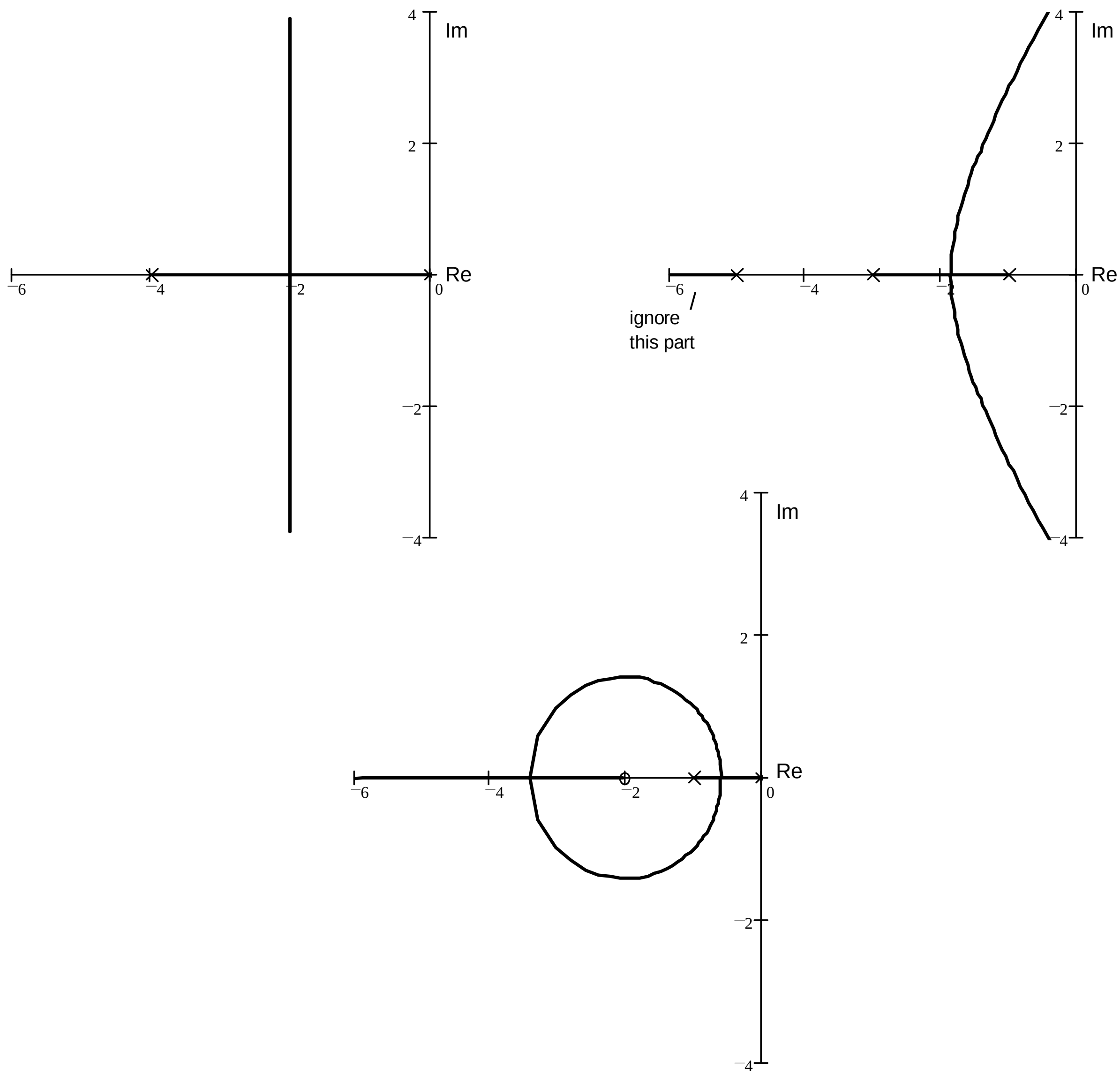
ECE 3510 Exam 3 given: Spring 06

1. (16 pts) Three root-locus plots are shown below. Complete parts a) and b) for each plot. Fastest settling time is your objective. Neglect the fact that some poles will dominate others, IE all closed-loop partial fraction expansion terms have equal coefficients.

   a) Assuming you can tolerate absolutely no overshoot in the step response, estimate the best position for the closed loop pole(s). Label that (or those) position(s) with the letter "a".



b) Assuming you can tolerate about 4% overshoot ($\zeta = .707$) in the step response and that the speed of response will increase with a little ringing, estimate the best position for the closed loop pole(s). Label that (or those) position(s) with the letter "b".

