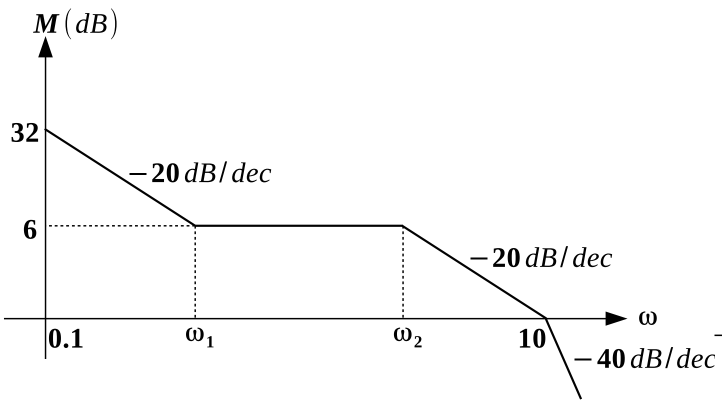
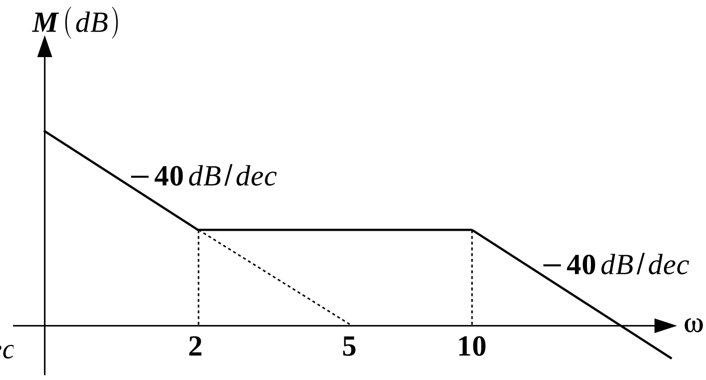
Tutorial & Homework #10 Due: 12 November 2018

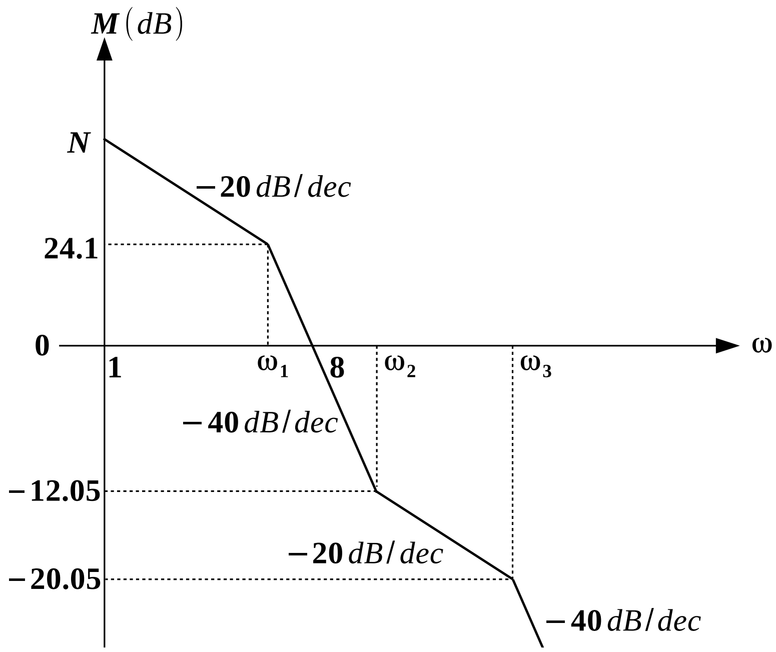
1. Sketch the Bode plot for the following transfer functions:
   a) $G(s) = \frac{10(s+5)^2}{(s+0.1)(s+2)(s+10)}$
   b) $G(s) = \frac{e^{-s}}{1+s}$
   c) $G(s) = \frac{50(s-8)}{s^2+6s+8}$
   d) $G(s) = \frac{1}{s^3(s-1)}$
   e) $G(s) = \frac{10(s^2+0.4s+1)}{s(s^2+0.8s+9)}$
2. Reconstruct the minimumphase transfer function for the following log-magnitude Bode plots.



