# ECE 3510 Exam 3 given: Spring 17 (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. (2 pts) You have a feedback system that doesn't work as well as you would like, but you don't know the open-loop transfer function. You've tried adjusting the gain, and have found the best balance of speed and overshoot that you can. Is it likely still possible to improve its performance? What would you use? What might you do?

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

3. (7 pts)   a) What is a PI compensator used for? (2 things)

   b) What other compensator can be used for the same or similar purpose as the PI ?

   c) What is a PD compensator used for?

   d) What other compensator can be used for the same or similar purpose?

4. (15 pts)   a) $\mathbf{G}(s) = $?
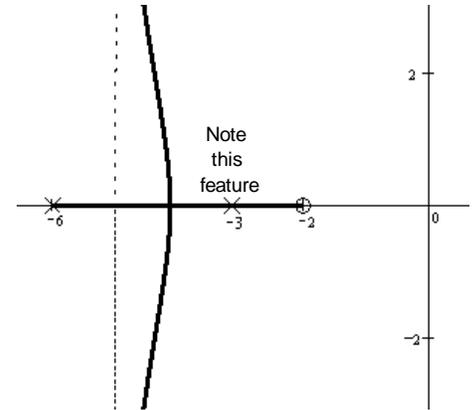
   b) Determine if the break-away point is at -4.5. Show your evidence. I want to see specific calculations and numbers to justify your answer.

   c) The gain required to place a closed loop pole at -4.5 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.

5. (18 pts) a) Draw the pole(s) and zero(s) of the following open-loop transfer function on the axis.

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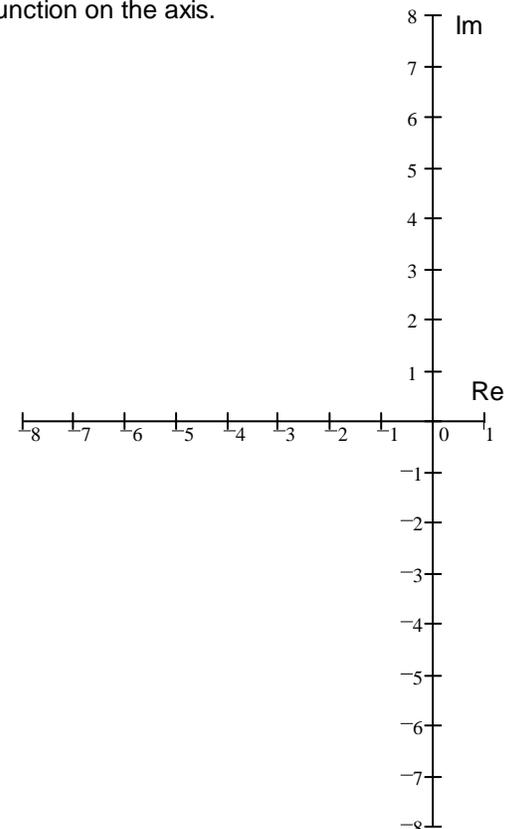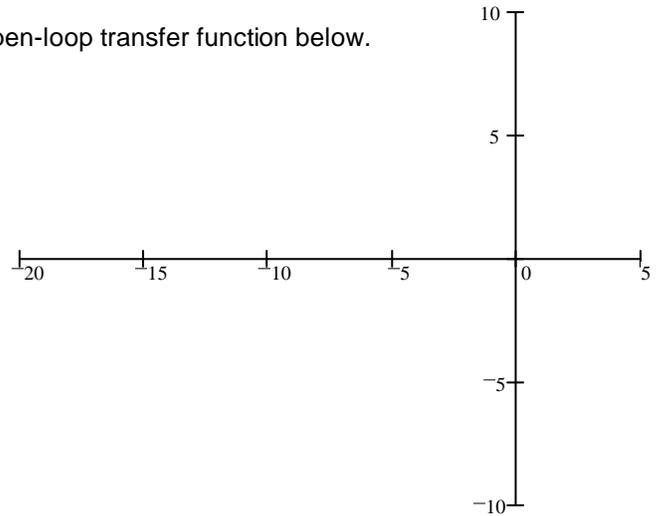

   b) Find the departure angle from one of
      the poles closest to the imaginary axis.

   c) Draw a root locus plot. Calculate the centroid and accurately draw the
      departure angle you found. You may guess on any others.

