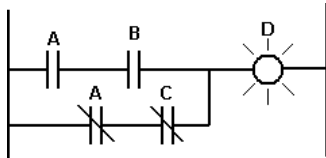


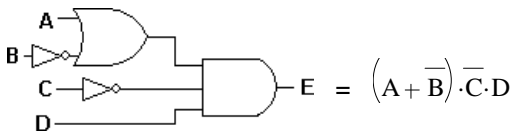
# ECE 3510 Exam 3 given: Spring 19 (Some of the space between problems has been removed.)

**Closed book, Closed notes,** may have Exam 1, 2, & 3 info sheets which may have additions.

1. (10 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-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.

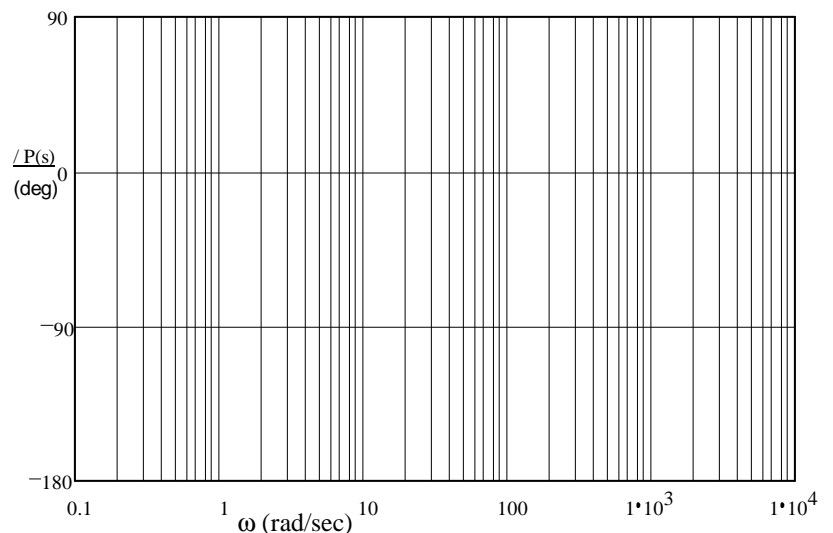
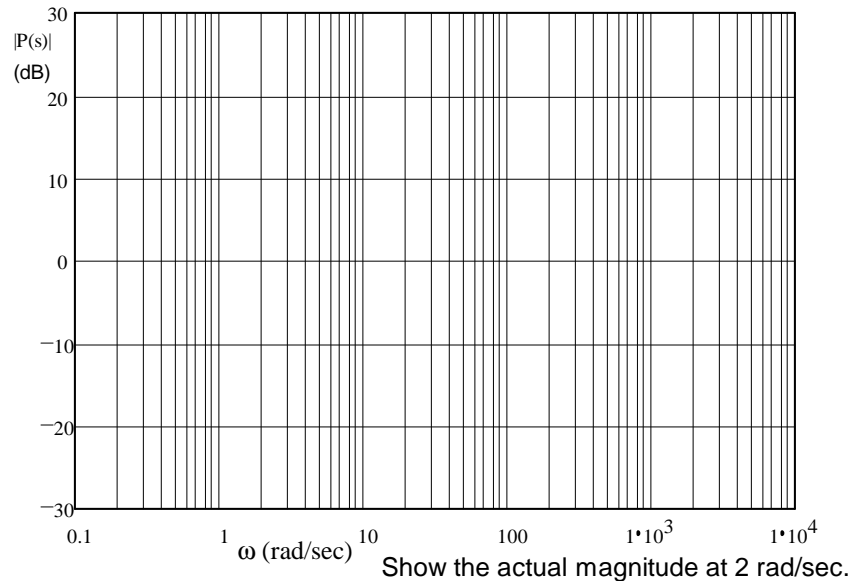


- d) Show the ladder-logic equivalent of the Boolean expression and the logic gates shown below. Let the output, E, be a light.



