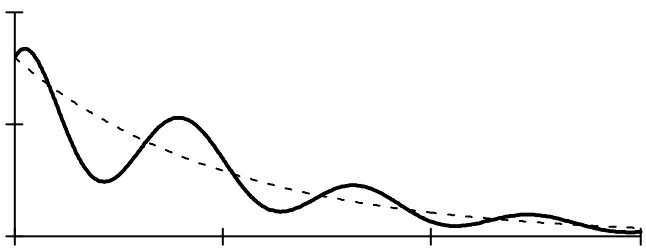
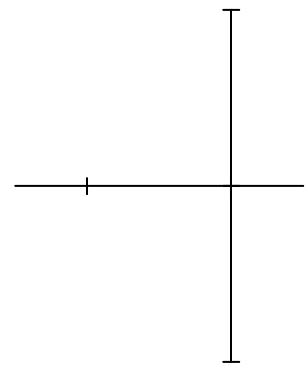
ECE 3510 Final given: Spring 11

This part of the exam is Closed book, Closed notes, No Calculator.

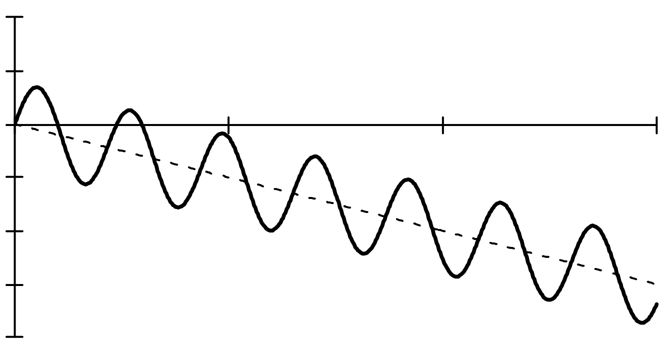
1. (12 pts) For each of the time-domain signals shown, draw the poles of the signal's Laplace transform on the axes provided. All time scales are the same. The axes below all have the same scaling. Your answers should make sense relative to one another. Clearly indicate double poles if there are any.

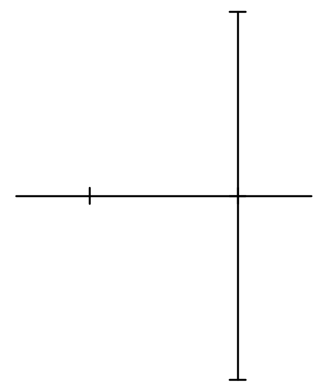
a)





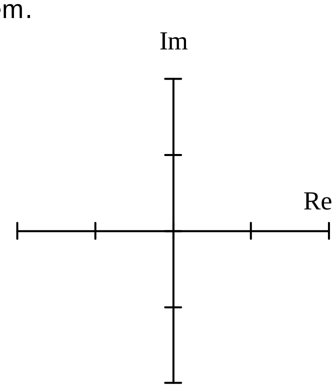
b)





2. (10 pts) a) Give the one characteristic of a feedback system that is more important than all others. Without this nothing else matters, you haven't even got a useable system.

b) To meet the requirement of part a), the system poles must lie in a certain region of the s-plane. Show that area on drawing at right. Make it clear where the poles must lie. Both axes have the same scale.



c) "Tracking" is considered an objective of a feedback system. List two characteristics of "good" tracking.

1

2

d) List one more characteristic or objective of a "good" feedback system.

3. (10pts) For the much of this semester we have been drawing root-locus plots. Be specific and clear in your answers below.

a) Each locus (line) starts at:

b) The __________ is _________ at this point.

c) Each locus (line) ends at:

d) The __________ is _________ at this point.

e) how many locus lines are there?

f)What do the lines actually represent?

4. (3 pts) Some compensators use differentiators, but real differentiators have some serious issues. What is the most important issue (the reason given in lab 5b for moving the differentiator into the feedback part of the loop and the reason for modifying the control law in lab 8).

5. (7 pts) In the Basic PLL lab you designed something which later provided the impetus for the unconventional root-locus plot. In the Advanced PLL lab you improved this item

   a) What was it that you designed, and what two items was it hooked between?

   b) At or near the end of both of these labs you testeed your PLL at a specific task to see how well your filter was performing. What was the special task your PLL was performing?