Remember: You need to do parts a) and b) for ALL 3 plots

c) What parameter sets the closed loop pole(s) in the positions found in parts a) and b).

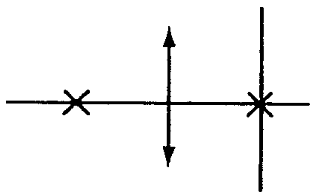
d) Say you actually wanted to set the closed-loop poles in the positions found in part b). If you had access to Matlab, what would you do to determine the value of the parameter of part c)?

2. (10 pts) a) Draw the block diagram of a PID compensator. Use the factors k_P, k_I, and k_D as the respective gains.

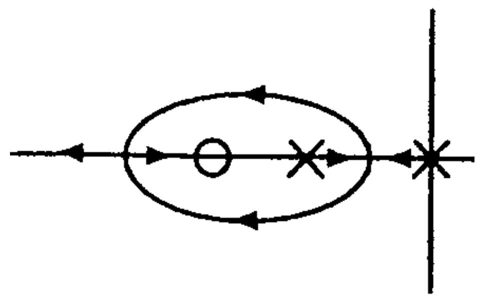
   b) Find the transfer function for a PID compensator.
   Express your answer in the standard form, as one polynomial over another.

3. (10 pts) Four root-locus plots are shown below. In each case the plant is: $P(s) = \dfrac{k}{s\cdot(s+a)}$

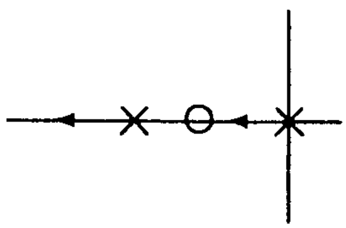
   For each plot, determine if the compensator is P, PD, PI, or PID. Circle the correct answer in each case.



