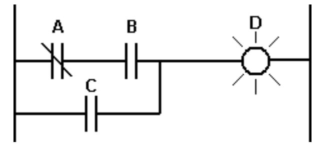
ECE 3510 Final given: Spring 15

1. (12 pts) a) Ladder logic was originally developed to help design logic circuits based on what type(s) of part(s)?

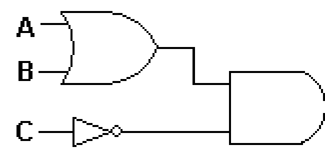
   b) Give the ladder-logic symbols of the following:

   i) Normally-closed switch or contact   ii) Normally-open switch or contact

   c) Show the Boolean expression or the equivalent logic gates for the ladder-logic shown. Inputs A, B and C control a light, D.



   d) Show the ladder-logic equivalent of the Boolean expression and the logic gates shown. Let the output, D, be a light.



$D = (A + B)\cdot\overline{C}$

2. (3 pts) An instrumentation amplifier is a good way to implement what function(s) or block(s) in a typical feedback loop?

3. (15 pts) When an electrical circuit is used as a representation if a mechanical system of translational motion, what do the following electrical quantities or parts represent in the mechanical system?

   a) Current source =

   b) Branch current =

   c) Nodal voltage =

   d) Ground =

   e) Resistor =

   f) Inductor =

   g) Capacitor =

   Also:

   h) Is the capacitor always hooked up in a certain way? If yes, say what.

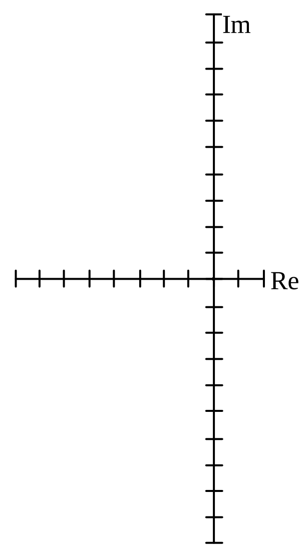
   i) Name two things represented by transformers. You may include items that rotate.

4. (9 pts) The **step response** of a system is:

   $$y(t) = 1.5\cdot e^{-3\cdot t}\cdot(4\cdot\cos(5\cdot t) + 2\cdot\sin(5\cdot t))\cdot u(t)$$

   The poles and zeroes of the **system**, not the signal.

   a) Draw the poles and/or zeroes of the **system** transfer function on the s-plane at right. Make sure I can tell the values of the real & imaginary parts.

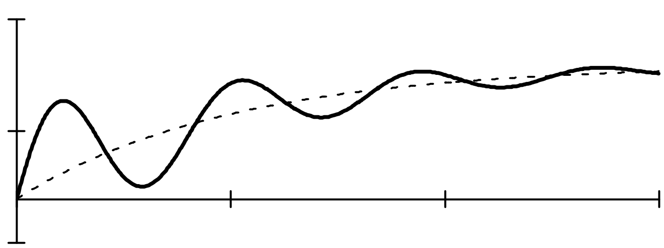


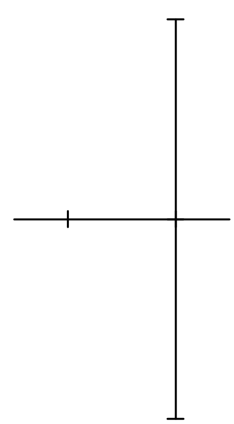
   b) What is the initial value of the output? (where does it start at time $t = 0$?)

   c) What is the final value of the output? (where does it end at time $t = \infty$?)

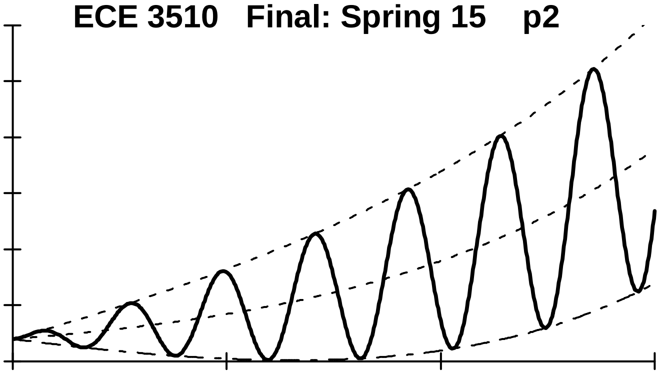
5. (12 pts) For each of the time-domain signals shown, draw the poles of the signal's Laplace transform on the axes provided. All time scales are the same. The axes below all have the same scaling. Your answers should make sense relative to one another. Clearly indicate double poles if there are any.

