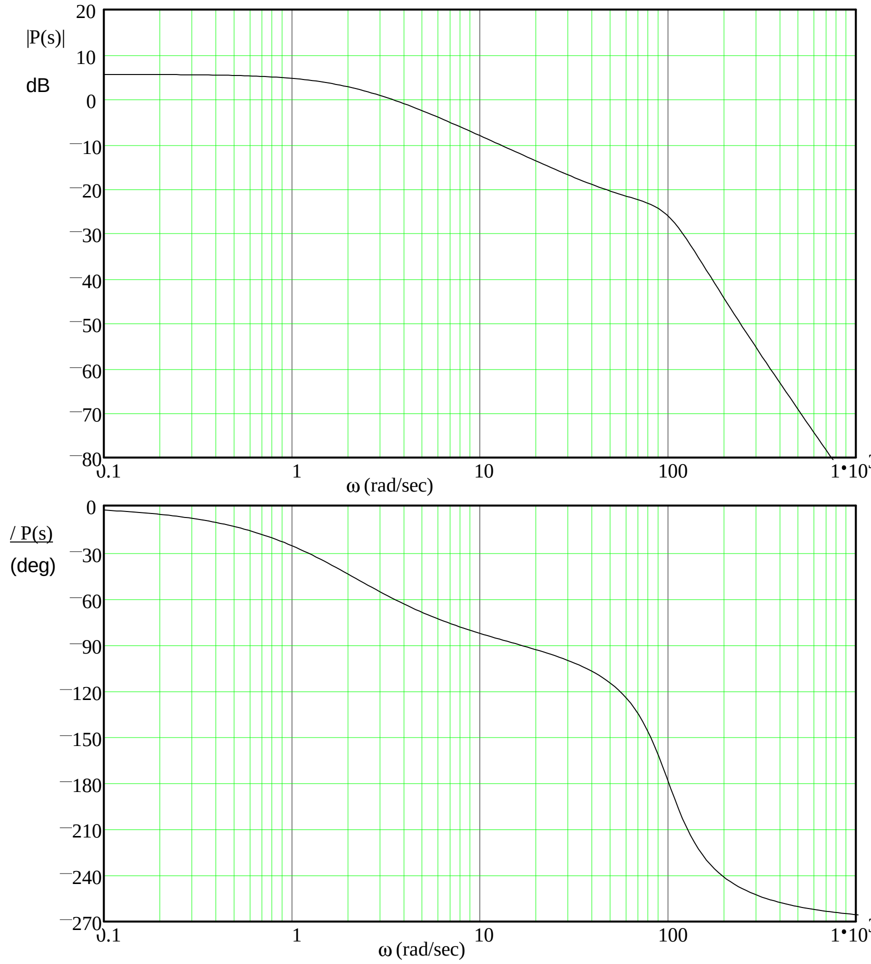
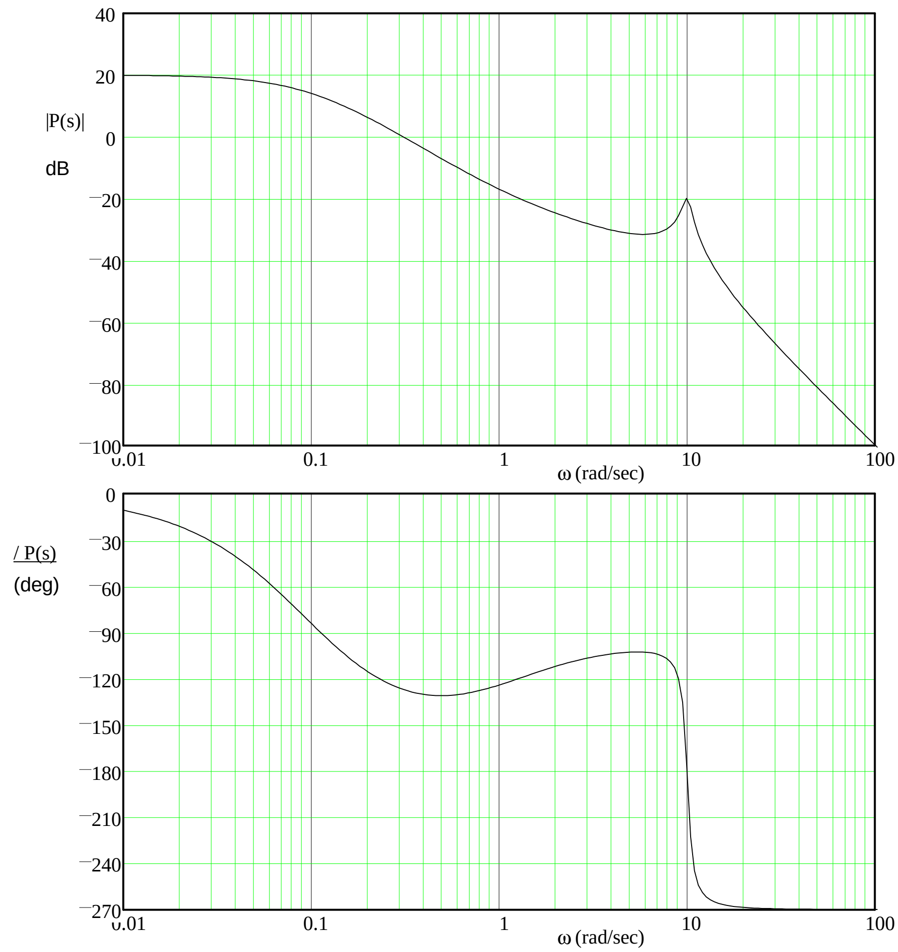
Name_______________________ ECE 3510 Homework Bd4 Due: Sat, 4/13/24 d