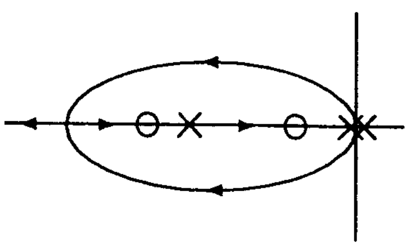
P
PD
PI
PID



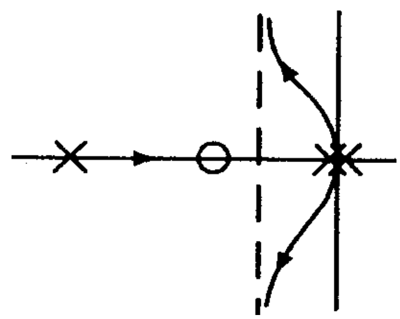
P
PD
PI
PID



P
PD
PI
PID

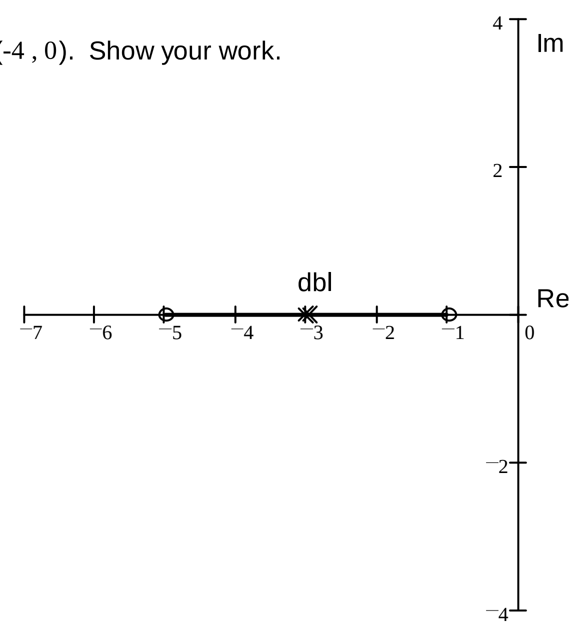


P
PD
PI
PID



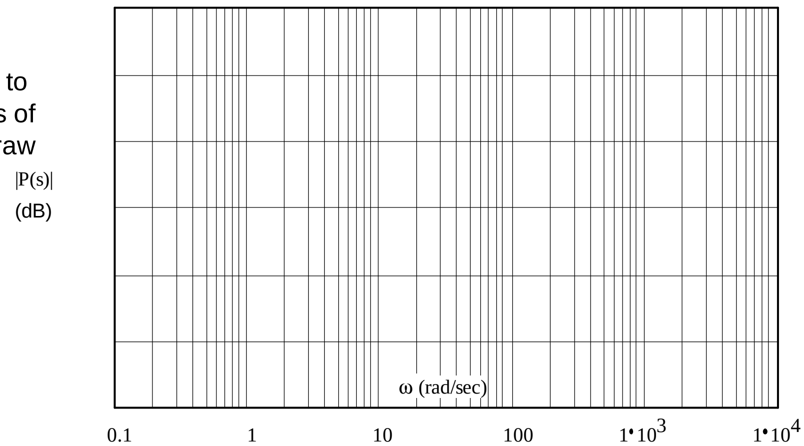
P
PD
PI
PID

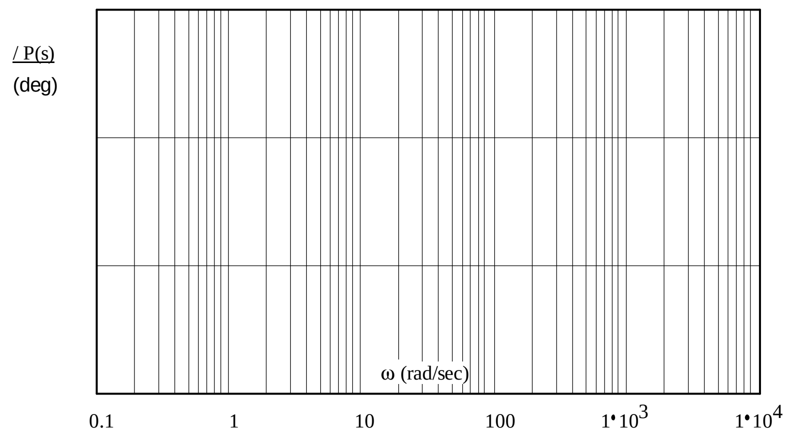
4. (8 pts) A root-locus plot is shown below.
   What gain would be required to set a closed-loop pole at (-4 , 0). Show your work.



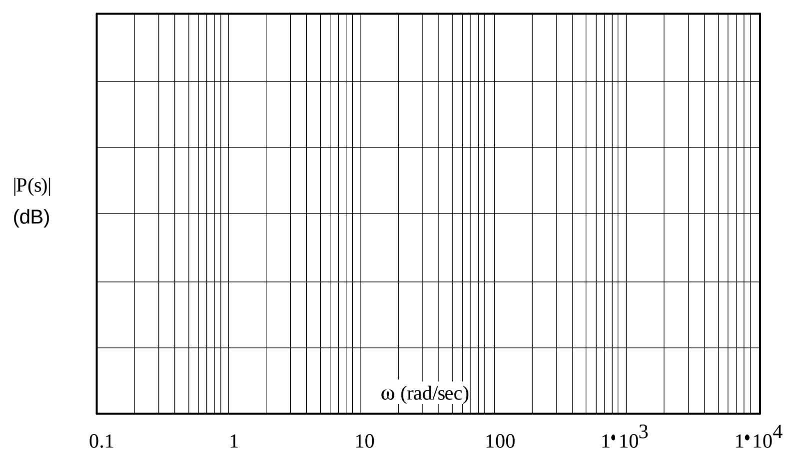
5. (22 pts) Sketch the Bode plots for the following transfer functions. Make sure to label the graphs, and to give the slopes of the lines in the magnitude plot. Also draw the "smooth" lines.