   a)

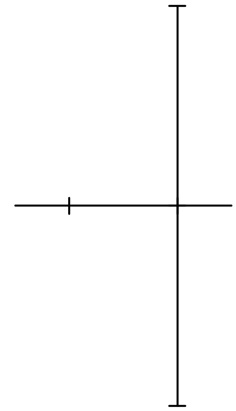




b)

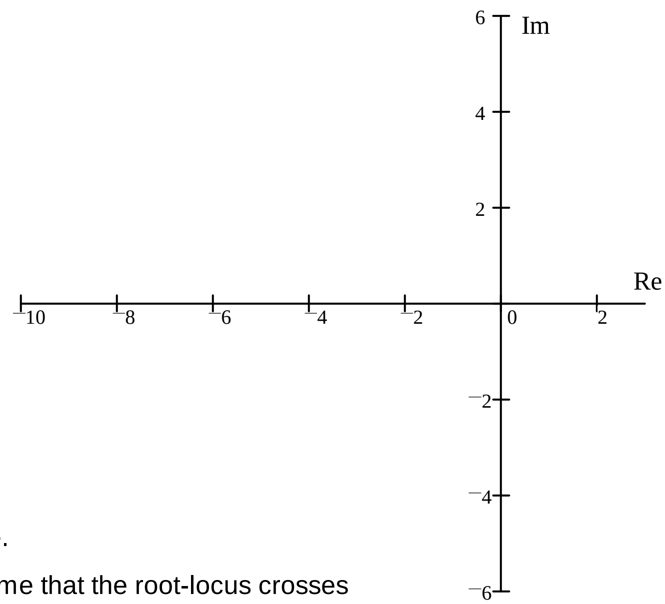


sine wave amplitude grows linearly (not exponentially)



6. (19 pts) a) Sketch the root-locus plots for the following open-loop transfer function and pole-zero plot. 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). Draw things like the asymptote angles carefully.
You MAY use your CALCULATOR.

a) $\mathbf{G}(s) = \dfrac{s+9}{(s+1)\cdot\left(s^2+4\cdot s+8\right)}$



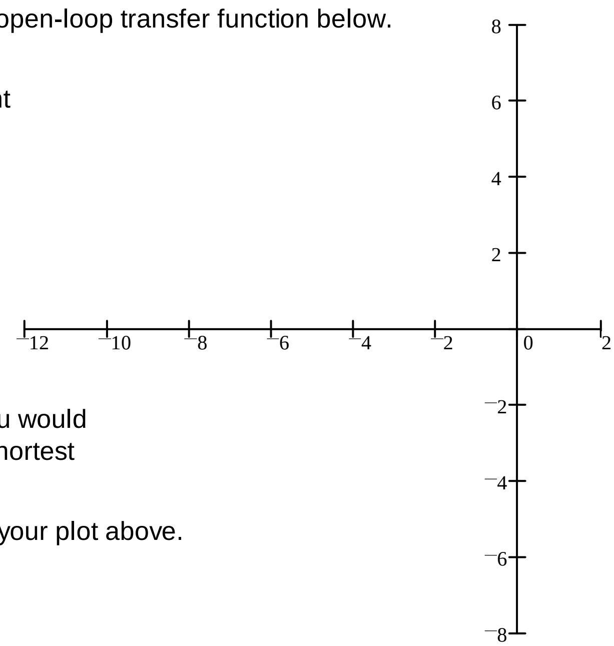
b) Does the root locus cross the $j\omega$ axis at 5?
Be sure to show the work and method you used to decide.

c) Regardless of what you found in part c), continue to assume that the root-locus crosses the $j\omega$ axis at 5. Give the range of gain k for which the system is closed-loop stable.