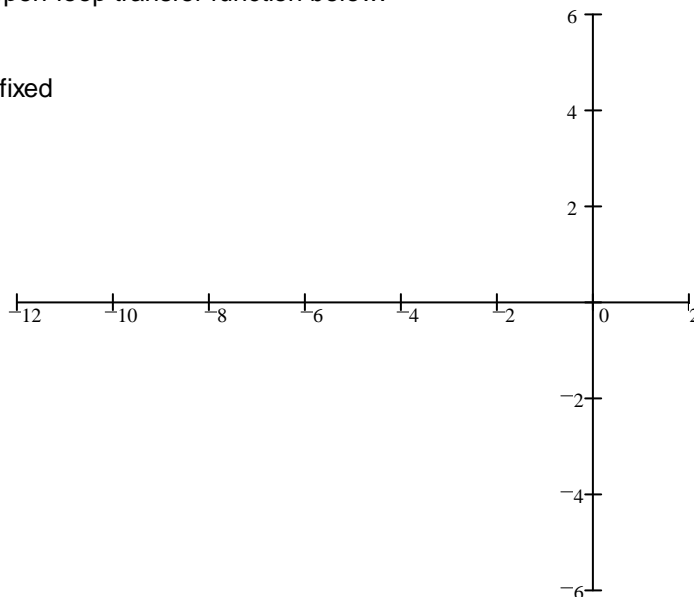
2. (16 pts) Sketch the Bode plot for the following transfer function. Also draw the "smooth" lines. Use the method I showed in class and check you numbers as you go. What is the actual magnitude at 2 rad/sec?

$$P(s) = \frac{500 \cdot s \cdot (s + 40)}{(s + 2)^2 \cdot (s + 1000)}$$



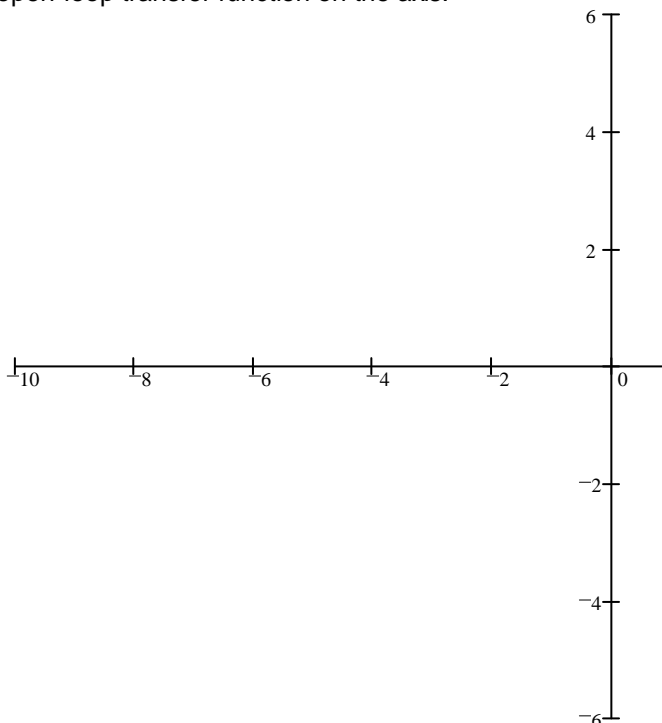
3. (19 pts) Sketch the unconventional root-locus plot for the open-loop transfer function below. The root-locus should be plotted for an increasing  $h$ .

$$G(s) = \frac{k \cdot (s + 38.5)}{(h \cdot s + s - 10) \cdot (s + 6)} \quad k = 2 \text{ and is fixed}$$



- b) Draw an arrow to the place(s) on your root locus where you would like to place the closed-loop poles for minimal ringing and the shortest settling time.
- c) Find the value of  $h$  needed, based on your best reading of your plot above.
4. (19 pts) a) Draw the pole(s) and zero(s) of the following open-loop transfer function on the axis. DON'T draw the root locus lines just yet.