6. (18 pts) Sketch the unconventional root-locus plot for the open-loop transfer function below.
   The root-locus should be plotted for an increasing a.

$$G(s) = \frac{3 \cdot (s + 2 \cdot a)}{(s + 5) \cdot (s + a)}$$

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 a needed, based on your best reading of your plot above.

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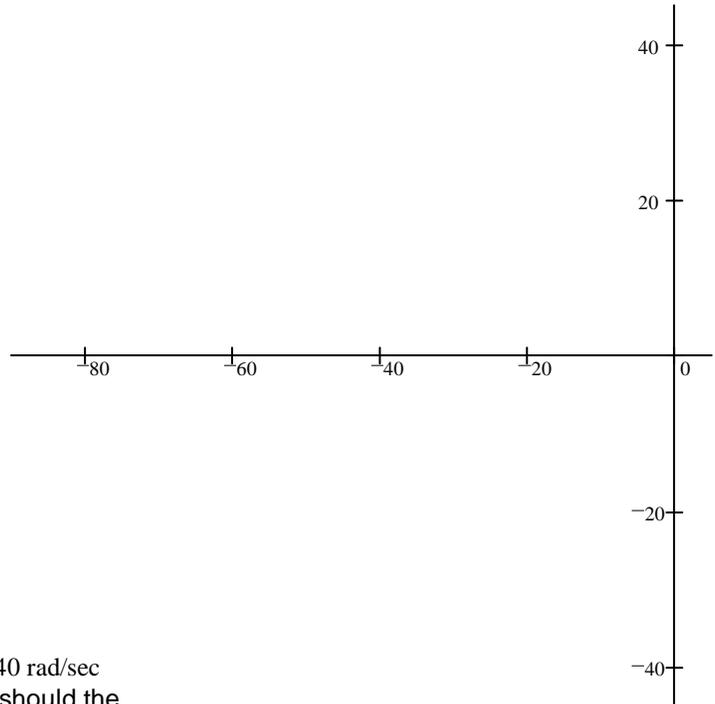   iii) less than the value found in part c).

7. (37 pts) a)   Sketch the root locus plot of,

$$G(s) := \frac{100}{(s + 25) \cdot (s + 40) \cdot (s + 70)}$$

The gain is set at 452, so that one
of the closed-loop poles is at,
   $s := -24.48 + 27.2 \cdot j$

Further calculations yield:
   Settling time: $0.163 \cdot sec$
   % overshoot: $5.92 \cdot \%$
   Steady-state error to a unit-step input: 60.8%

b) You wish to increase the frequency of ringing to 40 rad/sec without changing the % overshoot at all. Where should the closed-loop pole be located?

c) Add a LEAD compensator so that you will be able to place the closed-loop pole at the location found in b).
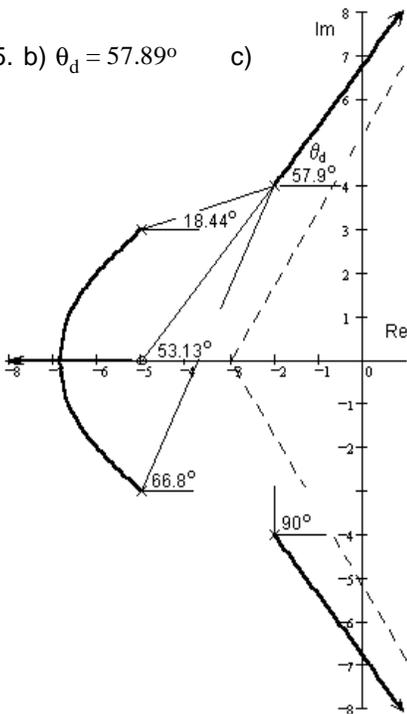   Add the new zero at -30. Find the location of the new pole.