Open-book Part

1. (18 pts) a) Sketch the unconventional root-locus plot for the open-loop transfer function below. The root-locus should be plotted for an increasing x.

$$G(s) = \frac{k\cdot(x\cdot s+8)}{(s+2\cdot x)\cdot(s+5)} \qquad k = 3 \quad \text{and is constant}$$



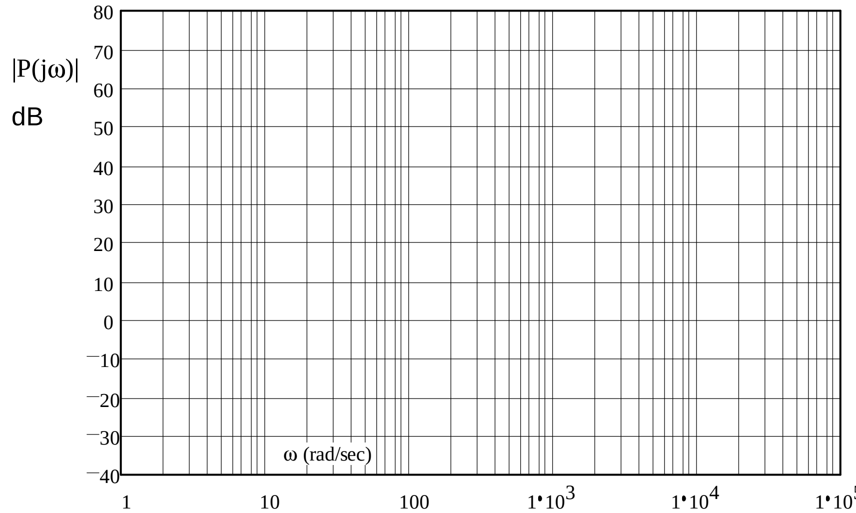
b) Draw an arrow to the place(s) on your root locus where you would like to place the closed-loop poles for no ringing and the shortest settling time. What is your best guess of s at this location?

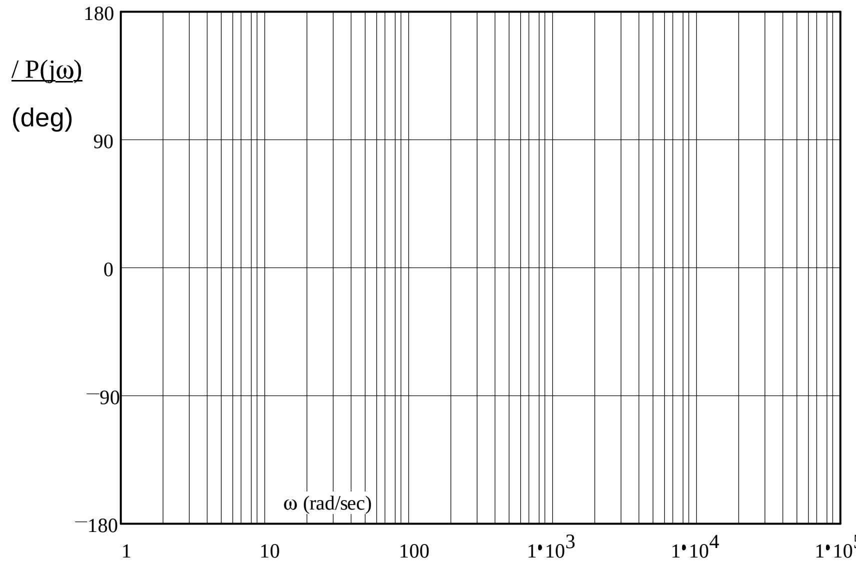
c) Find the value of x needed, based on your best reading of your plot above.

d) If you wanted more ringing (and overshoot), x should be:
i) greater than the value found in part c).
ii) equal to the value found in part c). (circle one)
iii) less than the value found in part c).