6. (17 pts) You would like to create an automatic control system for a double integrator system. (Note: you may recognize this system from one of your labs, but even if you don't, it's simple enough to work out.)

   The plant's transfer function is $\dfrac{X(s)}{\theta(s)} = \dfrac{k}{s^2}$ $\quad k := -\dfrac{5}{7}\cdot g$ $\quad$ and $\quad g = 9.807\cdot\dfrac{m}{sec^2}$

   You would like to use this control law: $\theta = k_p\cdot e + k_v\cdot\dfrac{d}{dt}e$ $\quad$ k_p and k_v are gain terms

   where $e = x_{REF} - x$ $\quad$ The difference between the disired output position and the actual output position (x)

   However, there can be problems differentiating the input signal (x_{REF}) so we'll simplify the control law to:

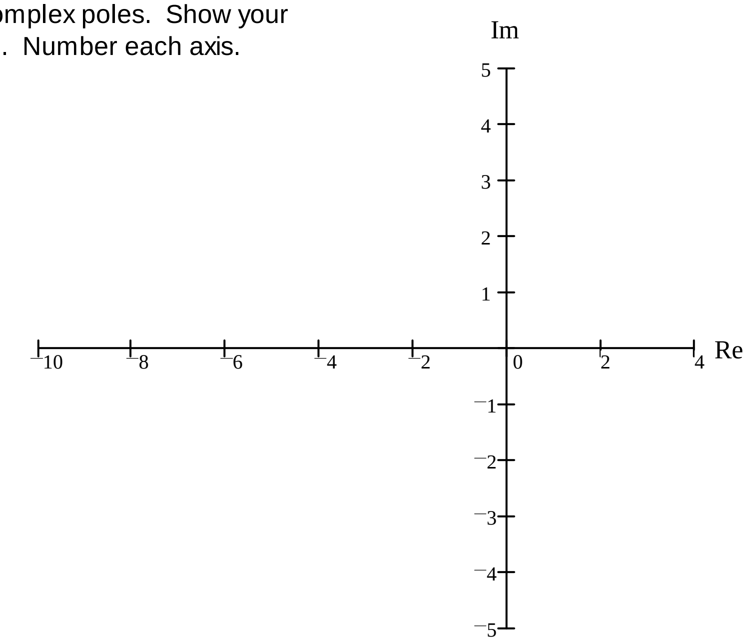
   $$\theta = k_p\cdot\left(x_{REF} - x\right) - k_v\cdot v \qquad \text{where} \qquad v = \frac{d}{dt}x \text{ , the velocity of the output}$$

   a) Draw a block diagram of the closed-loop system, showing the two feedback paths.

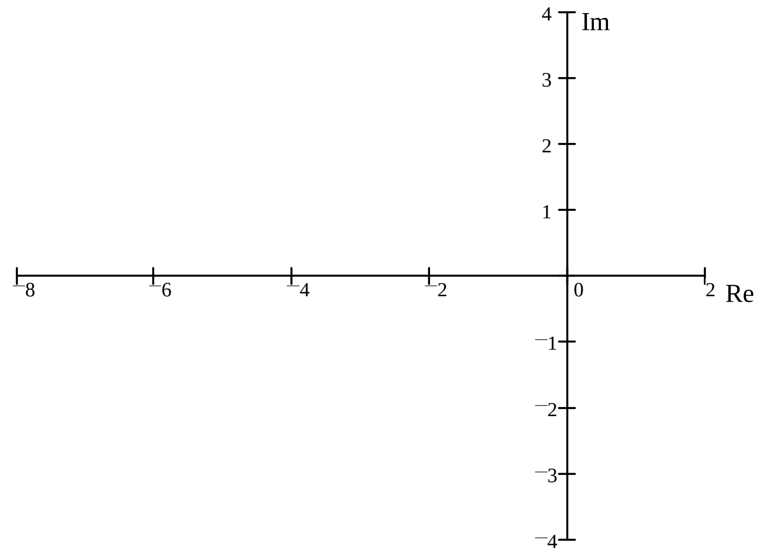
   b) Derive the closed-loop transfer function. Since there are two feedback paths, you will have to derive it mathematically like you did several times in lab. This should result in a second-order system whose poles can be placed arbitrarily by selecting the gain terms, k_p and k_v.

