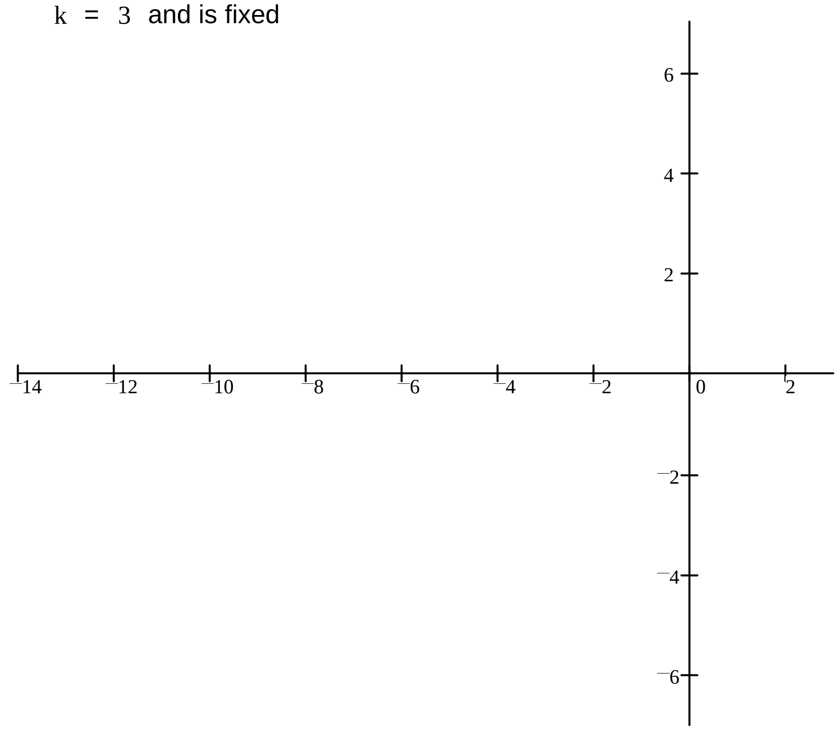
# ECE 3510 Exam 3 given: Spring 21

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

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

$$G(s) = k \cdot \frac{(s + 32 \cdot n)}{(s + n \cdot (s + 20)) \cdot s} \qquad k = 3 \text{ and is fixed}$$



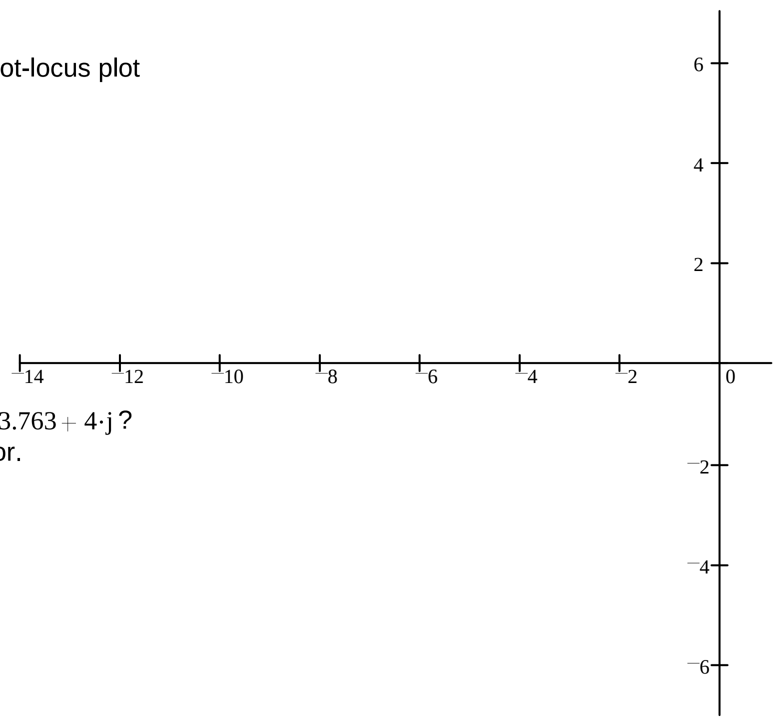

   b) Draw an arrow to the place(s) on your root locus where you would like to place the closed-loop poles for minimal (or no) ringing and the shortest settling time.

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

2. (40 pts) Consider the transfer function shown.

$$\mathbf{G}(s) := \frac{s + 8}{(s + 1) \cdot (s + 5) \cdot (s + 12)}$$

   a) Sketch the root-locus plot




   b) Does the root-locus pass through the point $s := -3.763 + 4 \cdot j$ ?
   Show your work or state what did in your calculator.