$$G(s) = \frac{s}{(s^2 + 6 \cdot s + 25) \cdot (s + 4) \cdot (s + 8)}$$

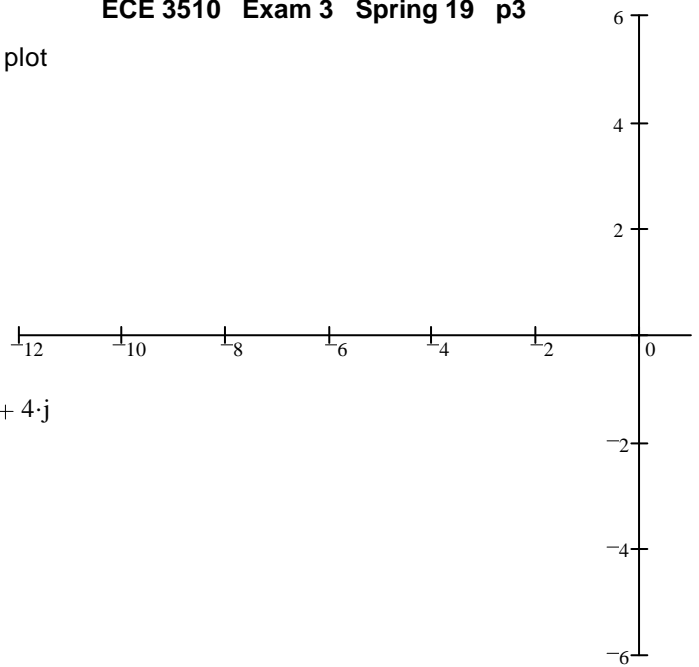


- b) Find the departure angle from one of the complex poles.
- c) Draw a root locus plot. Calculate the centroid and accurately draw the departure angle you found.

5. (36 pts) Consider the transfer function shown.

$$G(s) := \frac{1}{(s+2)(s+6)(s+10)}$$

a) Sketch the root-locus plot

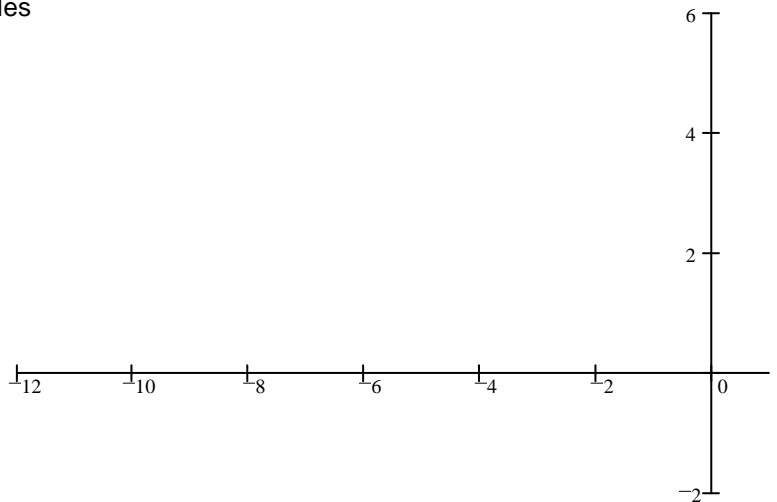


b) Does the root-locus pass through the point  $s := -2.734 + 4 \cdot j$   
 Show your work or state what did in your calculator.

Assuming the closed-loop pole is at  $-2.734 + 4 \cdot j$  leads to the following values (I calculated):

Gain: 174.2    Settling time: 1.463-sec    Overshoot: 11.7%    Steady-state error to a unit-step input: 40.8%

- c) Where should the closed-loop poles be located to decrease the settling time to 0.8 sec and increase the ringing frequency to 5 rad/sec (NOT  $\omega_n$ ) ? (Use the second-order approximation.)
- d) What would be the damping factor of those poles?  $\zeta = ?$
- e) Add a compensator so that the closed-loop poles can be placed at the location found in part c). Use the angle summing method and show your work, esp. the angles that you find.





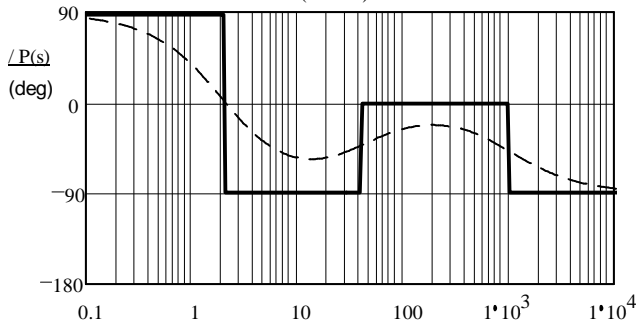
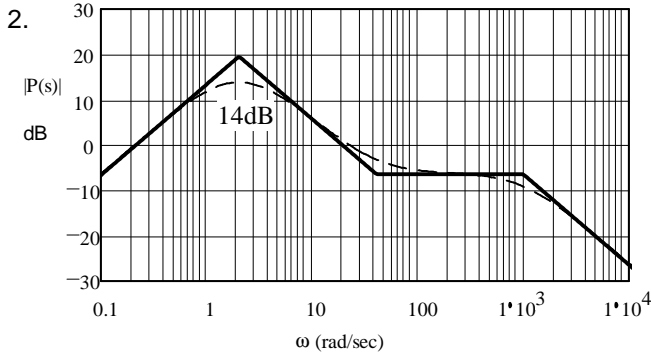
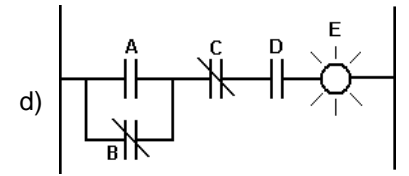
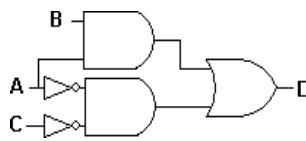
Note: If you can't calculate the zero location or doubt your calculation, assume it is at -8 for the rest of this problem.