7. (20 pts) Sketch the root-locus plots for the following open-loop transfer functions: Use only the rules you were told to memorize, that is, you may estimate details like breakaway points and departure angles from complex poles. Show your work where needed (like calculation of the centroid). Number each axis. Draw things like the asymptote angles carefully.

   a) $\mathbf{G}(s) = \dfrac{(s+5)\cdot(s+8)}{s^2 - 6\cdot s + 13}$



b) $\mathbf{G}(s) = \dfrac{1}{\left(s^2 + 4 \cdot s + 13\right) \cdot (s+1) \cdot (s+5)}$



Open-book Part

1. (18 pts) Consider this transfer function. $G(s) := \dfrac{100}{s(s+24)}$

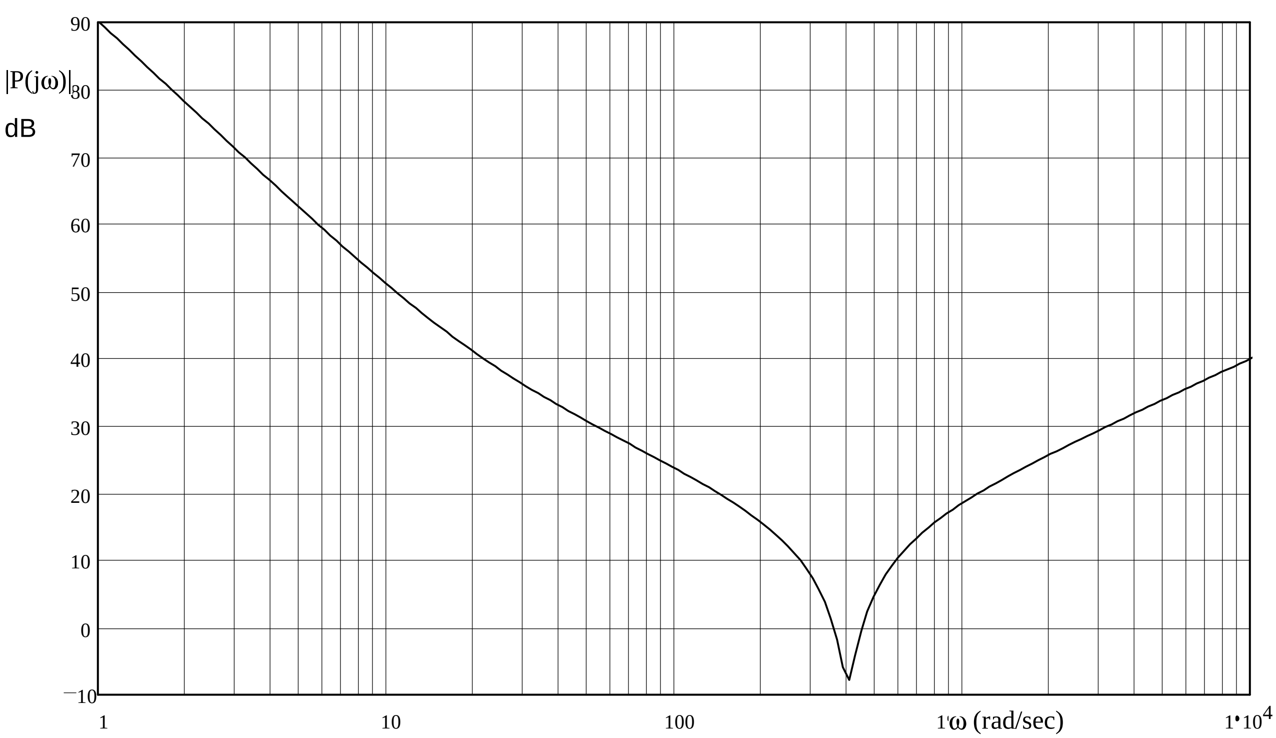
   a) Can the closed-loop poles be set to get ringing at 20 rad/sec and a settling time of 0.1sec?

   b) You wish to add a compensator to get the conditions of part a).
   Add a lead compensator so that you will be able to do this. Set the lead compensator's pole at -60.

   c) With the compensator in place and a closed-loop pole at the location desired in part b)

      i) What is the gain?

