ECE 3510 Exam 3 given: Fall 22

This part of the exam is Closed book, Closed notes, No Calculator.
Your answers should specific, clear, concise, and legible, or I'll assume you don't know.

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

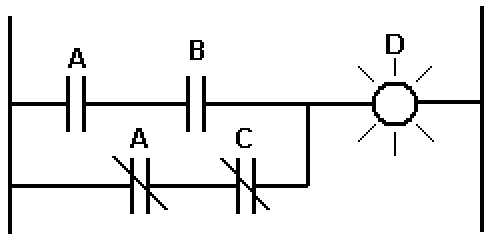
2. a) Ladder logic was originally developed to help design logic circuits based on what type(s) of part(s)?

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

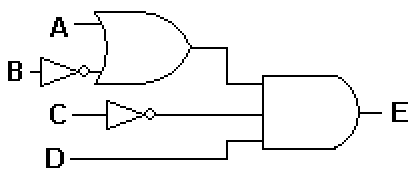
      i) Normally-open switch or contact

      ii) Normally-closed switch or contact

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

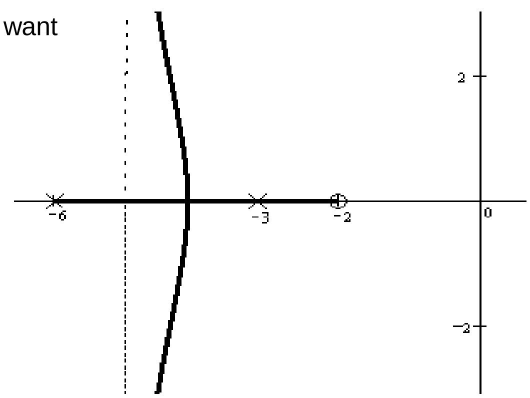


   d) Show the ladder-logic equivalent of the Boolean expression and the logic gates shown below. Let the output, E, be a light.



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

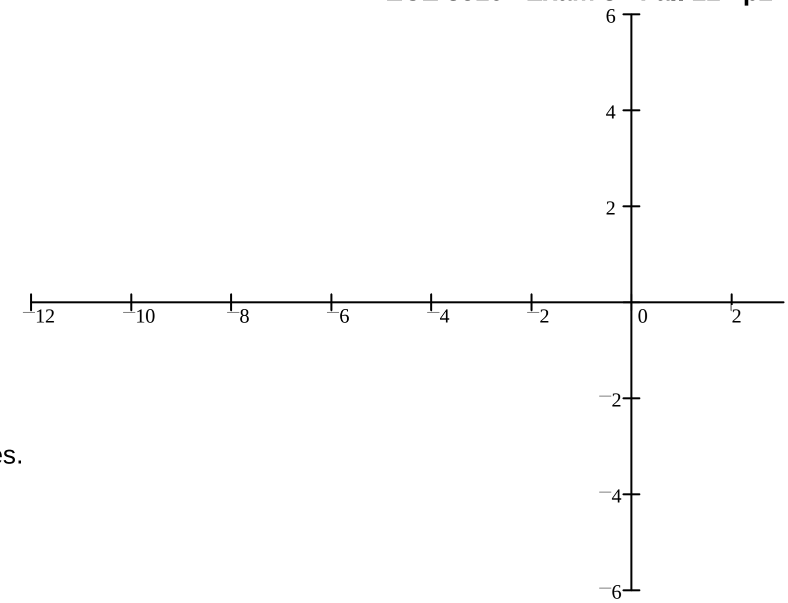
1. (10 pts) a) Determine if the break-away point is at -4. Show your evidence. I want to see specific calculations and numbers to justify your answer.



   b) The gain required to place a closed loop pole at -4 is: Answer without making more calculations.
      A) LESS than the gain required to place the closed loop poles at the break-away point.
      B) THE SAME as the gain required to place the closed loop poles at the break-away point.
      C) GREATER than the gain required to place the closed loop poles at the break-away point.
      D) It isn't possible to answer this without more calculations.