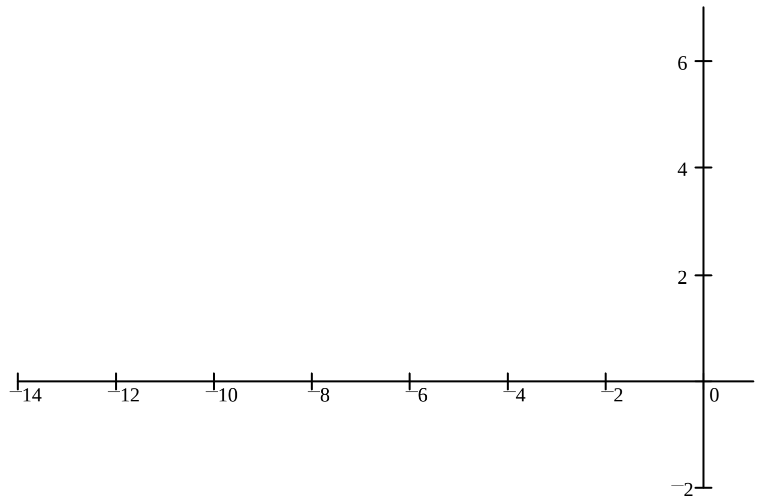
   Assuming the closed-loop pole is at $-3.763 + 4 \cdot$ leads to the following values (I calculated):

   Gain: $32$ Settling time: $1.063 \cdot \text{sec}$ Steady-state error to a unit-step input: $19.1\%$

c) Where should the closed-loop poles be located to decrease the settling time to 0.8 sec and without changing the ringing frequency at all? (Use the second-order approximation.)

d) What would be the damping factor of those poles?

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 -14 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?

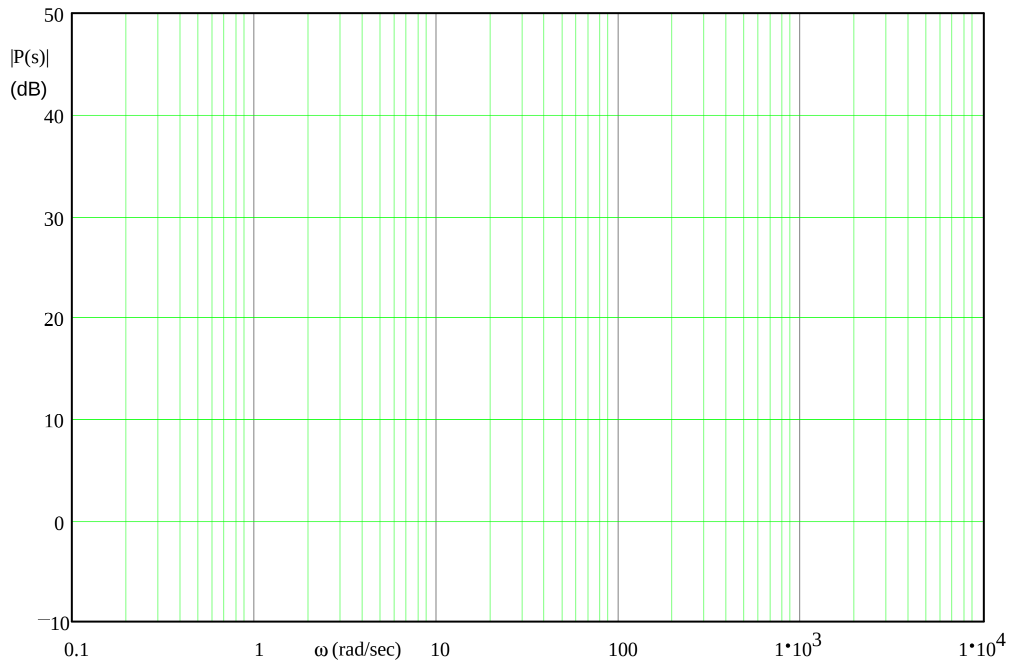
ii) What is the % overshoot? Use the second-order approximation.