(graph with axes marked 40, 20, 0, −20, −40 vertically; −80, −60, −40, −20, 0 horizontally)
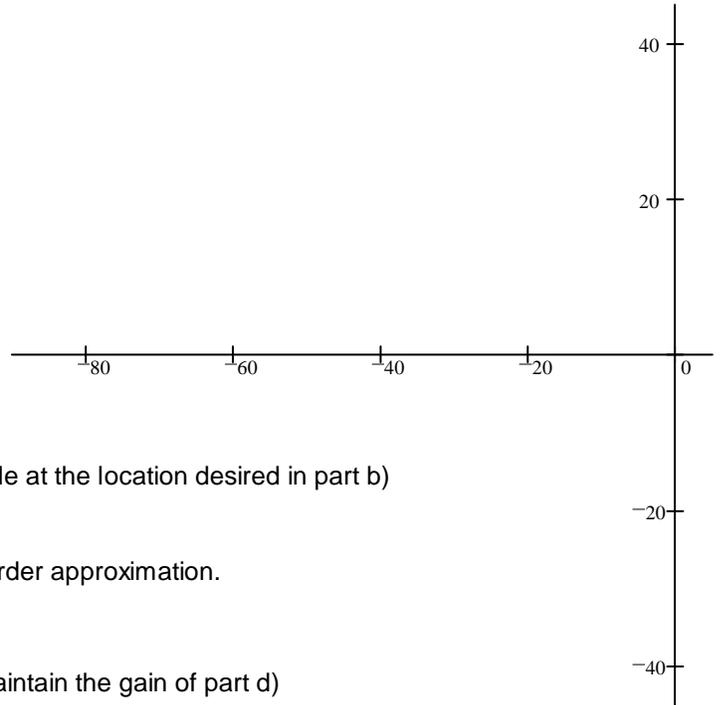
d) With the compensator in place and a closed-loop pole at the location desired in part b)

   i) What is the gain?

   ii) What is the 2% settling time?   Use the second-order approximation.

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

e) Add another compensator: $C_2(s) := \dfrac{s+2}{s}$ and maintain the gain of part d)

   i) What is this type of compensator called and what is its purpose?

   ii) Calculate what you need to to show that this compensator achieved its purpose.

f) With both compensators in place, is there possibility for improvement
(quicker settling time speed and/or lower ringing)? If yes, what would
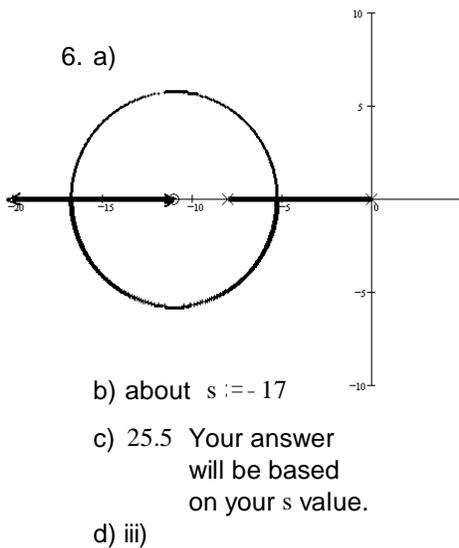be the simplest thing to do? Justify your answer.

Answers

1. Use a PID controller.   Use PID tuning techniques.
2. The summer with + and - , and the gain block
3. a) To eliminate steady-state error and reject disturbances   b) Lag
   c) To increase speed and/or decrease overshoot.   d) Lead
4. a) $\dfrac{s+2}{(s+3)^2 \cdot (s+6)}$ b) NO   c) A

5. b) $\theta_d = 57.89^\circ$ c)

6. a)

   b) about $s := -17$

   c) 25.5 Your answer
        will be based
        on your s value.

   d) iii)

7. a)
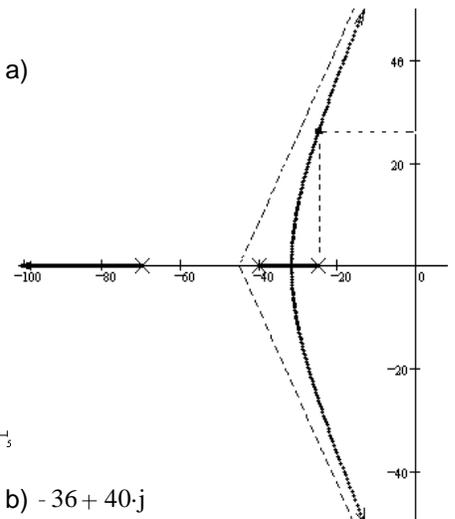
   b) $-36 + 40 \cdot j$

   c) $G_c(s) := \dfrac{100 \cdot (s+30)}{(s+25) \cdot (s+40) \cdot (s+70) \cdot (s+85)}$

   d) i) 1369   ii) $0.111 \cdot \sec$ iii) $59.2 \cdot \%$

   e) i) PI, used to eliminate steady-state error

      ii) $e_{step} = 0 \cdot \%$

   f) A quick sketch of the new root-locus
      shows that simply decreasing the
      gain would improve the system