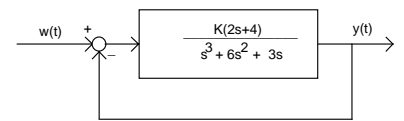
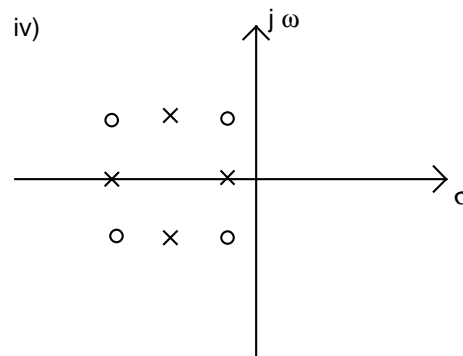
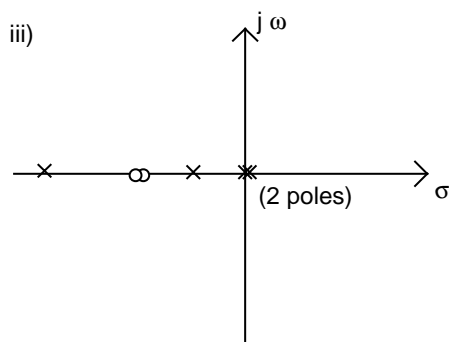
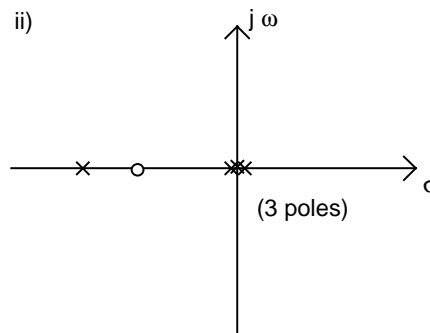
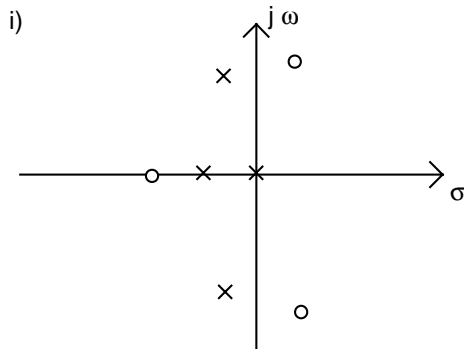


Problem 1 - 20 pts

a) Find the range on K for which the following closed-loop system is stable



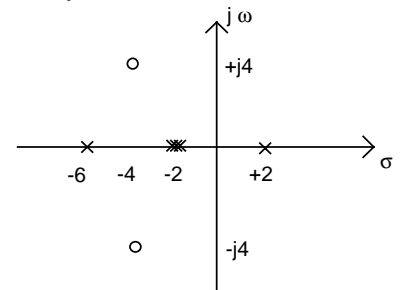
b) Sketch the root-locus plots for the following open-loop pole/zero configurations:



c) What is the type number of each system in part b)?

i) Type _____ ii) Type _____ iii) Type _____ iv) Type _____

d) Draw a point very close to the **3 poles** at $s=-2$ and determine the angle of departure (hint: there may be more than one)

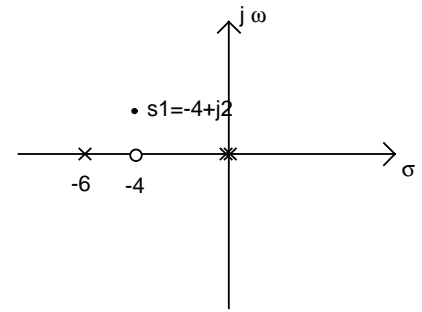


Problem 2 - 20 pts.

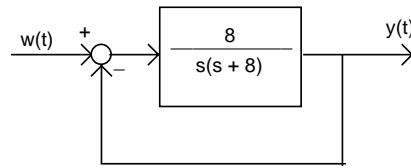
a) When should we use the following compensators:

- i) PD -
- ii) Lag -
- iii) PID -

b) Given the following open-loop pole/zero configuration, find the angle which a lead compensator must supply so that the root locus passes through the desired closed loop dominant pole (s_1) (use your cheat sheet)



- c) Suppose our lead compensator in part b) is of the form $G_c(s) = K_c(s + z_c)/(s + p_c)$. Why can't we pick $z_c = 20$? What's the problem with choosing $z_c = 2$?
- d) Suppose we choose $z_c = 5$ for our lead compensator in part b). Find an equation for p_c which involves the arctan() function (Do Not Solve This Equation!).
 $p_c =$ _____ (equation)
- e) Suppose that when we solve this equation, $p_c = 10$. Also, suppose $|G(s_1)| = |G(-4 + j2)| = 4$. Find the value of K_c
- Problem 3 - 15 pts.