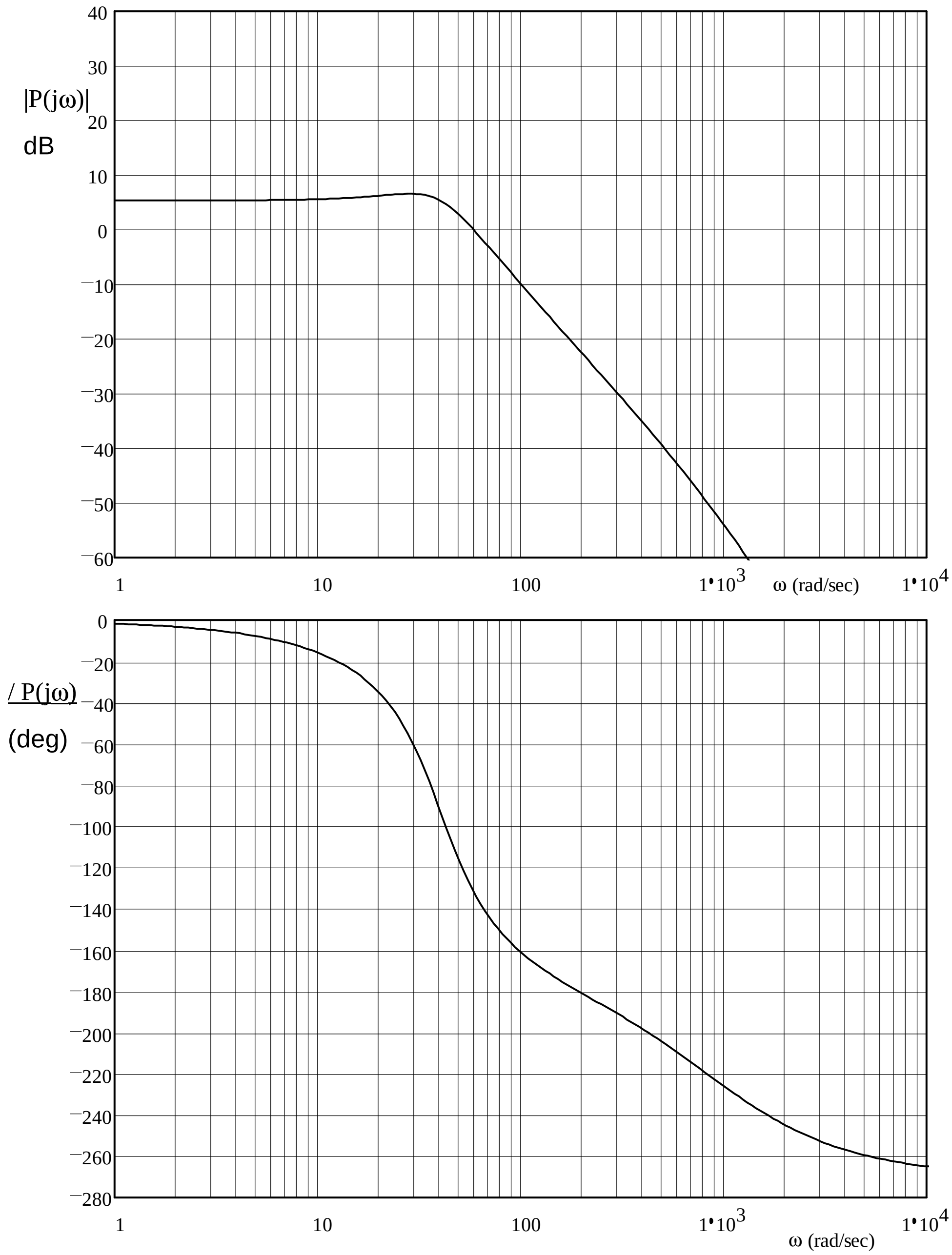
2. (16 pts) Given the magnitude Bode plot of a system, estimate the transfer function of the system.
   Assume there are no negative signs in the transfer function (all poles and zeros are in the left-half plane).
   Use a straight edge and show your work (how you made your estimate).



