ECE 3510 Exam 2 given: Spring 13

(Some of he space between problems has been removed.)

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

1. (10pts) Be sure to use the words "open-loop" (OL) and "closed-loop" (CL) where appropriate in the answers below.

   Note: all "b)" answers below are the same.

   A standard root-locus plot shows how the a)____ move as the b)_________________ of a feedback system changes. We usually think of the root locus as consisting of individual lines or branches that start at certain points and end somewhere else.

   The number of these lines is equal to the c)____ .

   Each line "starts" at d)____ .

   The b)_________________ of the feedback system is e)_________________ at the "start".

   Each line "ends" at f)____ .

   The b)_________________ of the feedback system is g)_________________ at the "end".

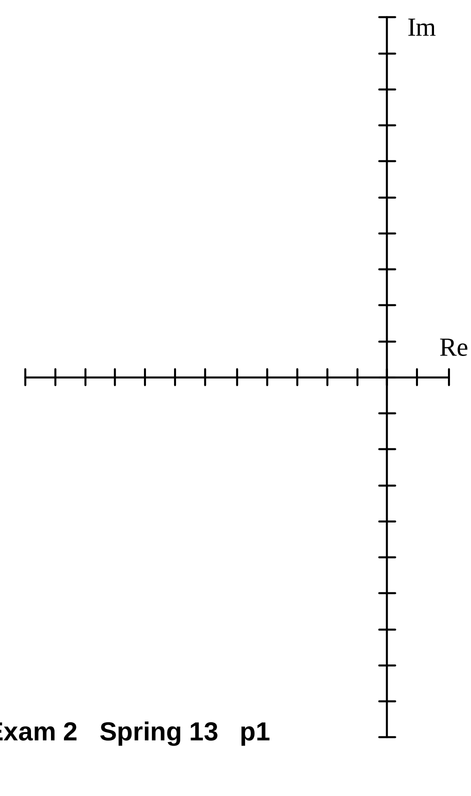
2. (6pts) Any point on the s-plane can be tested to see if it is on some branch of the root locus.

   a) If the point "s_1" is on some branch of the root locus, what must be true (what is the test)?

   b) If the point "s_1" is on some branch of the root locus, then there is a specific feedback system gain associated with this point. What is that gain?

   c) If the point "s_1" is on some branch of the root locus, AND the feedback system gain is what you showed in part b), then what actually exists at point "s_1"?

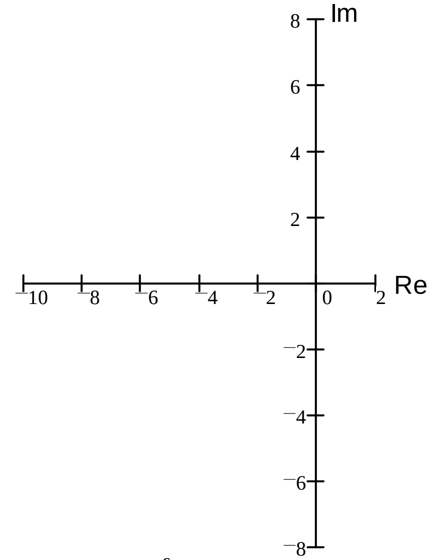
3. (7 pts) The time constant of a system's step response must be **between 0.1 sec and 0.4 sec** (longer than 0.1 sec but shorter than 0.4 sec). The overshoot must be **MORE** than 4%. Does that mean the system's poles must lie in a certain region of the s-plane? If yes, show that area on drawing at right, including numbers where appropriate. Make it clear where the poles must lie. If no, write NO below.



