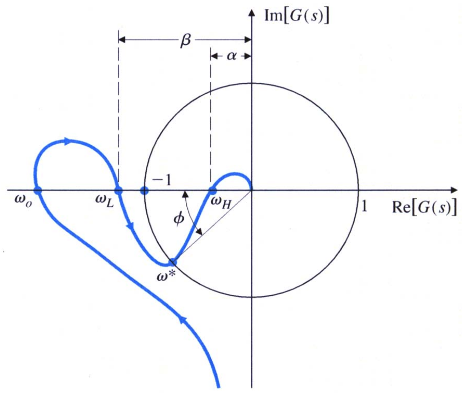
Control Systems : Set 7 : Loopshaping (3)

Prob 1 | The Nyquist plot of an open-loop stable system resembles the one shown in the figure below. What are the gain and phase margin(s) for this system given that $\alpha = 0.4$, $\beta = 1.3$ and $\phi = 40°$? Describe what happens to the stability of the system as the gain goes from zero to a very large value. Sketch what the corresponding Bode plot would look like for the system.



Note: What is shown in the figure is only half of the Nyquist plot from $\omega = 0$ to $\omega = \infty$ (i.e., the part that corresponds to the Bode diagram). The full nyquist plot also contains the range $\omega = -\infty$ to $\omega = 0$. However, since the coefficients of the polynomials in our system $G(s)$ are always real numbers, the segment from $[0, \infty]$ will always be a reflection across the real axis of the segment from $[-\infty, 0]$.

Prob 2 | The steering dynamics of a ship are represented by the transfer function

$$\frac{V(s)}{\delta_r(s)} = G(s) = \frac{K(0.1s + 1)}{s(0.5s + 1)^2(0.05s + 1)}$$

where v is the ship's velocity in meters per second and δ_r is the rudder angle in radians.

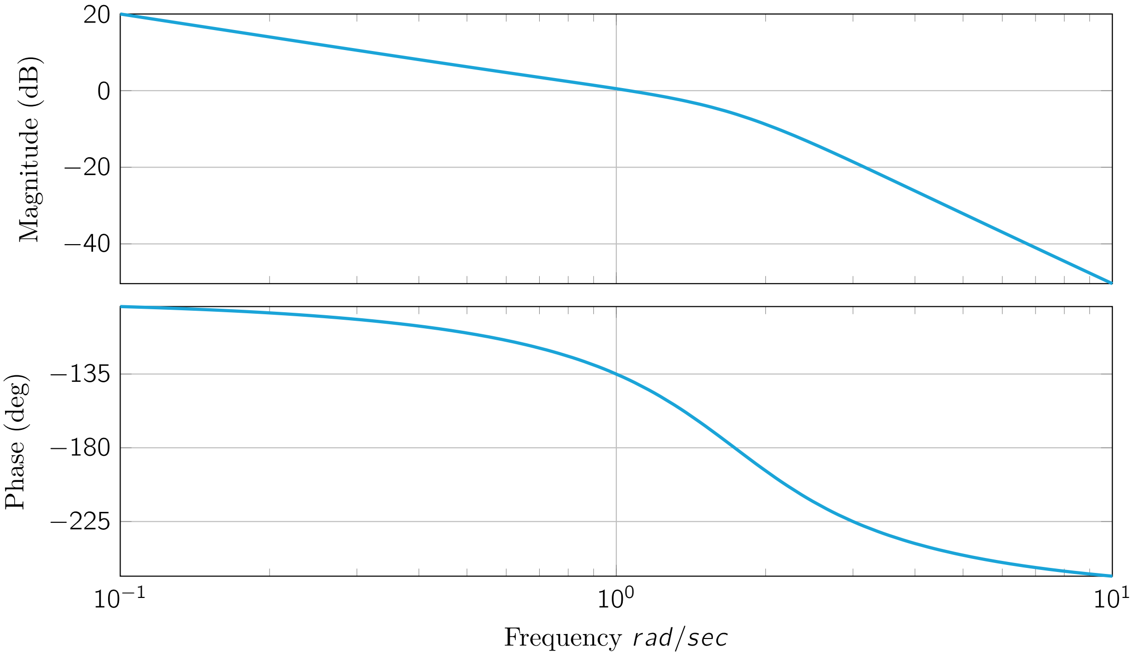
a) Use Matlab to generate the Bode plot for $K = 0.2$