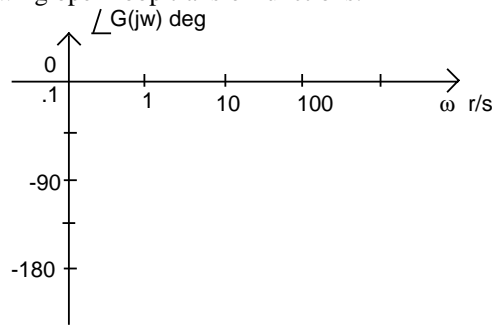
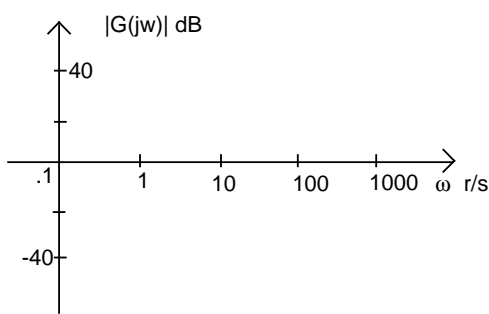
Given the following unity-feedback system

- a) Find: the type number, K_p , K_v , K_a , and $ess|_{step}$, $ess|_{ramp}$, $ess|_{parabola}$
 Type # = _____ K_p = _____ K_v = _____ K_a = _____ $ess|_{step}$ = _____ $ess|_{ramp}$ = _____ $ess|_{parabola}$ = _____
- b) Sketch the root locus
- c) Find the settling time and the damping coefficient (ζ) for the uncompensated system.
- d) Design the **simplest** compensator possible to meet the following specs: $t_s \leq 1$ second and $\zeta \geq 0.707$
- e) Now design a compensator to meet the following specs: $t_s \leq 1$ second and $\zeta \geq 0.707$ and $ess|_{parabola} = 1/10$ (find **values** for your compensator!)
- f) Sketch the compensated root locus and give **approximate** values for all closed-loop poles of the lag compensated system.
- Problem 4 - 15 pts.

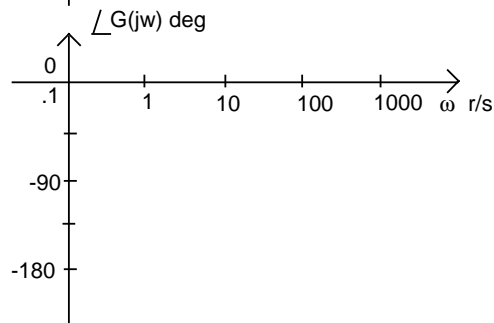
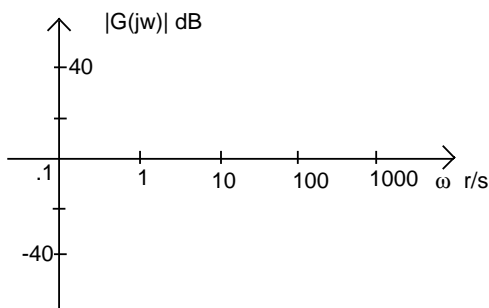
- a) Sketch the magnitude and phase Bode plots for the following open-loop transfer functions:

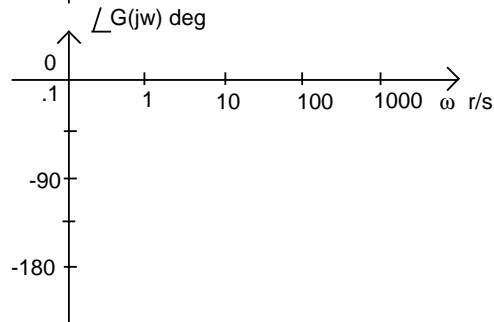
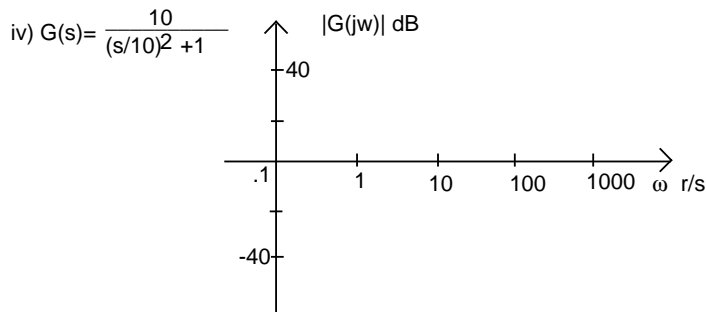
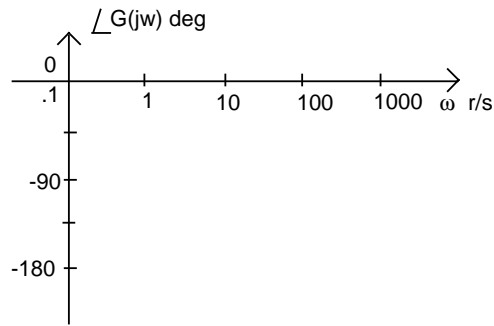
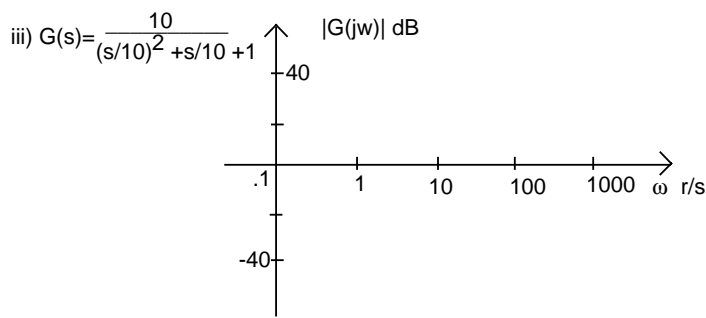
i) $G(s) = \frac{10(s+1)}{s(s/10+1)}$

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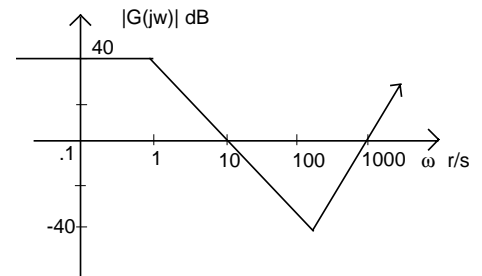


ii) $G(s) = \frac{10(s-1)}{s(s/10+1)}$

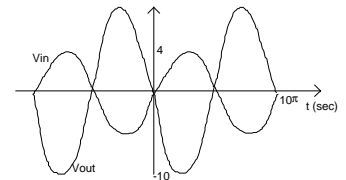




b) Find $G(s)$ from the following Bode plot (assume minimum phase)



c) From the following steady-state plot, find ω , $|G(j\omega)|$, and $\angle G(j\omega)$ if $G(j\omega) = V_{out}(j\omega)/V_{in}(j\omega)$:



Problem 5 - 15 pts.

a) Design a Feedback Regulator ($w = -Kx$) such that the closed-loop eigenvalues are $\{-3, -4\}$ (you must use a systematic design

procedure. No Guessing!) $\dot{x} = \begin{bmatrix} 0 & 4 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ -2 \end{bmatrix} w(t)$

$$y(t) = \begin{bmatrix} 3 & 0 \end{bmatrix} x$$

b) Now, design a CONTROLLER ($w = N_u y_{ref} + K(N_x y_{ref} - x)$) for the system in part a) such that the output goes to 6.25 (find values of N_u , N_x , and y_{ref})

c) Draw a block diagram of your CONTROLLER assuming that all of the states of the system in part a) are available for feedback.

Problem 6 - 15 pts.

Given the following state variable model: $\dot{x} = \begin{bmatrix} 1 & 2 \\ 0 & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ -6 \end{bmatrix} w(t)$ $y(t) = \begin{bmatrix} 0 & 2 \\ 1 & 0 \end{bmatrix} x$

- Find the observability matrix. Is the system completely observable?
- If yes, design a full-order observer for the system which sets the eigenvalues at -8 and -9. (you must use a systematic procedure)
- Use your answer to problem 5c) to draw a block diagram of a combined observer/controller
- Now design an improved-observer for your system (find values of R , Q_1 and Q_2 (Think! you can do this!))
- Draw a block diagram of a combined improved observer/controller