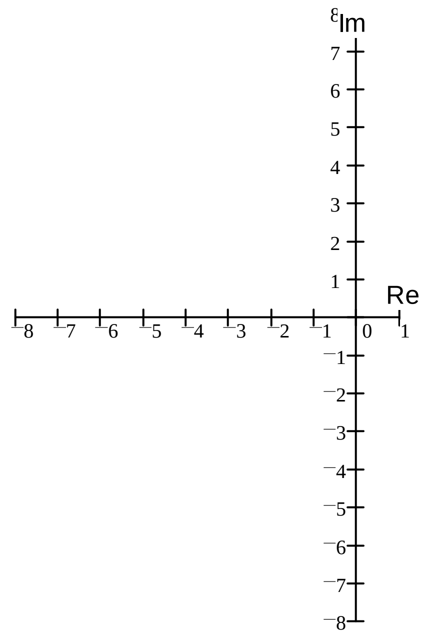
Go back and read the question again carefully so that you won't tell me later that "I knew that, I just didn't read it right."

4. (24 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).
Draw things like the asymptote angles carefully.

a) sketch $G(s) = \dfrac{1}{\left(s^2 + 6 \cdot s + 25\right) \cdot (s+6) \cdot (s+8)}$



b) $G(s) = \dfrac{(s+5)}{\left[(s+2)^2 + 4^2\right] \cdot \left[(s+5)^2 + 3^2\right]}$



Open-book part

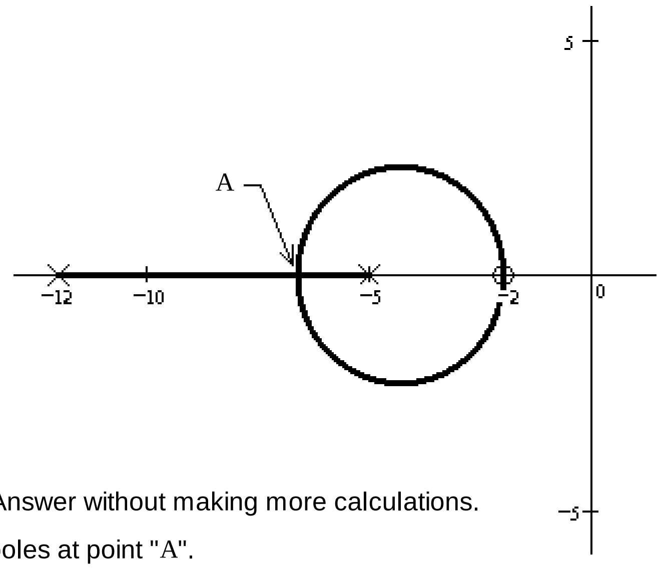
1. (10 pts) The controller and plant transfer functions shown below are part of a standard unity feedback system.

$$C(s) = \frac{1}{s+3} \qquad\qquad P(s) = \frac{2s+8}{s-2}$$

a) As is, without any extra gain in the loop, will the whole feedback system be BIBO stable?
You must justify your answer.

b) If you added gain factor to the controller, so that it is now: $C(s) = \dfrac{k}{s+3}$ Can you now change the stability of the system?
(That is, make stable if it was unstable, or unstable if it was stable.)
You must justify your answer and find the k value to make the change, if possible.

2. (10 pts) a) Point "A" is a special point on the root locus plot.
What is it called?



b) Determine if point "A" is at -7. Show your evidence.
I want to see specific calculations and numbers to justify your answer.

c) The gain required to place a closed loop pole at -7 is: Answer without making more calculations.

A) LESS than the gain required to place the closed loop poles at point "A".