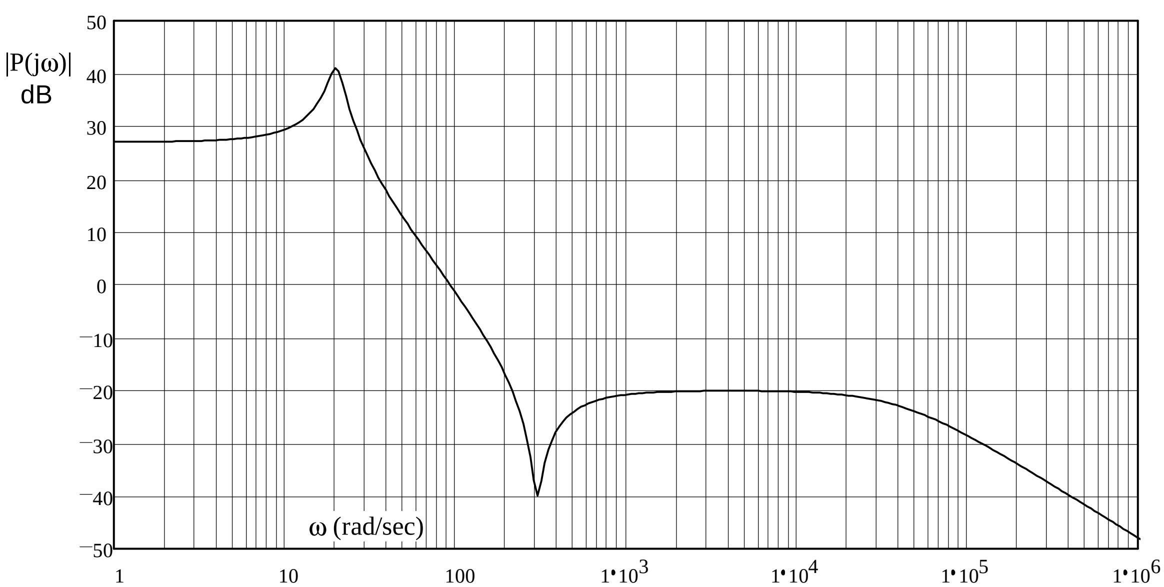
2. (20 pts) Sketch the Bode plot for the following transfer function. Make sure to label the graphs as necessary to show the magnitudes and slopes. Also accurately draw the "smooth" lines. Include dB values at important points

$$P(s) = \frac{5\cdot(s+10000)\cdot s^2}{(s+3)\cdot\left(s^2+100\cdot s+160000\right)}$$

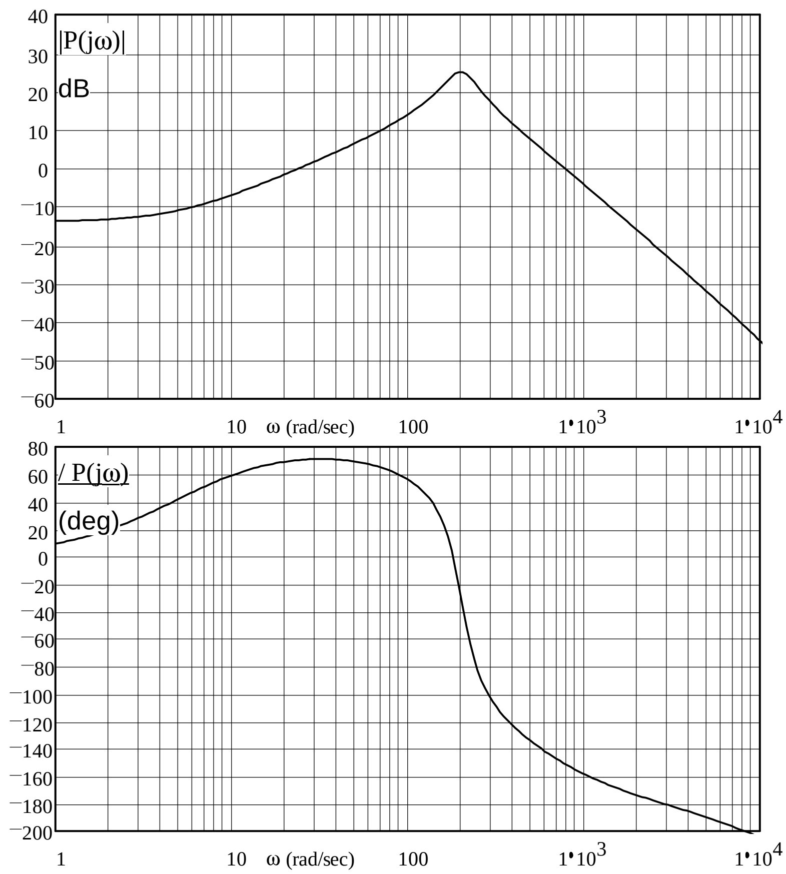




3. (20 pts) Given the magnitude Bode plot of a system, estimate the transfer function of the system. Assume there are no negative signs in the transfer function (all poles and zeros are in the left-half plane). Use a straight edge and show your work (how you made your estimate).



4. (20 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.