b) Indicate the phase margin and the gain margin on the plot

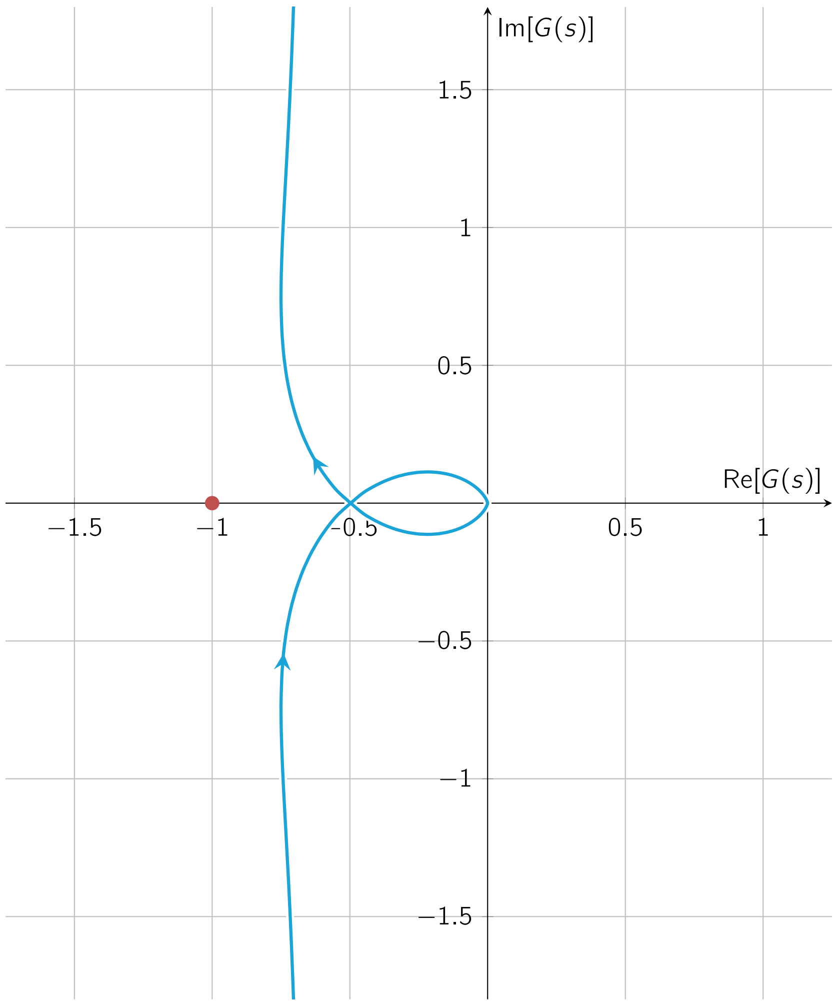
c) Is the ship steering system stable for $K = 0.5$

d) What value of K would yield a PM of $30°$ and what would the crossover frequency be?

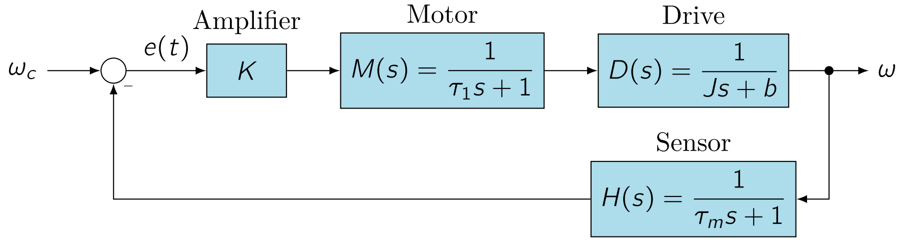
Prob 3 | Consider the Bode plot and the Nyquist plot for the system $G(s)$ below.
Show how the ultimate period (the period of oscillation for Ziegler-Nichols tuning) and the ultimate gain (the gain at which the system oscillates) can be read from the Bode plot and from the Nyquist plot.