(a)



(b)



(c)

3. The frequency response of an unknown plant is illustrated in figure 7 in the form of a Bode plot. Provide a mathematical description, denoted by $G(s)$, of the plant. Is the plant a minimum-phase system? Consider the unity feedback system with plant described $G(s)$. Sketch the Nyquist plot and comment on the closed loop stability using the Nyquist criterion. Calculate the crossover frequencies and the corresponding stability margins using the Nyquist plot. Calculate also the crossover frequencies and the corresponding stability margins from Bode plot, and compare the results. Calculate the appropriate steady state error constant.

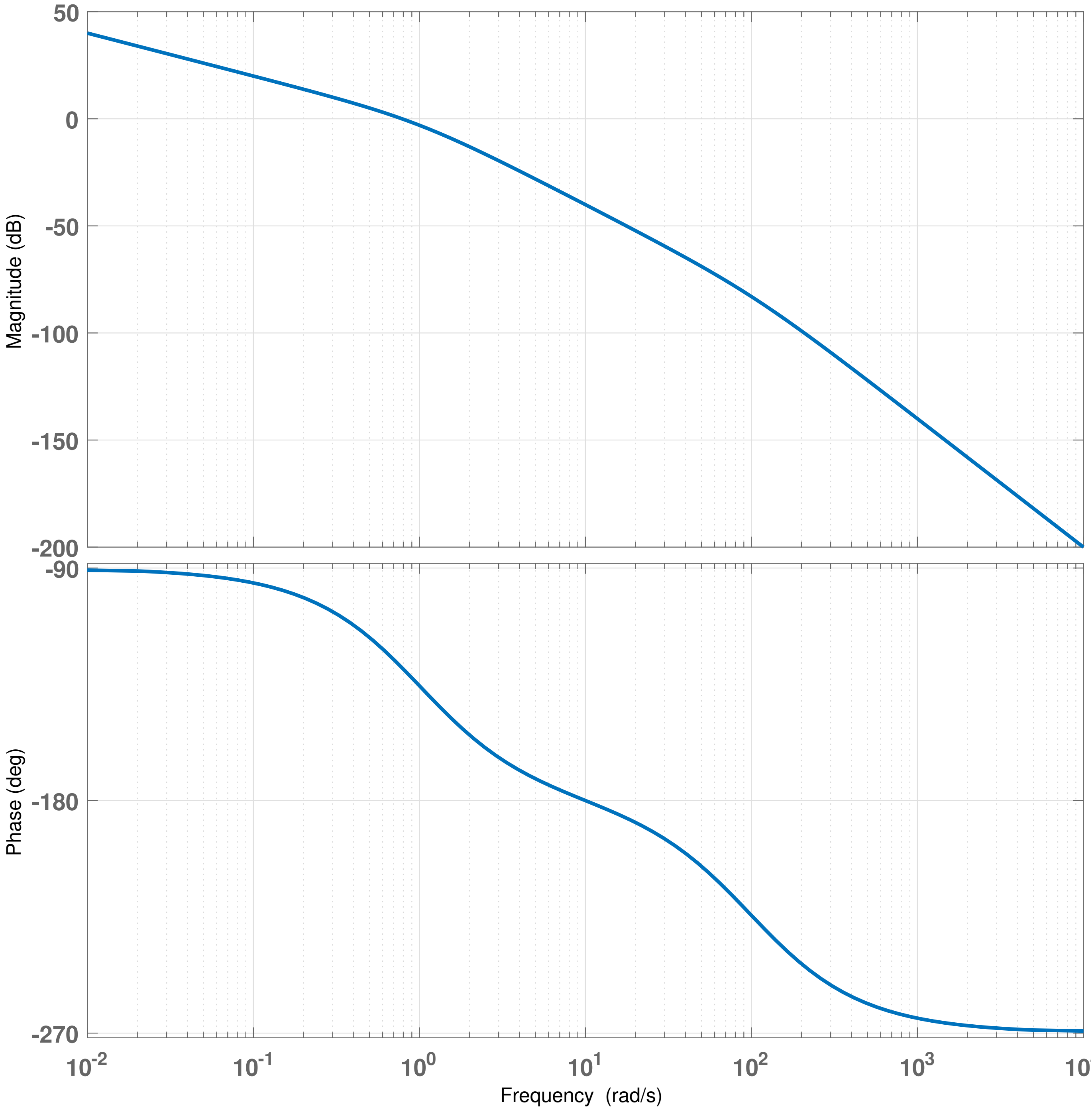


Figure 2: Frequency response of an unknown plant

4. Repeat problem (3) for the frequency response shown in figure 8

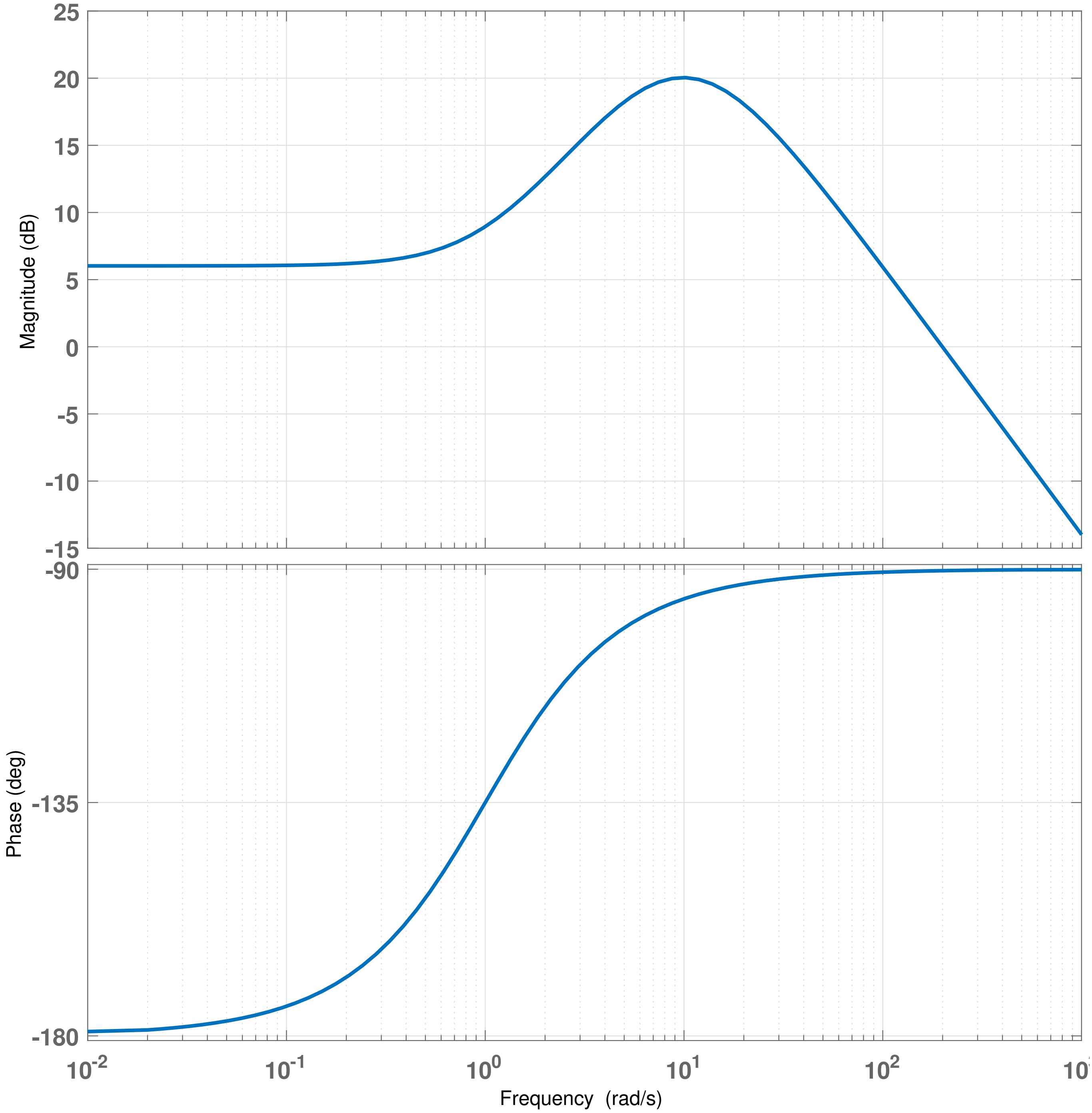


Figure 3: Frequency response of an unknown plant

5. The frequency response of a closed loop system is shown in figure 4. Calculate ζ, ω_n, bandwidth, ω_r (resonant frequency), and the resonant peak M_r.