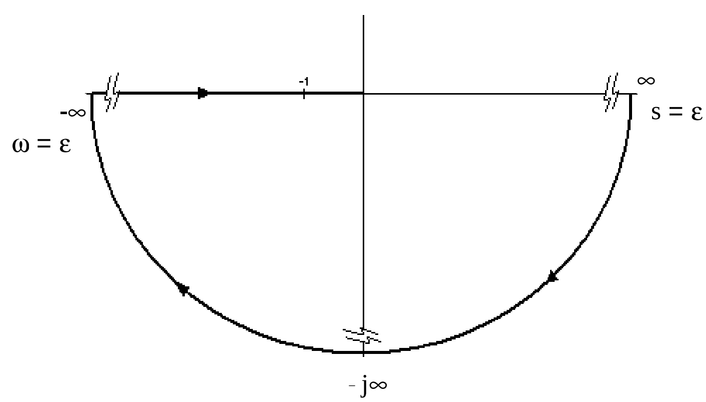
b) Find the delay margin.

c) For the system of part (a), give the steady-state response of the open-loop system an input $x(t) = 5\cos(10t)$. Express the answer in the time-domain.

$y_{ss}(t)$ = ?

d) Give the steady-state response of the closed-loop system for the same input.

5. (18 pts) Refer to the Nyquist curve at right (only the portion for $\omega > 0$ is plotted).

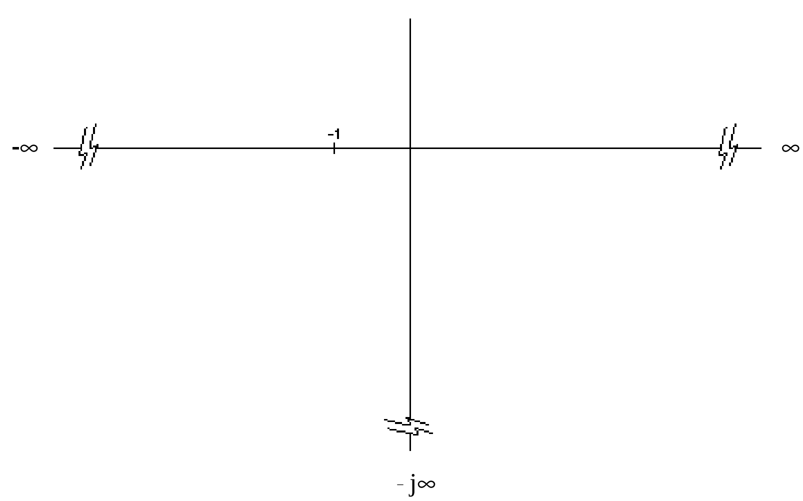


a) This is a simple plot of a simple system (plant). What is the transfer function of this plant? If you can't figure this out, read the rest of the problem and if you need P(s), come and ask for hints. They will cost you points, but at least you'll be able to do the rest of the problem.

$P(s)$ = ?

b) Can the closed-loop system be BIBO stable?

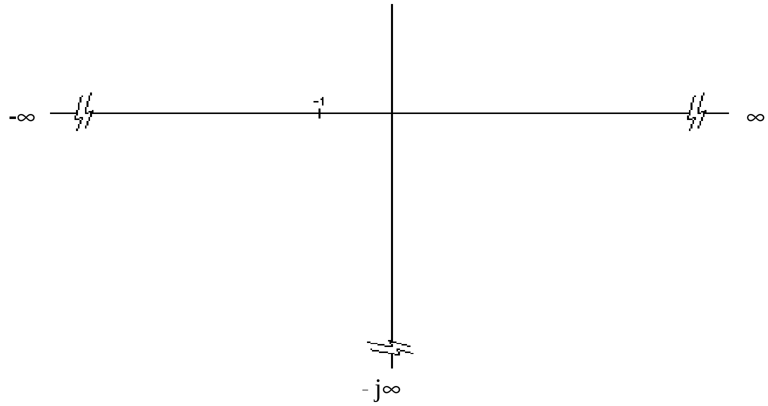
c) Name a common compensator that can make the closed-loop system stable with a phase margin of approximately 45°.



Sketch the new Nyquist diagram for $C(s)P(s)$ showing the change made by the compensator. Specifically, show the phase margin.

d) Name a different common compensator that would make the closed-loop system hopelessly unstable. (The compensator of part c) is <u>replaced</u> by this one.)

Sketch the new Nyquist diagram for $C(s)P(s)$ showing the change made by the compensator.