- f) With the compensator in place and a closed-loop pole at the desired position of part c)
  - i) What is the gain?
  - ii) What is the % overshoot? Use the second-order approximation.
  - iii) What is the steady-state error to a unit-step input?
- g) Is there still a performance issue that the compensator hasn't significantly improved? If yes how would you improve that? If it is another compensator, give specifics (numbers). Determine if the location from part c) is still close to the RL plot.

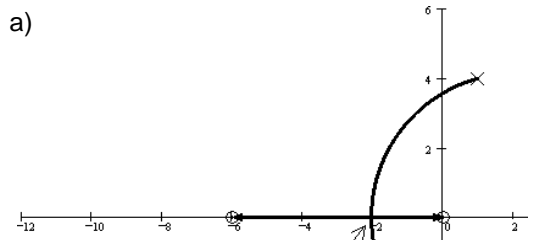
**Answers**

1. a) Electromechanical relays and simple switches

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



3. a)

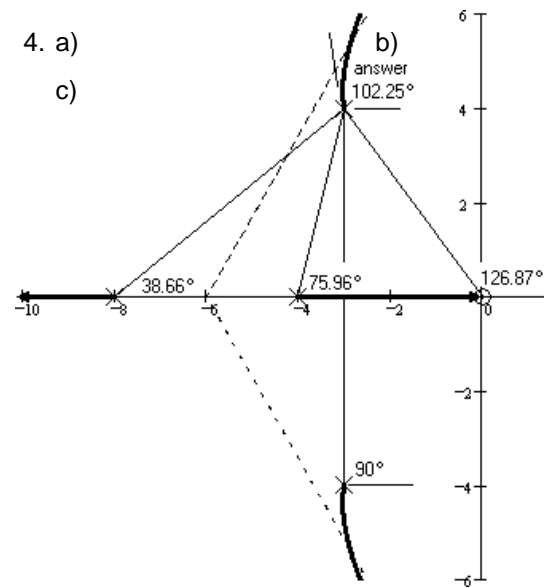


b) Place CL poles here

c) if  $s := -2$   $h := 3.125$

4. a)

c)



5. a)

b) YES

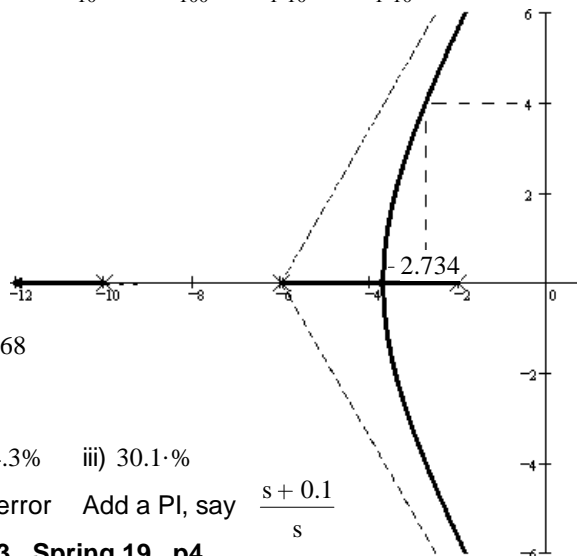
c)  $s := -5 + 5j$

d) 0.707

e)  $C(s) := s + 7.368$

f) i) 38 ii) 4.3% iii) 30.1%

g) Steady-state error Add a PI, say  $\frac{s + 0.1}{s}$



$$\arg \left[ \frac{s + 7.368}{(s + 2) \cdot (s + 6) \cdot (s + 10)} \cdot \frac{s + 0.1}{s} \right] = \text{yes, still close}$$