3. (12 pts) The open-loop Bode plots of a system are given at right.

   a) Find the gain margin and phase margin of the closed-loop system. Show your work on the drawings.

   b) Find the delay margin.



5. (10 pts) An open-loop system has:

   No unstable poles

   A DC gain of 3

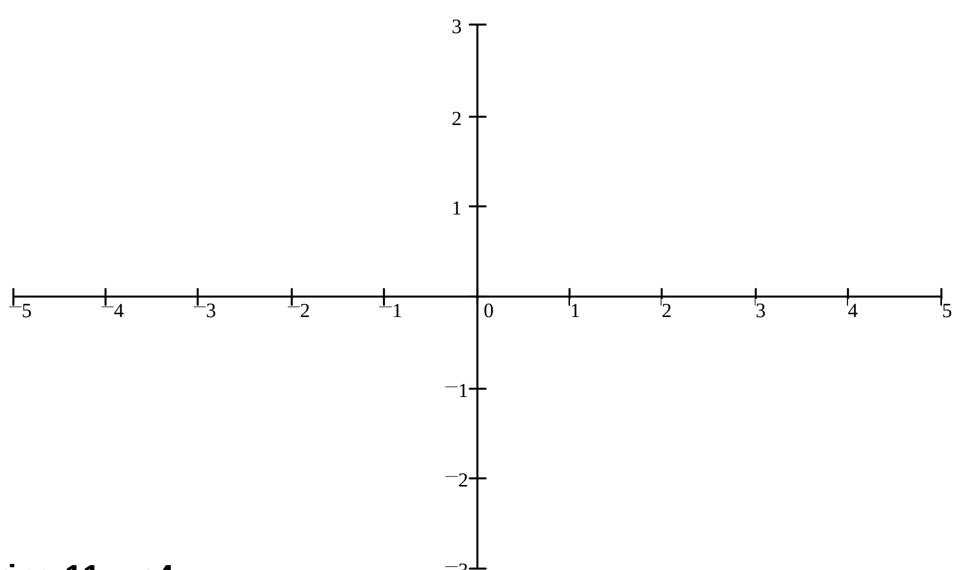
   3 more pole than zeros

The closed-loop gain margin is

$$GM = \left[\frac{1}{4} \;,\; 2 \right]$$

   & less than 0.2

Draw a possible Nyquist plot for this system. label important points, like crossings



4. (21 pts) For the given Nyquist plot, find the following for the open-loop system:

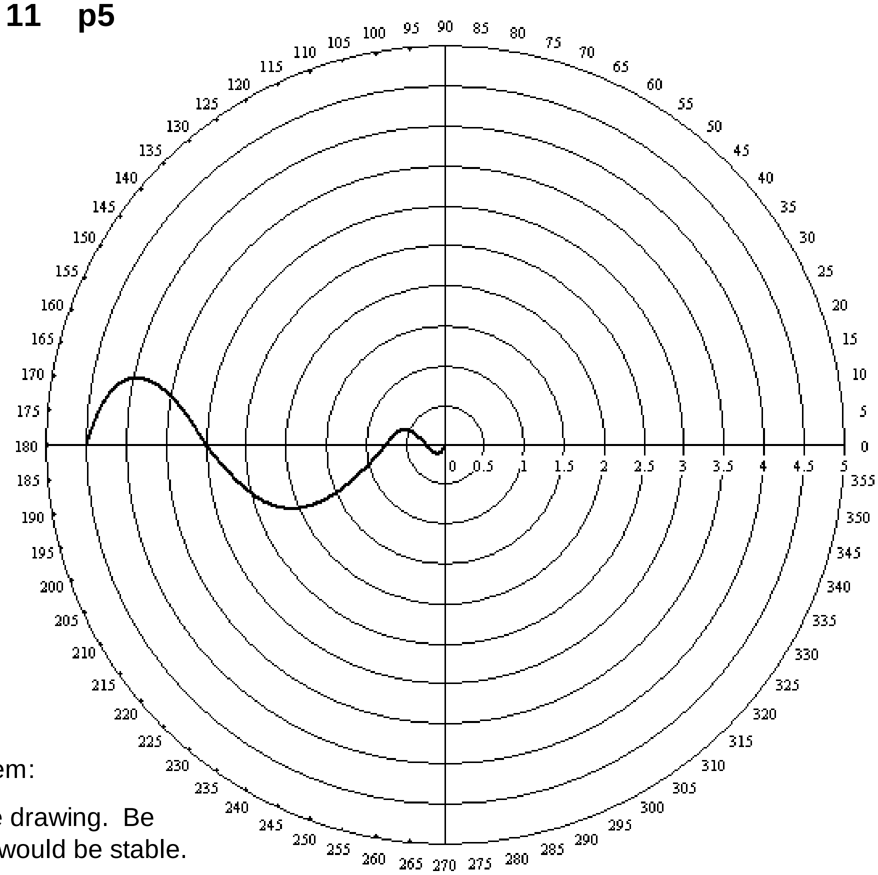
   a) the DC gain

   b) $n - m$ (number of poles - number of zeros)

   c) Number of poles at the origin

      How do you know?

   d) Number of poles in RHP, given the closed-loop system is stable at the current gain and is not stable at a gain of 0.1.



Find the following for the closed-loop system:

   e) Gain margin. Show your work on the drawing. Be sure to indicate ALL the regions that would be stable.

   f) Phase margin. Show your work on the drawing.

   g) What gain would result in the best GM an PM?

6. (16 pts) a) Draw the block diagram of a simple direct implementation of the difference equation.

$$y(k) = 2\cdot x(k) + \frac{x(k-2)}{3} - 1.5\cdot x(k-3) - \frac{1}{4}\cdot y(k-2) + \frac{1}{2}\cdot y(k-3)$$

   b) Find the $H(z)$ corresponding to the difference equation above. Show your work.

   c) List the poles of $H(z)$. Indicate multiple poles if there are any.
      If you can't find the actual poles, show the equation you would have to solve in order to find them.

   d) Is this system BIBO stable? Justify your answer. If you don't have the information you need, say how you would determine this.

7. (8 pts) Draw a minimal implementation of a system with the following transfer function

$$H(z) = \frac{-z^3 + (z-2)\cdot(z+4)}{z\cdot\left(z^2 + \frac{z}{3} - 2\right)}$$

8. Do you want your grade and scores posted on the Internet?
   If your answer is yes, then provide some sort of alias.

   ____
   otherwise, leave blank

   The grades will be posted on line in pdf form in alphabetical order under the alias that you provide here. I will not post grades under your real name. It will show the homework, lab, and exam scores of everyone who answers here.

ECE 3510 Final

Name ______________________________
Scores:
Closed Book __________ / 79 pts

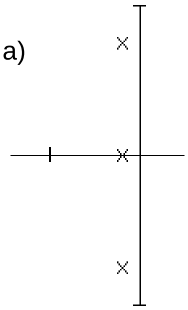
pages 3-4 __________ / 34 pts

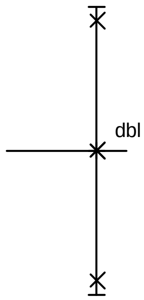
pages 5-6 __________ / 33 pts

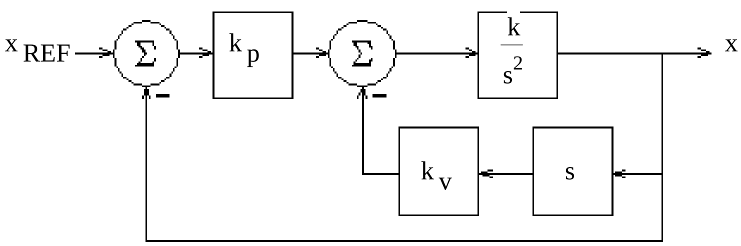
pages 7-8 __________ / 34 pts

Total __________ / 180 pts

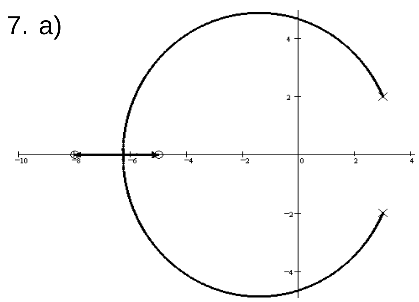
<u>**Answers**</u>

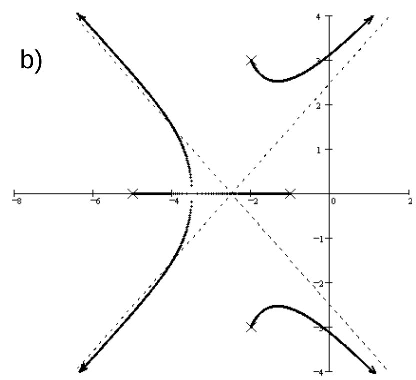
1. a) 

b) 