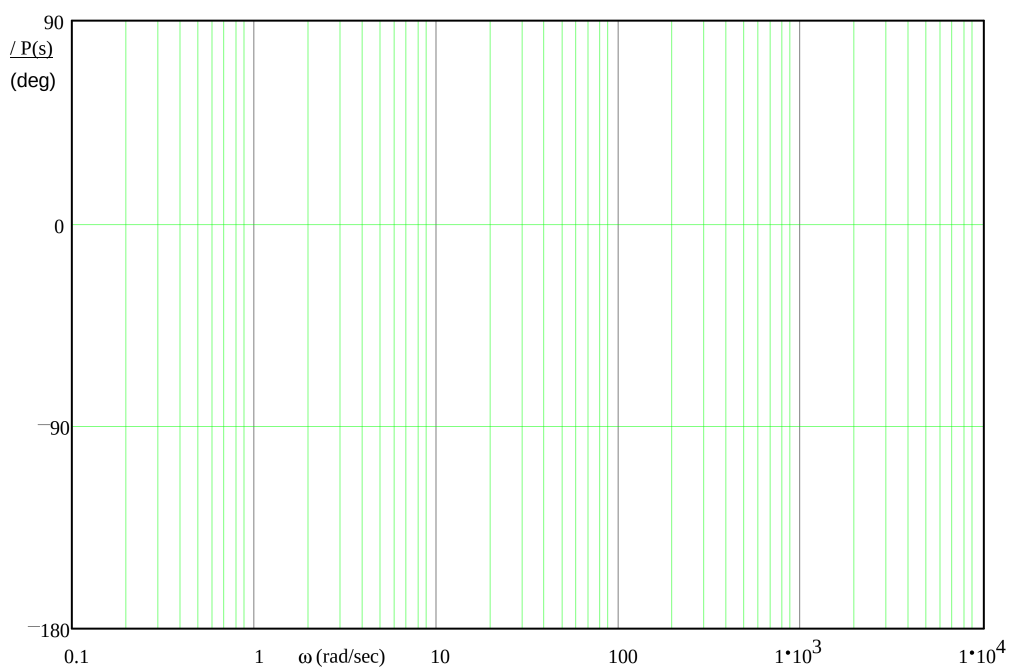
iii) What is the steady-state error to a unit-step input?

g) What is the simplest way to improve the steady-state error to a unit-step input (below 2%)? If it is another compensator, give specifics (numbers). Determine if the location from part c) is still close to the RL plot. Justify your answer.

3. (32 pts) Sketch the Bode plots for the following transfer functions. Use plots provided or legible semilog paper. Use the method I taught in class to find magnitudes, slopes and angles and to check yourself. Also draw the "smooth" lines.

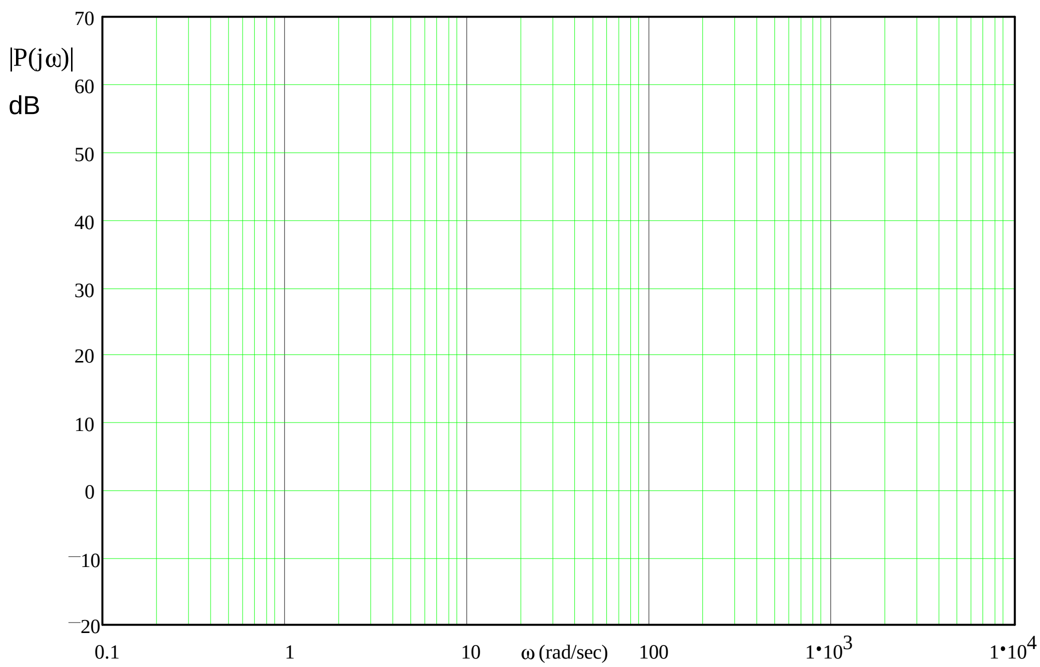
a) $P(s) = \dfrac{s\cdot(s+3000)}{(s+4)\cdot(s+200)}$