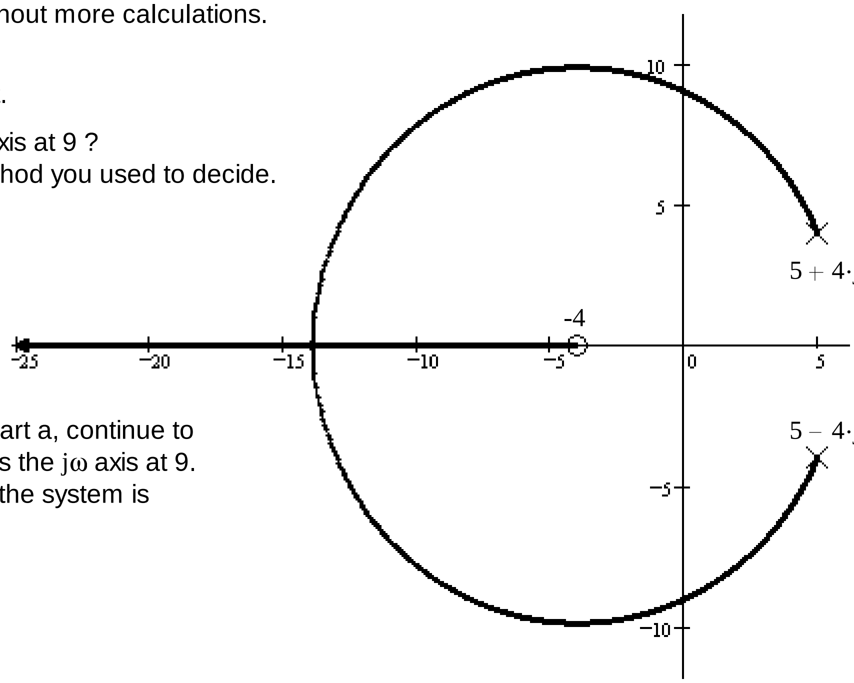
B) THE SAME as the gain required to place the closed loop poles at point "A".

C) GREATER than the gain required to place the closed loop poles at point "A".

D) It isn't possible to answer this without more calculations.

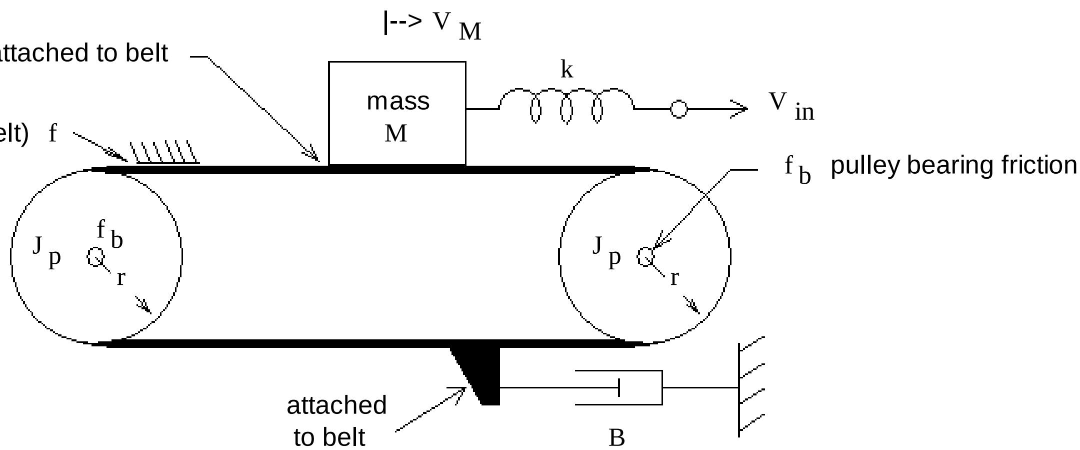
3. (14 pts) A root locus is shown at right.

a) Does the root locus cross the $j\omega$ axis at 9 ?
Be sure to show the work and method you used to decide.



b) Regardless of what you found in part a, continue to assume that the root-locus crosses the $j\omega$ axis at 9.
Give the range of gain k for which the system is closed-loop stable.

4. (19 pts) Find the equivalent electric circuit for the mechanical system shown. It is a belt and 2 pulleys.
Each pulley has has a moment of inertia, J_p, bearing friction, f_p, and radius, r . V_{in} is a velocity input.



4. continued

a) Show the circuit with one or more transformers. Show the parts in terms of M's, k's, B's, etc., above. Indicate the mass velocity, V_M, on your drawing.

b) Show how to eliminate a transformer, just like you did in the homework. Show the equivalent parts in terms of M's, k's, B's, etc., above. You don't have to redraw the whole circuit as long as I can tell how the section of the circuit you draw would connect in above.