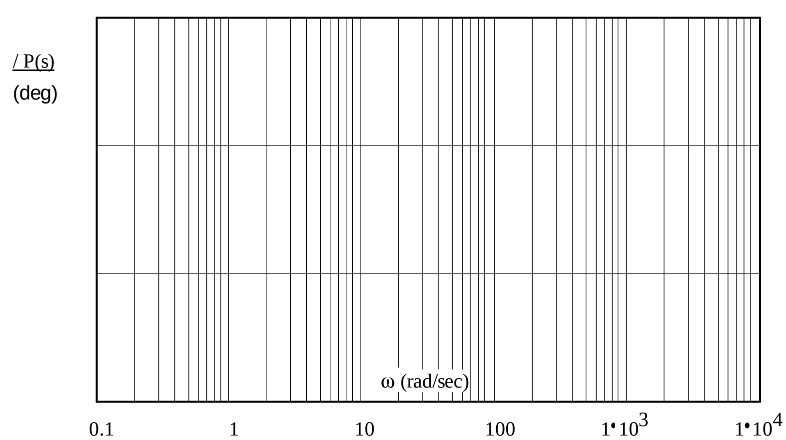
a) $P_a(s) = \dfrac{s \cdot (s+40)}{(s+4)\cdot(s+1000)}$



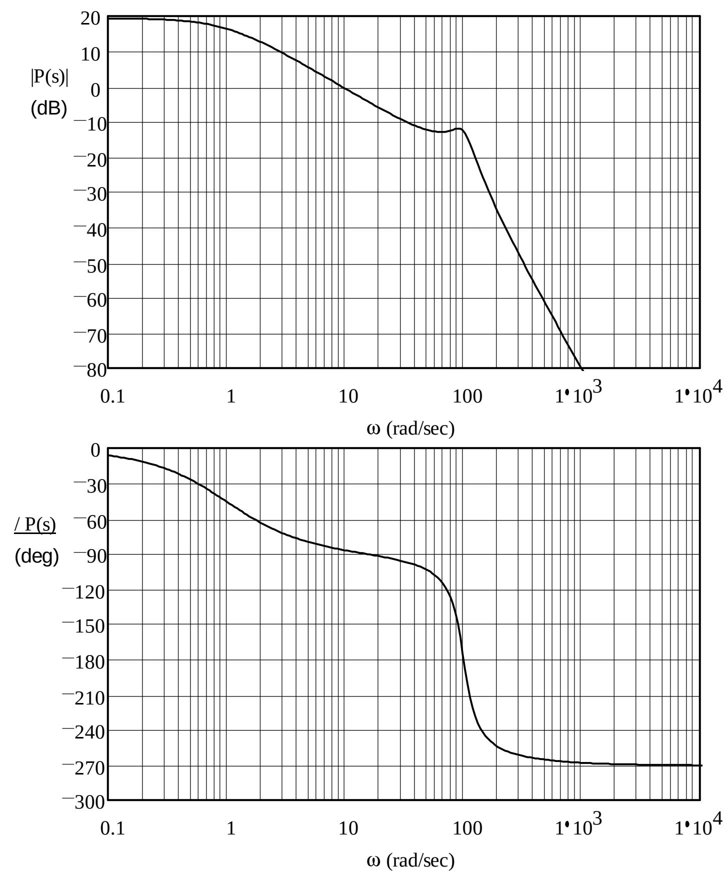


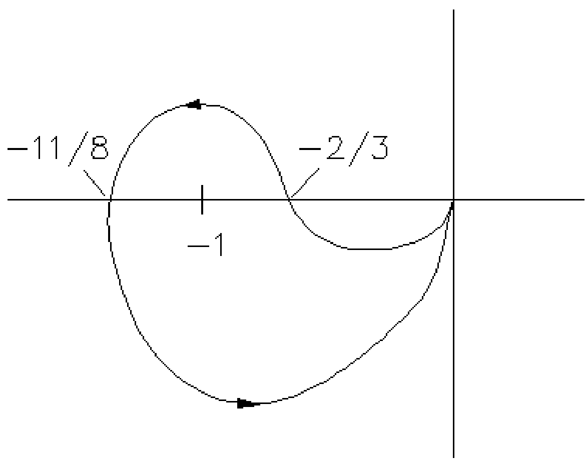
b) $P_b(s) = \dfrac{s+100}{s^2 + 1\cdot s + 100}$