6. (14 pts) For the given Nyquist plot, The closed-loop is stable at the current gain. Find the following for the open-loop system:

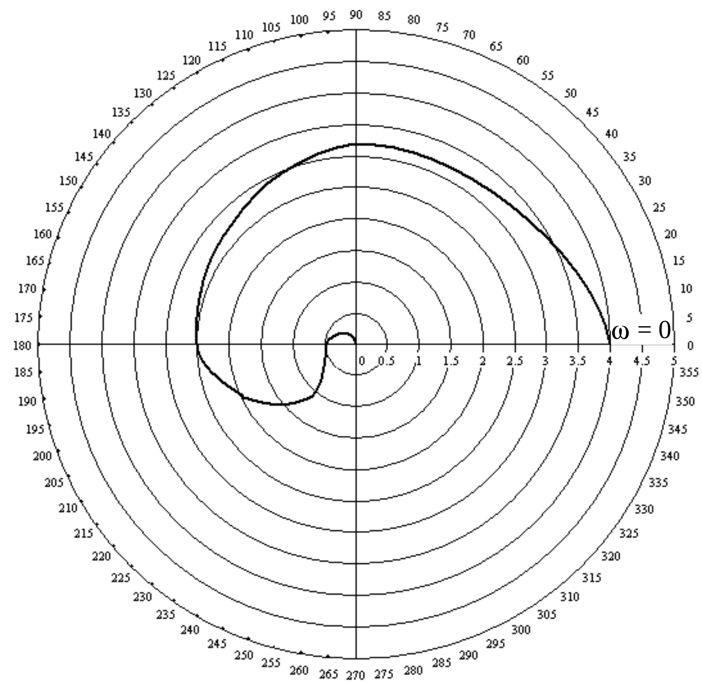
a) the DC gain

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

c) The number of unstable poles. (Note Z cannot be negative at any gain.)

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

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



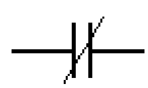
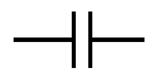
7. Do you want your grade and scores posted on the Internet? If your answer is yes, then provide some sort of alias.

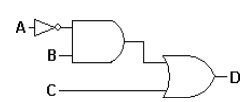
____
otherwise, leave blank

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 or an alias that looks like a real name or u-number. The pdf spreadsheet will show the homework, lab, and exam scores of everyone who answers here.

Answers

1. a) Electromechanical relays and simple switches

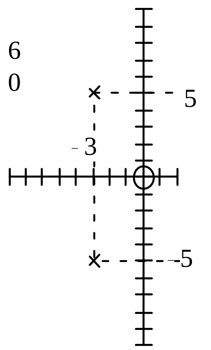
b) i)  ii)  c) $\overline{A} \cdot B + C$ OR



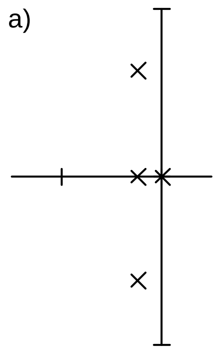
2. The summer with + and - , and the gain block

3. a) Force input
   b) Force
   c) Velocity
   d) Stationary reference of zero velocity
   e) Friction or damping
   f) Spring
   g) Mass
   h) Yes, one side is always hooked to ground
   i) Levers Wheels Belts Gears Electric motors 2 of these

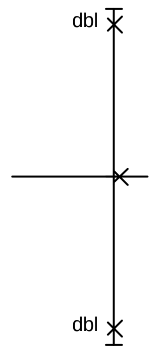
4. a)
   b) 6
   c) 0



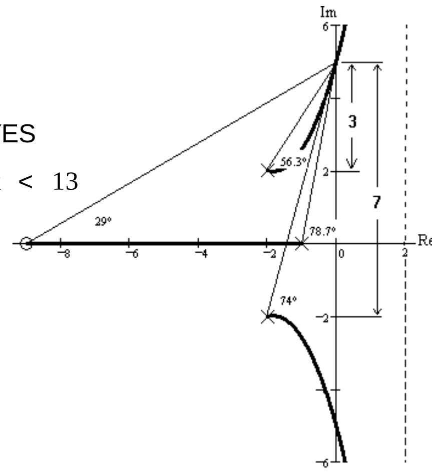
5. a)



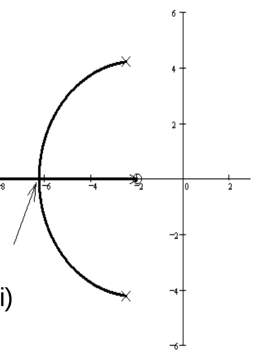
b)