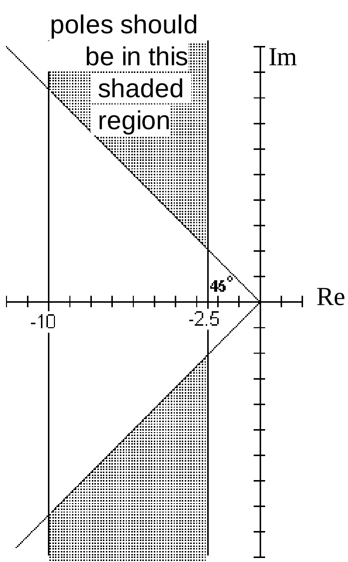
Answers

1. A standard root-locus plot shows how the a) the positions of the closed-loop poles move as the b) gain of a feedback system changes. We usually think of the root locus as consisting of individual lines or branches that start at certain points and end somewhere else.
   The number of these lines is equal to the c) The number of open-loop poles, one per pole .
   Each line "starts" at d) an open-loop pole .
   The b) gain of the feedback system is e) zero at the "start".
   Each line "ends" at f) an open-loop zero or at infinity along an asymptote .
   The b) gain of the feedback system is g) infinite at the "end".

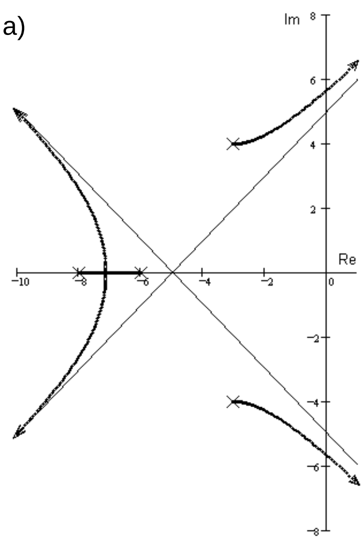
2. a) The open-loop transfer function evaluated for s = s_1 is negative (angle is ± 180 deg) b) $k = \dfrac{1}{|G(s_1)|}$

c) A closed-loop pole

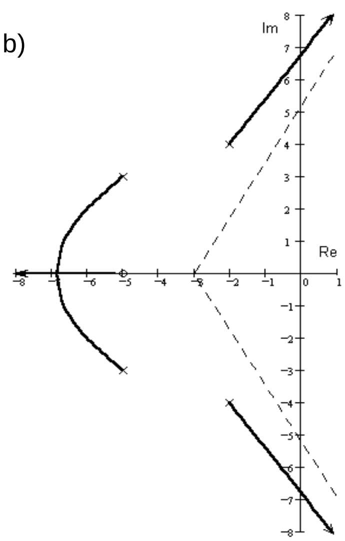
3.



4. a)



b)

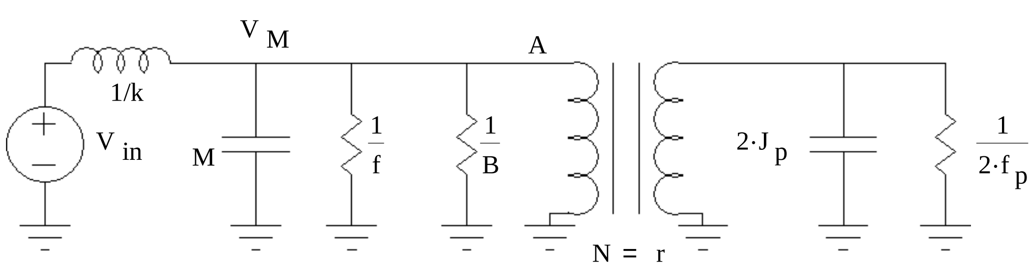


1. a) $D_H(s) = (s+1)\cdot(s+2)$ YES b) $D_H(s) = s^2 + (1+2\cdot k)\cdot s + (8\cdot k - 6)$ Becomes unstable for $k \le 3/4$

2. a) Break-away point b) NO c) A)

3. a) YES, the point, $s = 9j$ **IS** on the root locus plot. b) $k > 10$

4. a)



b)