6. (6 pts) The system whose Bode plots are given at right is stable in closed-loop. Find its gain margin and phase margin.





7. (12 pts) A Nyquist curve is shown above (only the portion for $\omega > 0$ is plotted).

   a) Knowing that the closed-loop system is stable, could the open-loop system be stable?

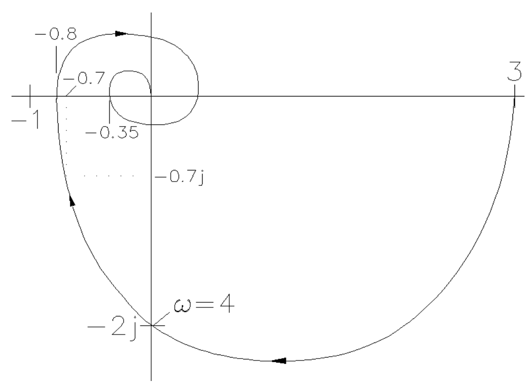
   b) How many unstable poles could the open loop system have?

      Assume it has that number for the rest of this problem.

   c) What is (are) the gain margin(s)?

   d) This Nyquist plot was draw for a system with a gain of 10. What is the range of gains for which the closed-loop system will be stable?

8. (14 pts) All parts of this problem refer to the system whose Nyquist curve is shown at right (only the portion for $\omega > 0$ is plotted). Recall that the Nyquist curve represents the frequency response of the open-loop system, or $G(j\omega)$. If $G(s)$ is the open-loop transfer function. The closed-loop transfer function is $G(s)/(1 + G(s))$.



   a) Knowing that the closed-loop system is stable, can one say for sure that the open-loop system is stable?

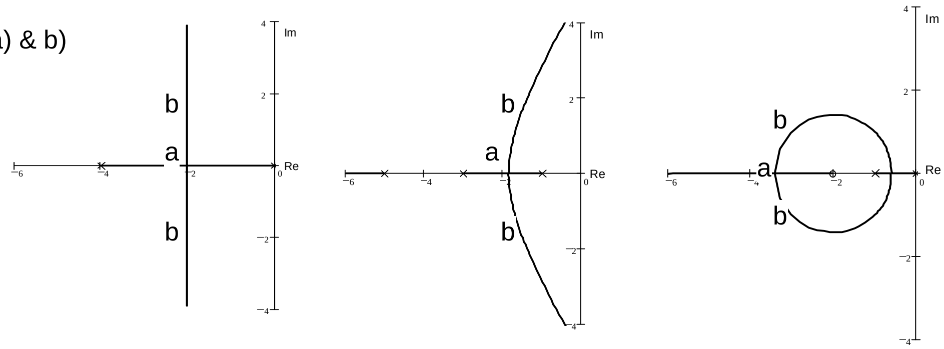
   b) Given the closed-loop system is stable, estimate the phase margin of the closed-loop system.

   c) How many unstable poles does the closed-loop system have if the open-loop gain is multiplied by 5?

   d) Give the steady-state response $y_{ss}(t)$ of the open-loop system to an input $x(t)=3\cos(4t)$. Express your answer in the time-domain, not as a complex number.

   e) Give the steady-state response $y_{ss}(t)$ of the closed-loop system to an input $x(t) = 8$. Express your answer in the time-domain, not as a complex number.