1. The system whose Bode plots are given at right is stable in closed-loop. Find its gain margin, phase margin, and delay margin. Show your work on the drawings.



2. Problem 5.3 in the text.

a) The system whose Bode plots are given at left is stable in closed-loop. Find its gain, phase, and delay margins. Show your work on the drawings.



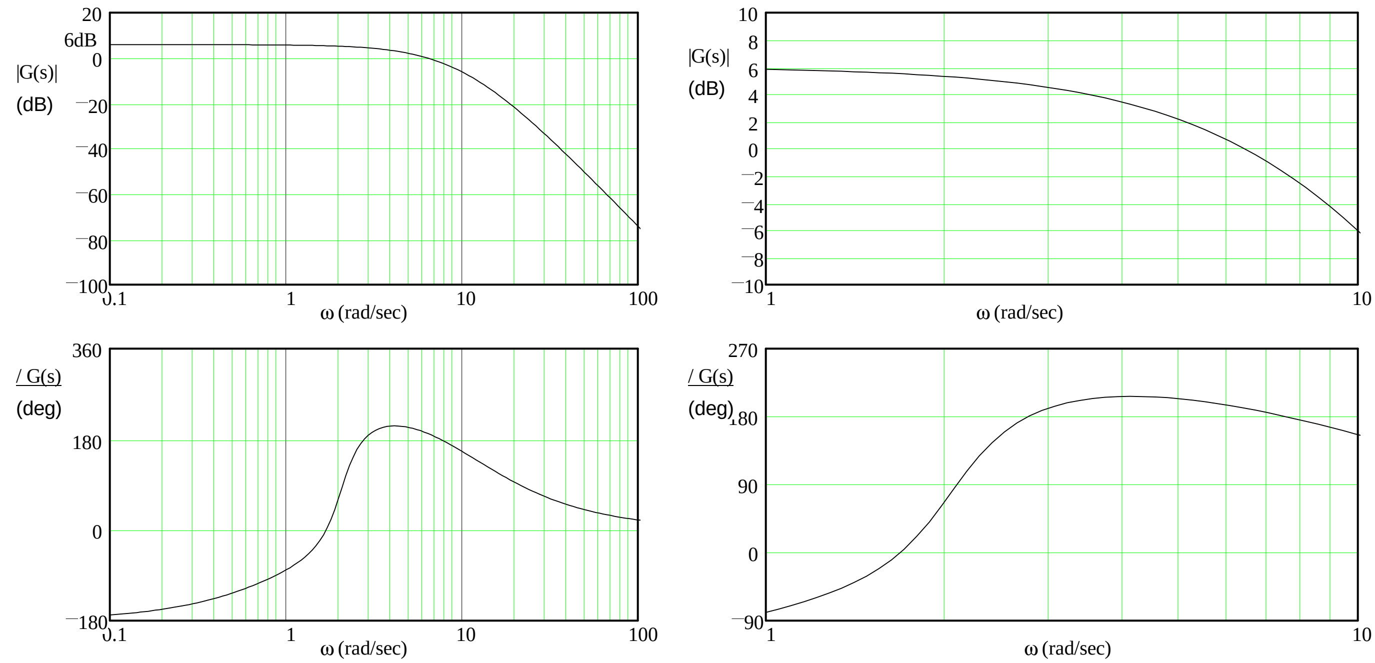
b) Describe the behavior of the closed-loop system of part (a) if the open-loop gain is increased to a value close to the maximum value given by the gain margin. In particular, what can you say about the locations of the poles of the closed-loop system?