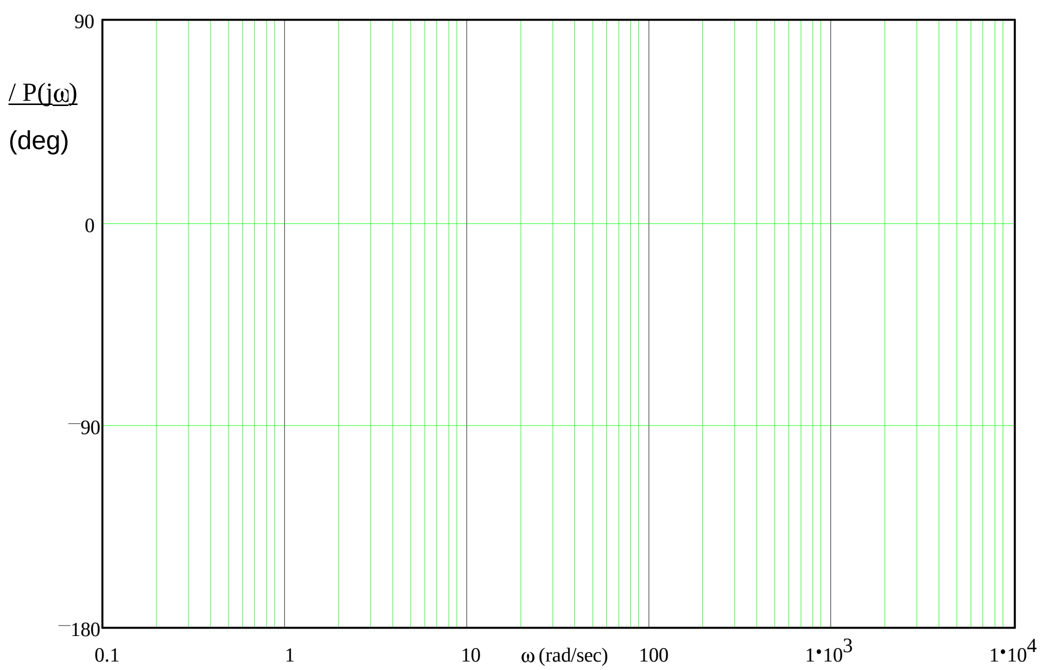


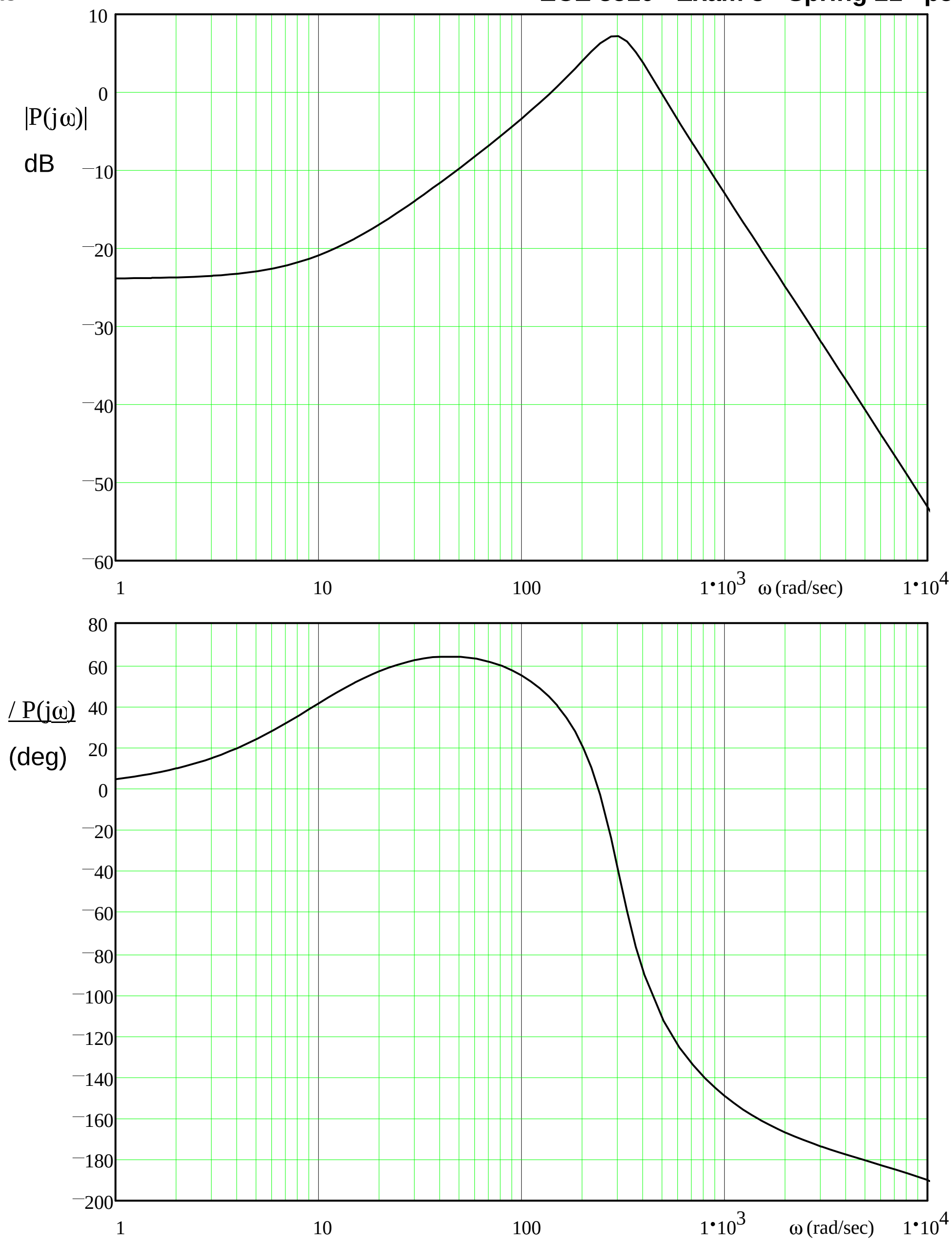
3. continued

b) $P(s) = \dfrac{(s^2 + 6\cdot s + 900)}{s\cdot(s+4)}$



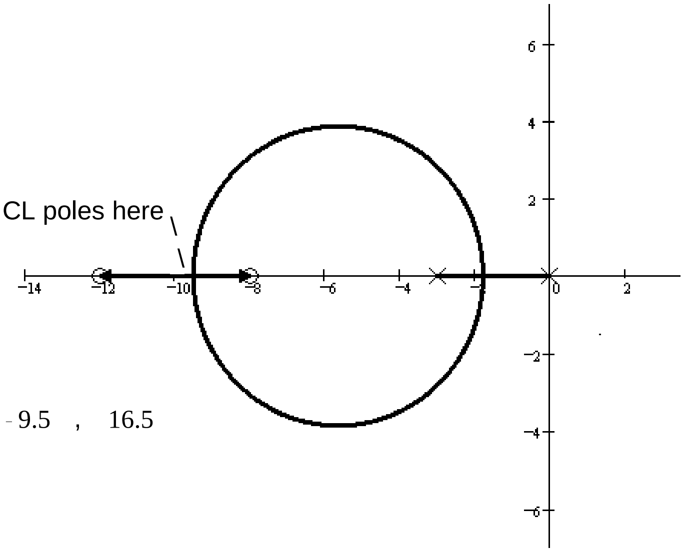
4. (10 pts) The open-loop Bode plots of a system are given at right.
   a) Find the gain margin and phase margin of the closed-loop system. Show your work on the drawings.




   b) Find the delay margin.

## Answers

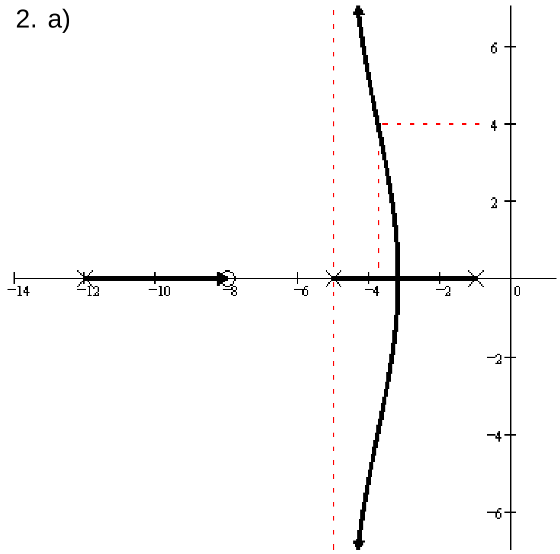
1. a)



b) Place CL poles here

c) if $s = -9.5$ , 16.5

2. a)