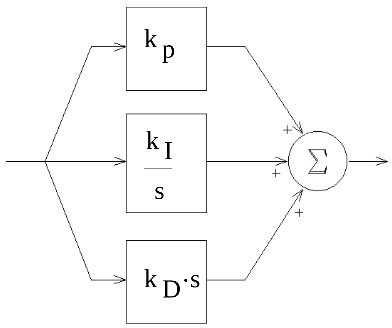
1. a) & b)



b) The gain, k

c) Use MATLAB to plot the root locus and use the cursor to determine the k at the points shown.

2. a)

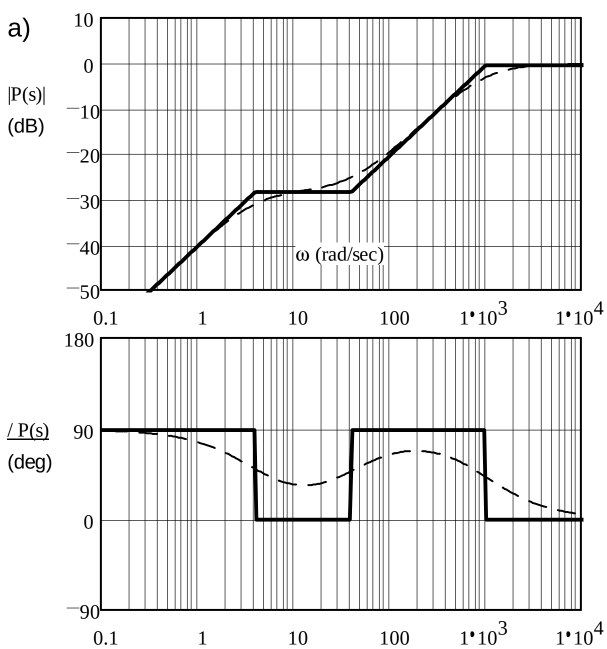


b) $k_D \cdot \dfrac{s^2 + \frac{k_P}{k_D} \cdot s + \frac{k_I}{k_D}}{s}$

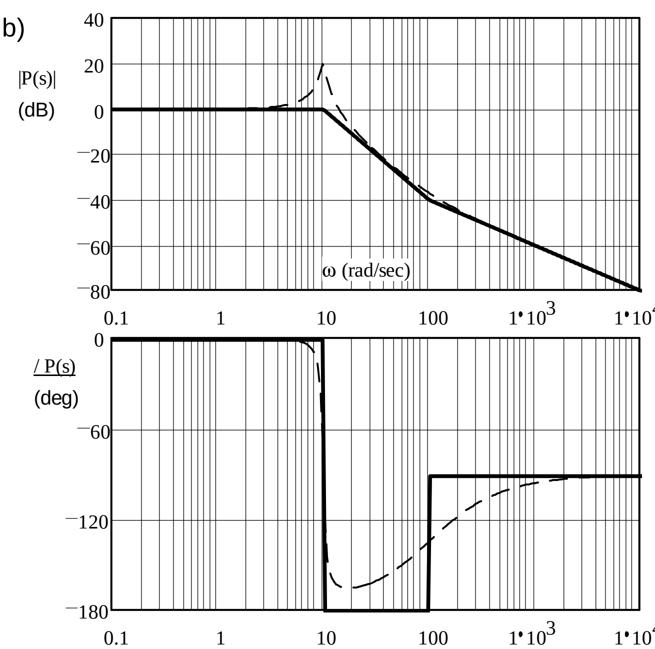
3. P PD PID PD PI

4. $\dfrac{1}{3}$

5. a)



b)



6. $12 \cdot dB$ $94 \cdot deg$

7. a) yes b) 2 c) $\dfrac{3}{2}$ & $\dfrac{8}{11}$

d) $10 \cdot \dfrac{8}{11} = \dfrac{80}{11} < k < 10 \cdot \dfrac{3}{2} = 15$

8. a) yes b) $45 \cdot deg$ c) 4

d) $6 \cdot \cos(4 \cdot t - 90 \cdot deg)$ or $6 \cdot \sin(4 \cdot t)$ e) 6

The numbers below and the plot at right were given with the exam

$1 = 6 \cdot dB$ $3 = 6 \cdot dB$ $4 = 6 \cdot dB$