c) Consider an open-loop stable system which is such that the magnitude of its frequency response, including the gain factor k, is less than 1 for all ω ($|kG(s)| < 1$). Can you determine whether the closed-loop system is stable with only that information? If yes, show how.

3. Problem 5.13 b & new c & d (p.149) in the text.

b) Bode plots of the open-loop transfer function of a feedback system are shown below, with the detail from 1 to 10 rad/sec shown on the left. For this system:

- How much can the open-loop gain be changed (increased and/or decreased) before the closed-loop system becomes unstable ?
- What is a rough estimate of the phase margin of the feedback system? Show on the graph how the results are obtained. The numerical results do not have to be precise.
- How much time delay can there be in feedback system before the phase margin disappears.



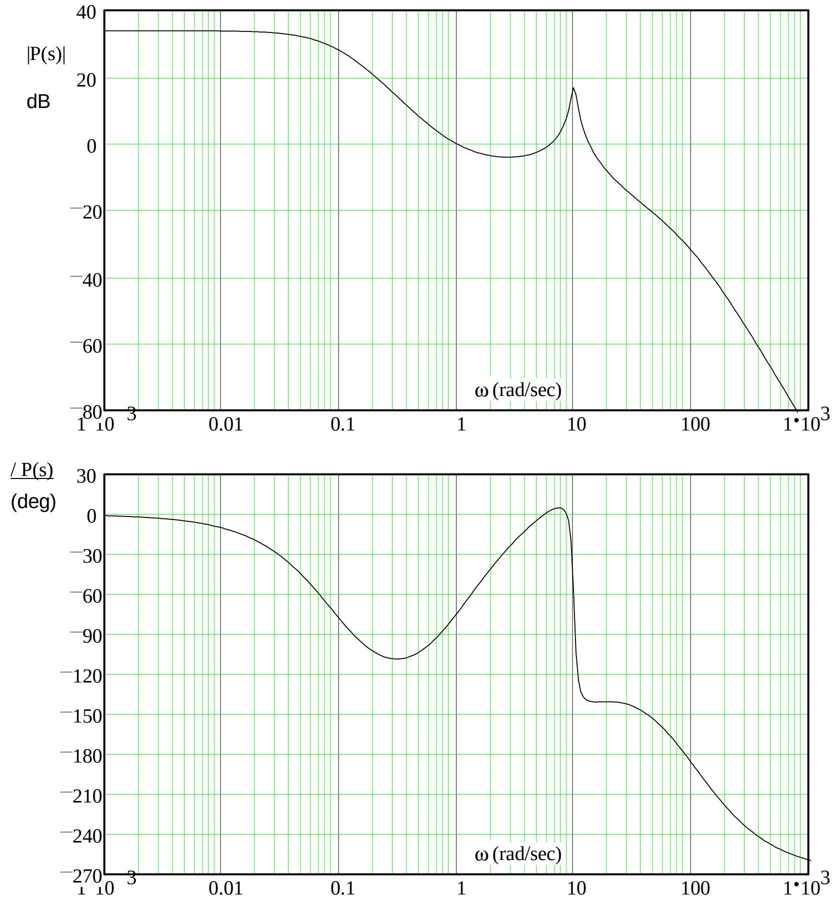
c) For the system of part (a), give the steady-state response of the open-loop system an input $x(t) = 4\cos(10t)$. express the answer in the time-domain.

d) Give the steady-state response of the closed-loop system for the same input. Hint: closed loop output is: $\text{input}\cdot\dfrac{G(10\cdot j)}{1+G(10\cdot j)}$

ECE 3510 homework Bd4 p4

4. Like problem 5.9a (p.147) in the Bodson text.

   a) Give the gain margin, the phase margin and the delay margin of the system whose Bode plots are shown at right (the plots are for the open-loop transfer function and the closed-loop transfer function is assumed to be stable).