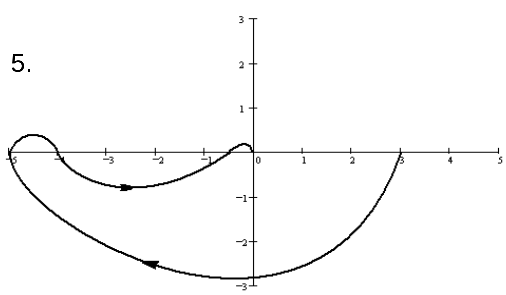
2. a) Stability b) In LHP & not on $j\omega$ axis
   c) fast smooth minimum error. Often measured in steady state but also means minimum overshoot, etc.
   d) Reject disturbances Insensitive to plant variations Tolerant of noise
3. a) An open-loop pole b) gain zero
   c) An open-loop zero or at infinity d) gain infinite
   e) The number of closed-loop poles, one per pole. f) The positions of the closed-loop poles
4. A true differentiator would produce an impulse when the input is a step. No real differentiator can do this.
5. a) The filter between the phase detector and the VCO b) FM demodulation
6. a) 

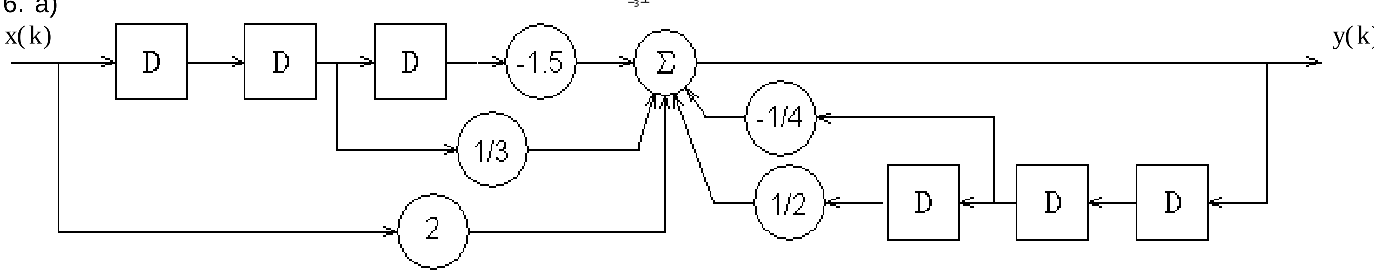
b) $\frac{X(s)}{X_{REF}(s)} = \frac{k \cdot k_p}{s^2 + k \cdot k_v \cdot s + k \cdot k_p}$

7. a) 

b) 

OPEN BOOK PART

1. a) No b) $\frac{s+9.09}{s+60}$ c) 8.8
2. $0.01 \cdot \frac{(s+20)\cdot\left(s^2+40\cdot s+160000\right)}{s^2}$
3. a) $22 \cdot dB$ $47 \cdot deg$ b) $14 \cdot ms$
4. a) -4.5 b) 1 c) 0 No arc at ∞ d) 1
   e) $\left[\frac{1}{3}, \frac{4}{3}\right]$ OR make gain greater than 4 f) $15 \cdot deg$
   g) about 0.6
   A very large gain is even better, but may be unrealistic in practice
5. 

6. a) 

b) $\frac{2 \cdot z^3 + \frac{1}{3} \cdot z - 1.5}{z^3 + \frac{1}{4} \cdot z - \frac{1}{2}}$

c) Poles at: 0.689
$-0.345 + 0.779 \cdot j$
$-0.345 - 0.779 \cdot j$

d) Yes, all poles are inside the unit circle

7.