20
0
−20
−40
Magnitude (dB)
−135
−180
−225
Phase (deg)
10^{-1}
10^{0}
10^{1}
Frequency rad/sec

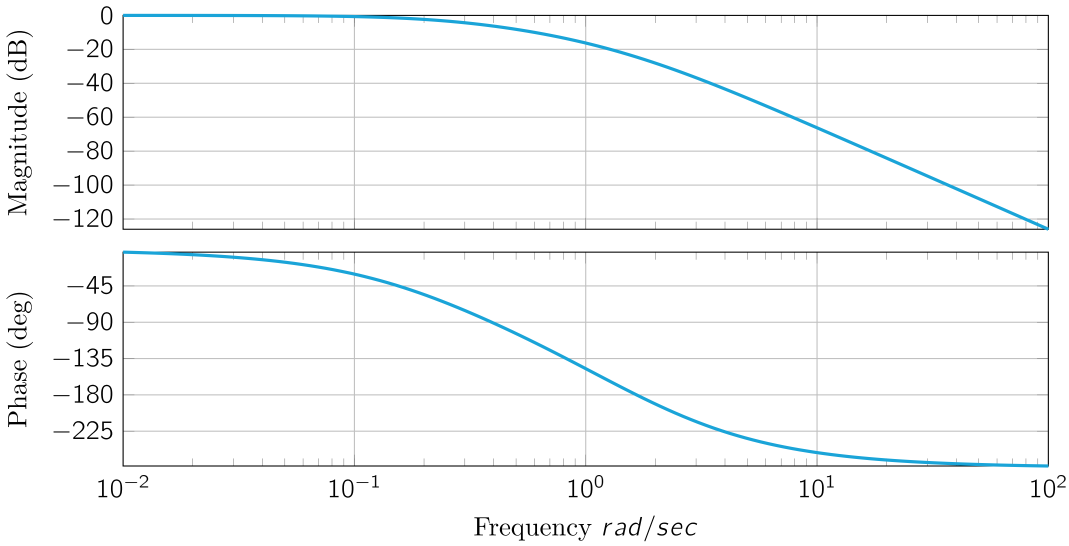


Prob 4 | A speed control system is shown in the figure below. Note that the speed sensor is slow enough that its dynamics mush be included, since the speed-measurement time constant is $\tau_m = 0.5sec$. The time constant of the drive being controlled is $\tau_r = J/b = 4sec$, where the damping constant $b = 1N \cdot m \cdot sec$ and the motor time constant is $\tau_1 = 1sec$.

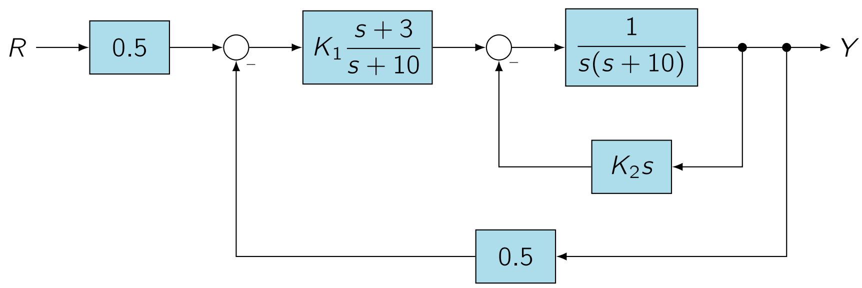


a) Determine the gain K required to keep the steady-state speed error to less than 7% of the reference speed setting

b) Consider the bode plot of the open-loop system $M(s)D(s)H(s)$ show below. Determine the gain and phase margins for the value of K determined above. Is a proportional controller a good design for this system?



Prob 5 | A block diagram of a control system is shown in the figure below.



a) What is the system type?

b) If R is a step input and the system is closed-loop stable, what is the steady-state tracking error?

c) What is the steady-state error to a ramp input of velocity 5.0 if $K_2 = 2$ and K_1 is adjusted to give a system step overshoot of 17%? Use Matlab and the step command to determine the value of K_1.