6. a)
   b) YES
   c) $k < 13$

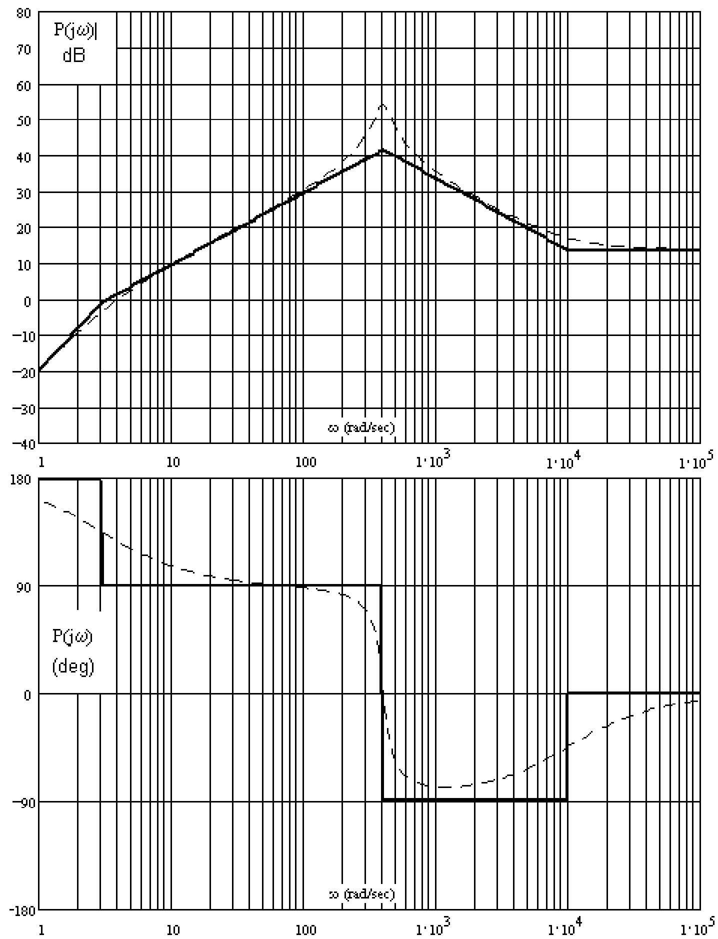


1. a)



   b) $s = -6.24$
   c) 1.5 d) iii)

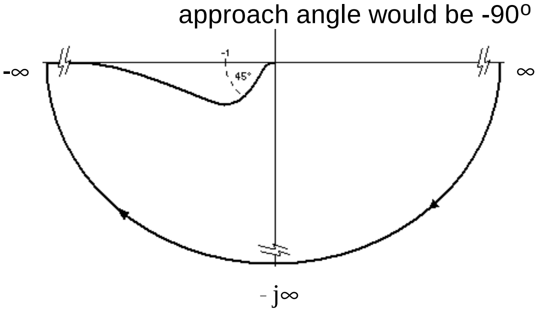
2.



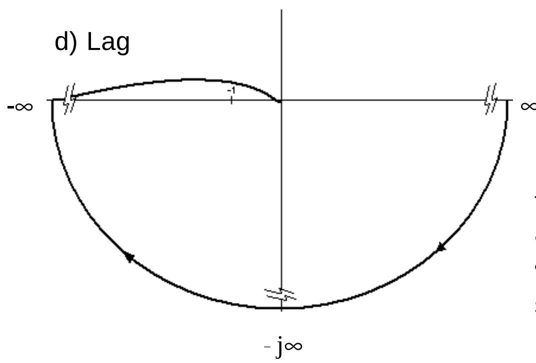
3. $$\frac{4000\cdot\left(s^2+30\cdot s+90000\right)}{\left(s^2+4\cdot s+400\right)\cdot(s+40000)}$$

4. a) $23\cdot dB$ $30\cdot deg$
   b) $0.65\cdot ms$
   c) $2.23\cdot\cos(10\cdot t+60\cdot deg)$
   d) $1.74\cdot\cos(10\cdot t+42\cdot deg)$

5. a) $\frac{k_p}{s^2}$ b) NO
   c) Lead   PD would also work, then approach angle would be -90º



   d) Lag



PI would also do, then there would be another 90º of arc at ∞ , approach angle stil -180º

6. a) ~ 4   b) 3   c) 2   d) [0.4 , 2]   e) $50\cdot deg$