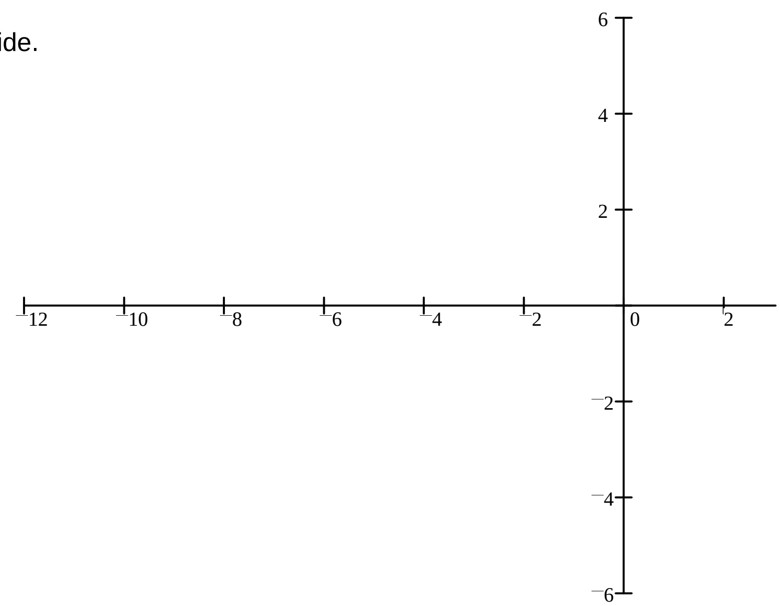
2. (30 pts) a) Lightly sketch (or use a dotted line) the root locus for the OL transfer function shown below.

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



b) Find the departure angle from one of the complex poles.

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



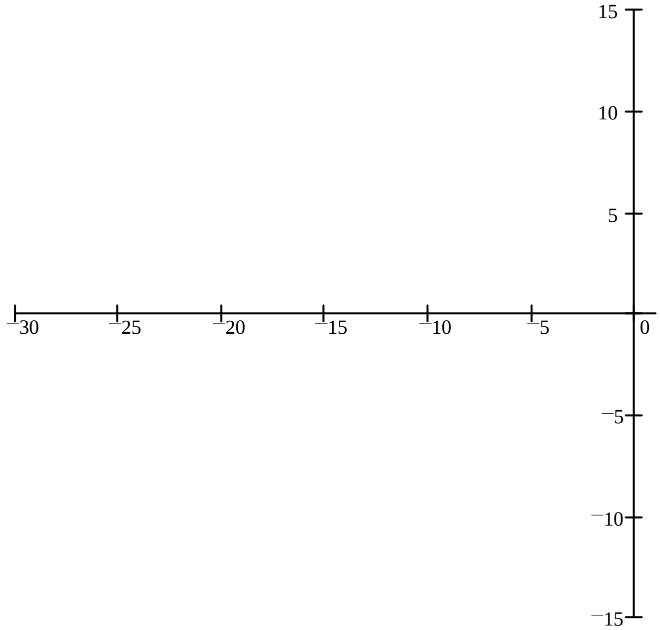
d) Regardless of what you found in part c), continue to assume that the root-locus crosses the $j\omega$ axis at 5.
Give the range of gain k for which the system is closed-loop stable.

Remember, I asked for a **range** for stability

e) Use what you found in parts b) and c) to draw your final root-locus plot (at part a)).
Clearly show the angle and possibly the crossing (show numbers on the drawing).

3. (30 pts) Consider this transfer function. $\mathbf{G}(s) := \dfrac{s+8}{s\cdot(s+5)\cdot(s+20)}$

a) You wish to add a compensator to get closed-loop settling time to 1/3 sec and the ringing frequency to 12 rad/sec. (using the second-order approximation). Find the simplest compensator and show all your work, including angle calculations.

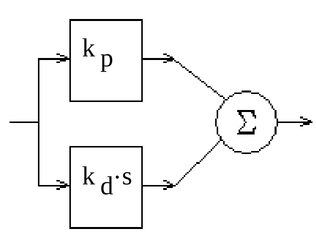


b) With the compensator in place and a closed-loop pole at the location desired in part a)

i) What is the gain?

ii) What is the steady-state error to a unit-step input?