Answers

1. GM ~ 25·dB PM ~ 120·deg DM := 600·ms

2. a) GM ~ 21·dB PM ~ 50·deg DM := 2.6·sec

   b) The system will have a transient ring at about 10 rad/sec. Two poles of the closed loop system will be close to ± 10j.

   c) Yes, it must be stable. Prove by closed-loop transfer function, Bode gain margin or Nyquist: N=0, P=0, Z=0

3. b) Gain may be increased by ~ 2dB and reduced by ~ 4.4dB. PM ~ 13·deg DM ~ 36·ms

   c) $2 \cdot \cos(10 \cdot t + 158 \cdot deg)$ d) $3.5 \cdot \cos(10 \cdot t + 140 \cdot deg)$

4. a) GM ~ 30·dB PM ~ 40·deg DM ~ 50·ms

5. a) 3.6·deg 36·deg 360·deg 3600·deg b) 0.573·deg 5.73·deg 57.3·deg 573·deg

6. a) A straight line of negative slope, ωD, where D is the time delay.

   b) A negative sloping line with a slope of ωD. Since the frequency increases by a factor of 10 each decade, so would the downward slope of the line.

7. Any system with mass where a force is the input and position is the "output". $F = m \cdot a = m \cdot \frac{d^2}{dt^2} x$

ECE 3510 homework Bd4 p5

5. A system has a delay of $D := 0.01 \cdot sec$ How many degrees of phase does this represent at:

a) $f := 1 \cdot Hz$

$f := 10 \cdot Hz$

$f := 100 \cdot Hz$

$f := 1 \cdot kHz$

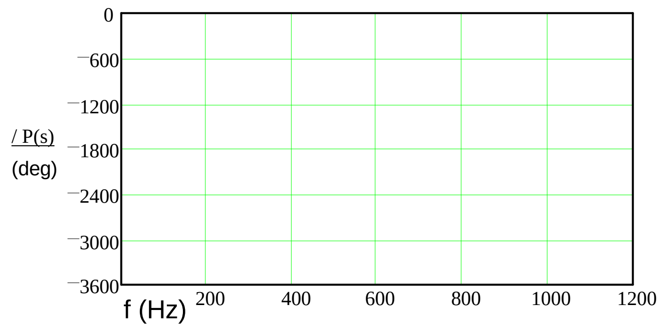
b) $\omega := 1 \cdot \frac{rad}{sec}$

$\omega := 10 \cdot \frac{rad}{sec}$

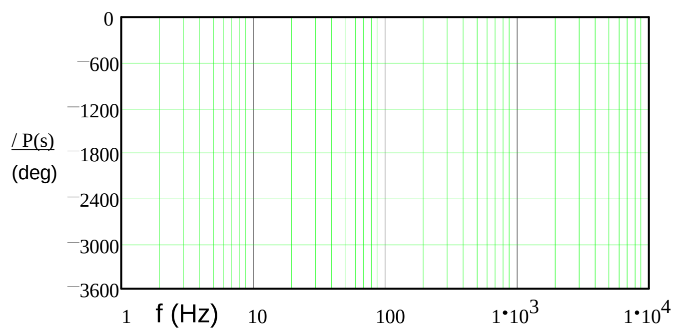
$\omega := 100 \cdot \frac{rad}{sec}$

$\omega := 1000 \cdot \frac{rad}{sec}$

6. a) If the phase response of a pure time delay were plotted on linear phase vs. linear frequency plot, what would be the shape of the curve?



b) If the phase response of a pure time delay were plotted on linear phase vs. logarithmic frequency plot, what would be the shape of the curve?



7. In section 5.3.9 of Bodson's book, he discusses using a lead controller to stabilize a system (plant) represented by a double integrator. Give two or more examples of real systems that are essentially double integrators.