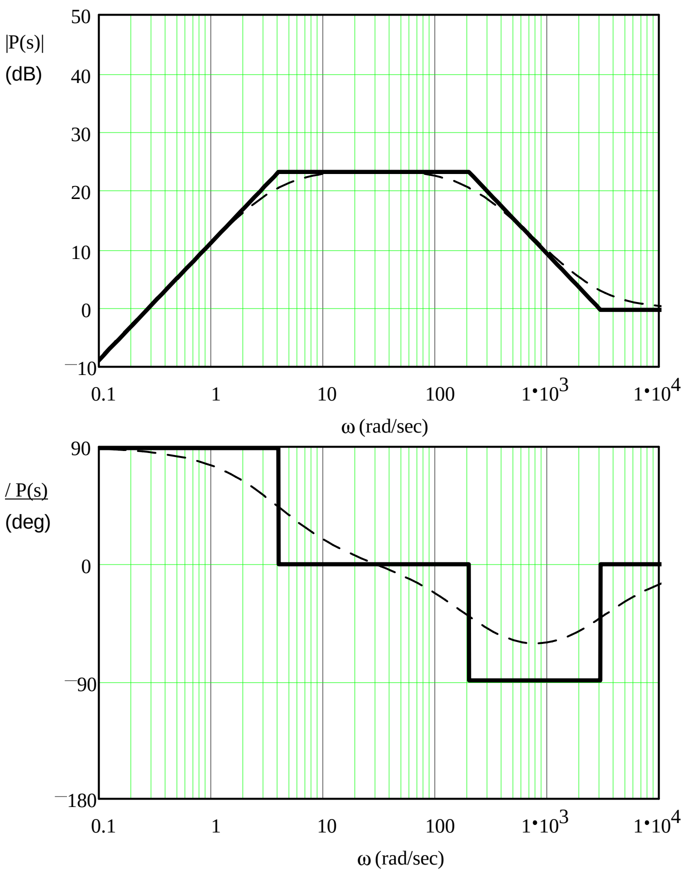
b) YES      c) $s = -5 + 4 \cdot j$      d) 0.781

e) $C(s) = s + 15.095$

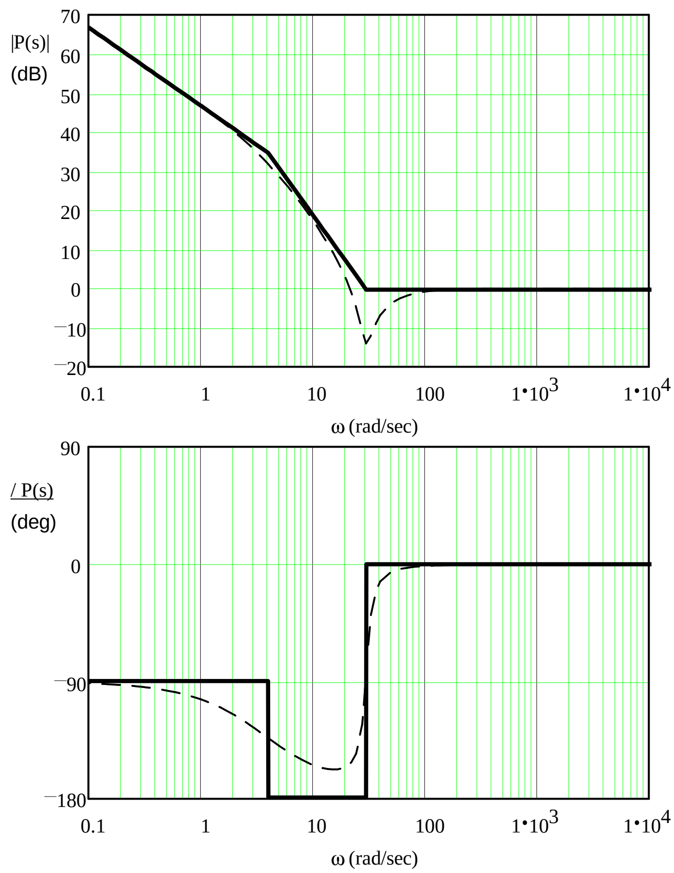
f) i) 3.36      ii) $1.97 \cdot \%$      iii) $12.9 \cdot \%$

g) Just increase the gain

3. a)




b)




4. a) $41 \cdot dB$      $68 \cdot deg$      b) $2.4 \cdot ms$