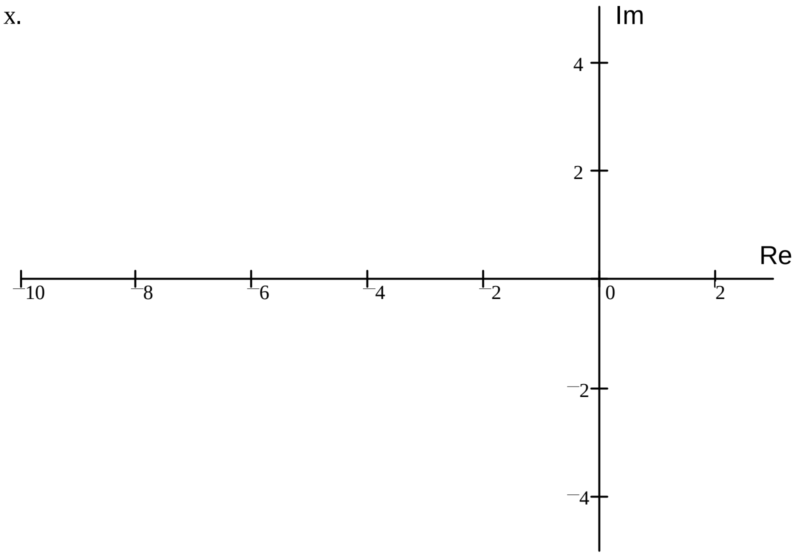
c) Find k_p and k_d of a standard PD controller.



d) With this compensator in place, is there possibility for improvement (better speed and/or lower ringing)? If yes, what would be the simplest thing to do? Justify your answer.

4. (18 pts) Sketch the unconventional root-locus plot for the open-loop transfer function below. The root-locus should be plotted for an increasing x.

$$\mathbf{G}(s) = k\cdot\frac{s^2 + 2\cdot s\cdot(x+2) + 20}{s\cdot(s\cdot x + 6) + 15 - 16\cdot x} \qquad k = 3 \text{ and is fixed}$$

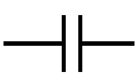


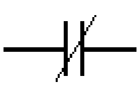
b) Is there a value of x above which the closed-loop system becomes BIBO unstable?
If **YES**, find the range of x needed for BIBO stability.
If **NO**, draw an arow to any other point on the root locus and find the value of x needed to place the closed-loop pole at that location.

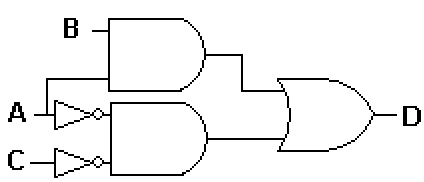
Answers

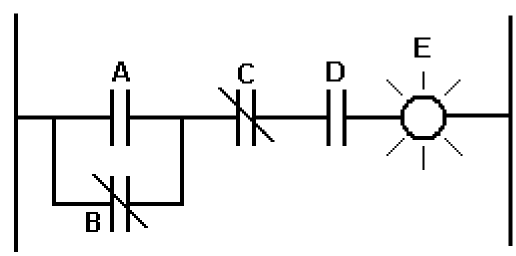
1. The summer with + and - , and the gain block

2. a) Electromechanical relays and simple switches

b) i) 

ii) 

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

d) 

1. a) $\frac{1}{-4+2} = -0.5 \overset{?}{=} \frac{2}{-4+3} + \frac{1}{-4+6} = -1.5$ b) A)

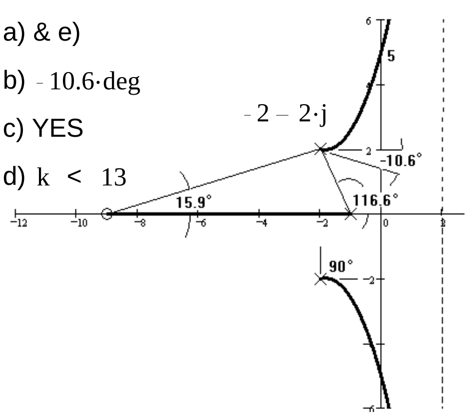
NO, they are not equal

2. a) & e)

b) $-10.6\cdot deg$

c) YES

d) $k < 13$



3. a) $\mathbf{C}(s) := (s + 40.1)$

b) i) 8.8 ii) $0\cdot\%$

c) 353 8.8

d) Increase the gain

4. a)

b) $x < 4.688$