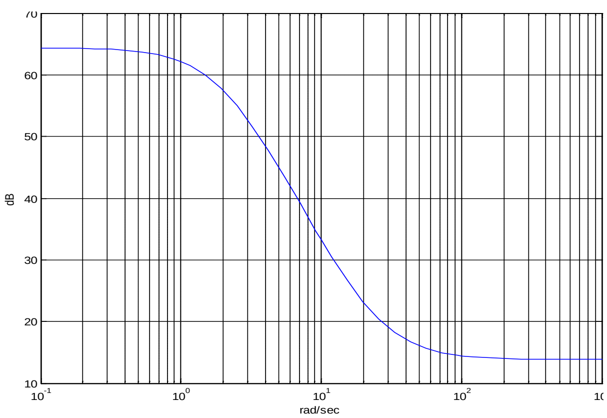
9. Some controllers' frequency response plots are given below (either amplitude plot or phase plot). Label each plot with either PI, or PD, or Lead, or Lag.

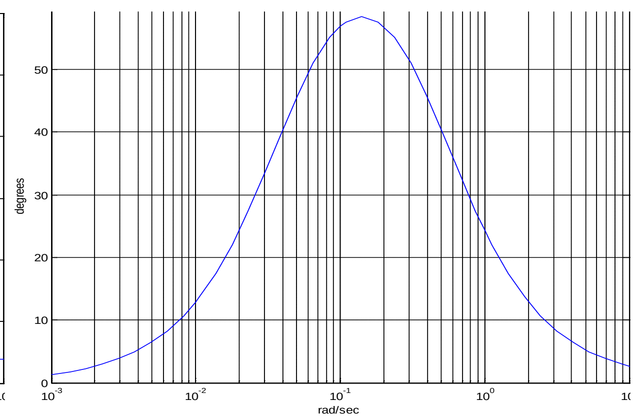


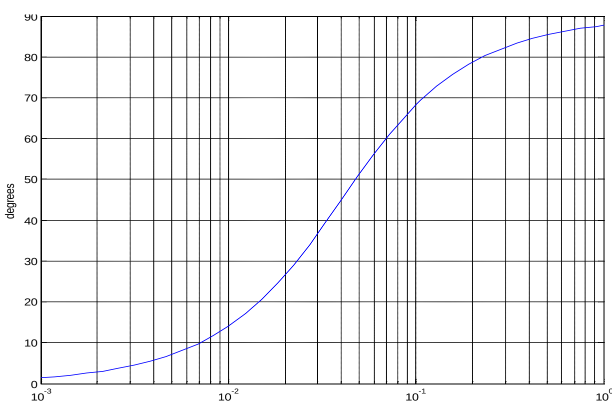


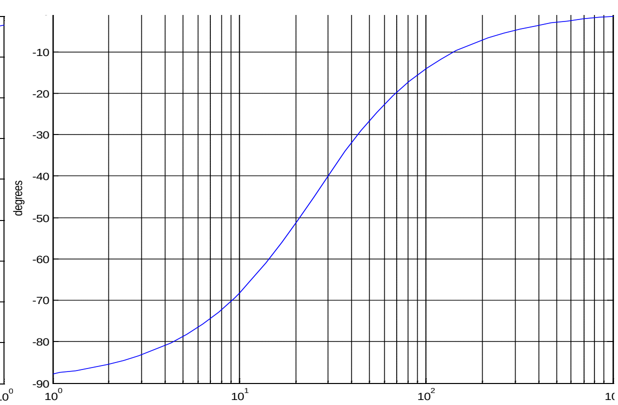




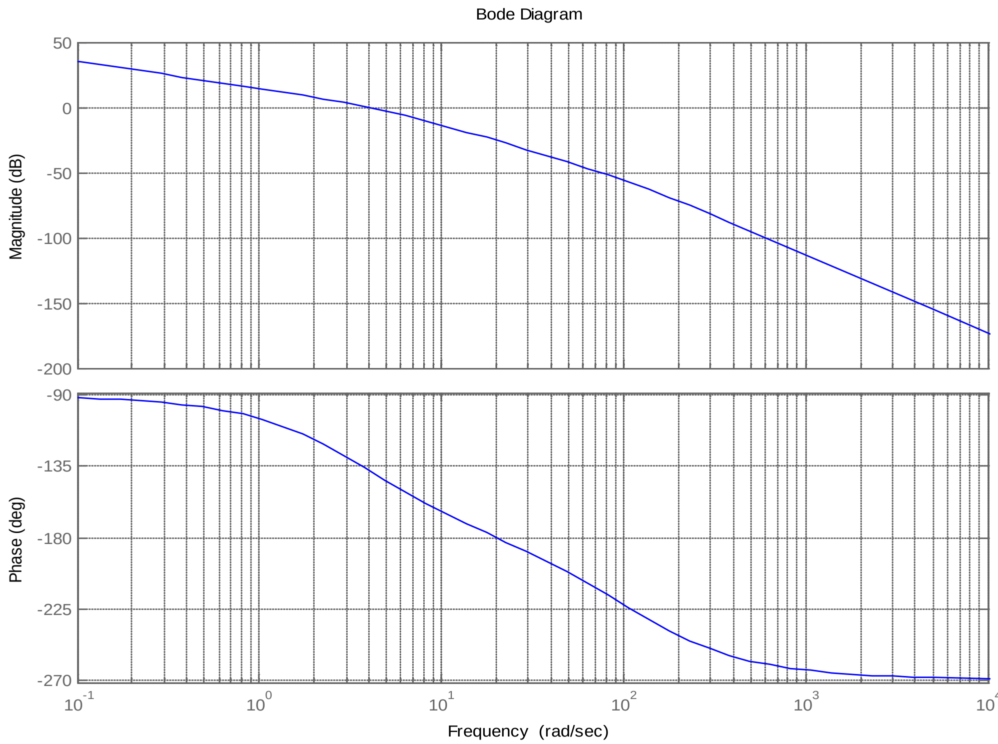








10. A unity gain feedback control system has open-loop bode plot as shown below.



1) The system type is __________
2) Position error constant Kp = ______________
3) Velosity error constant Kv ≈ ______________
4) Acceleration error Constant = _____________
5) Steady state error due to a unit step input is ______________
6) Steady state error due to a unit ramp input is ≈__________________
7) Steady state error due to a unit acceleration input is ______________
8) The gain cross over frequency is ≈_________ rad/sec
9) The phase cross over frequency is ≈_________rad/sec
10) The gain margin is ≈________ dB
11) The phase margin is ≈_______ degrees
12) The closed-loop stability is _______________
13) The closed-loop dominant pole has damping ratio ≈ ______________
14) The closed-loop step response will have overshoot ≈ _____________
15) The closed-loop bandwidth is approximately ≈ ____________
16) The closed-loop resonance frequency is approximately ≈ _________
17) The closed-loop resonance peak Mr is approximately ≈ __________
18) The closed-loop step response will have rise time ≈ _______
19) The closed-loop step response will have settling time ≈ __________
20) How many times does the root locus cross the jw-axis: ___________
21) The value of jw-axis at such points are ≈__________
22) What controllers can be used to improve the overshoot_____, _____, _____
23) If C(s)=K(s+z)/(s+p) is used to improve the overshoot with minimal effect on speed, we should have z_____p (use "= < >") and z*p≈___________