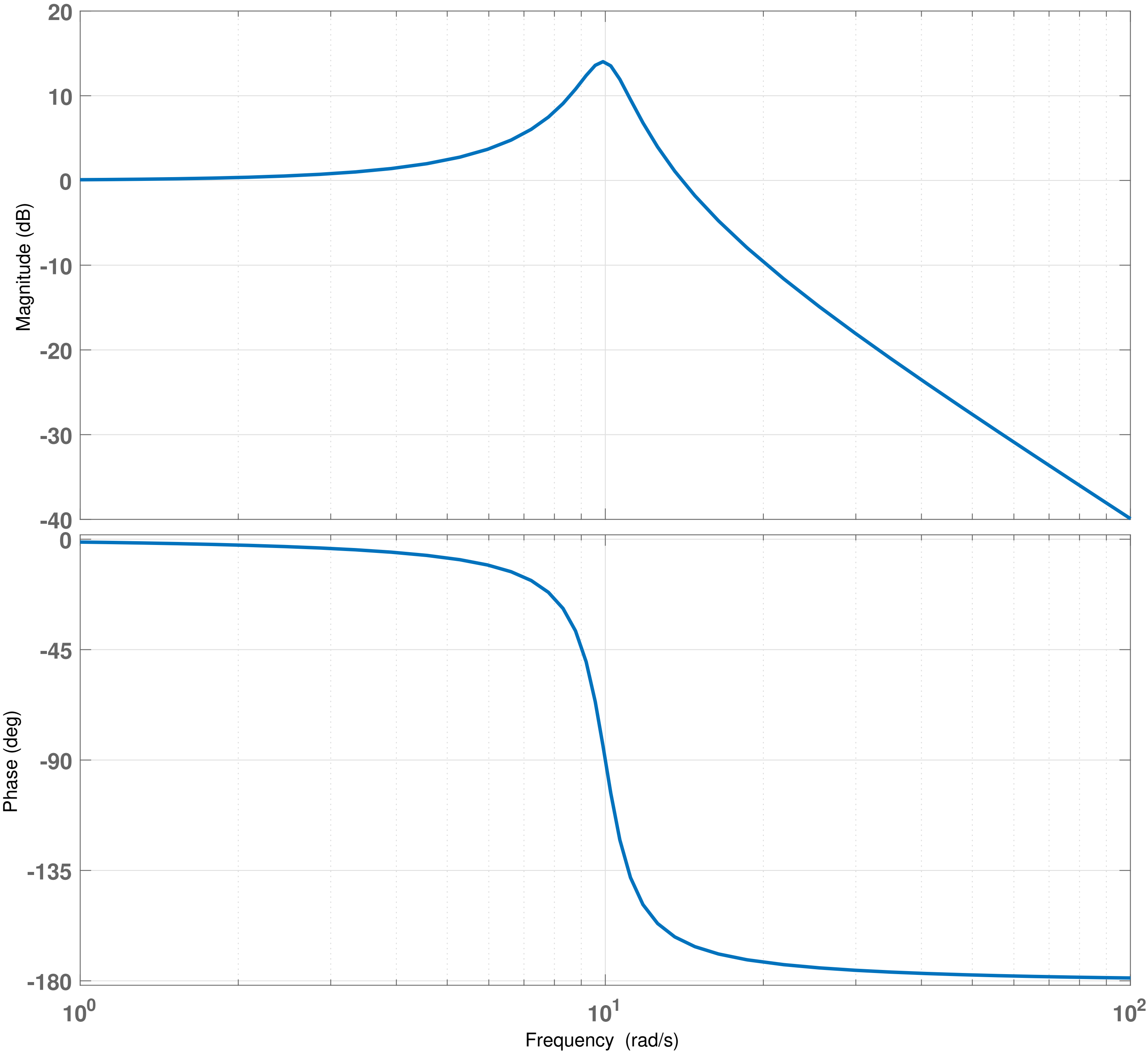


Figure 4: Frequency response of an unknown plant

6. Figure 5 illustrates the frequency response of unknown systems. Verify if the system is minimum phase or not. Justify your answer.

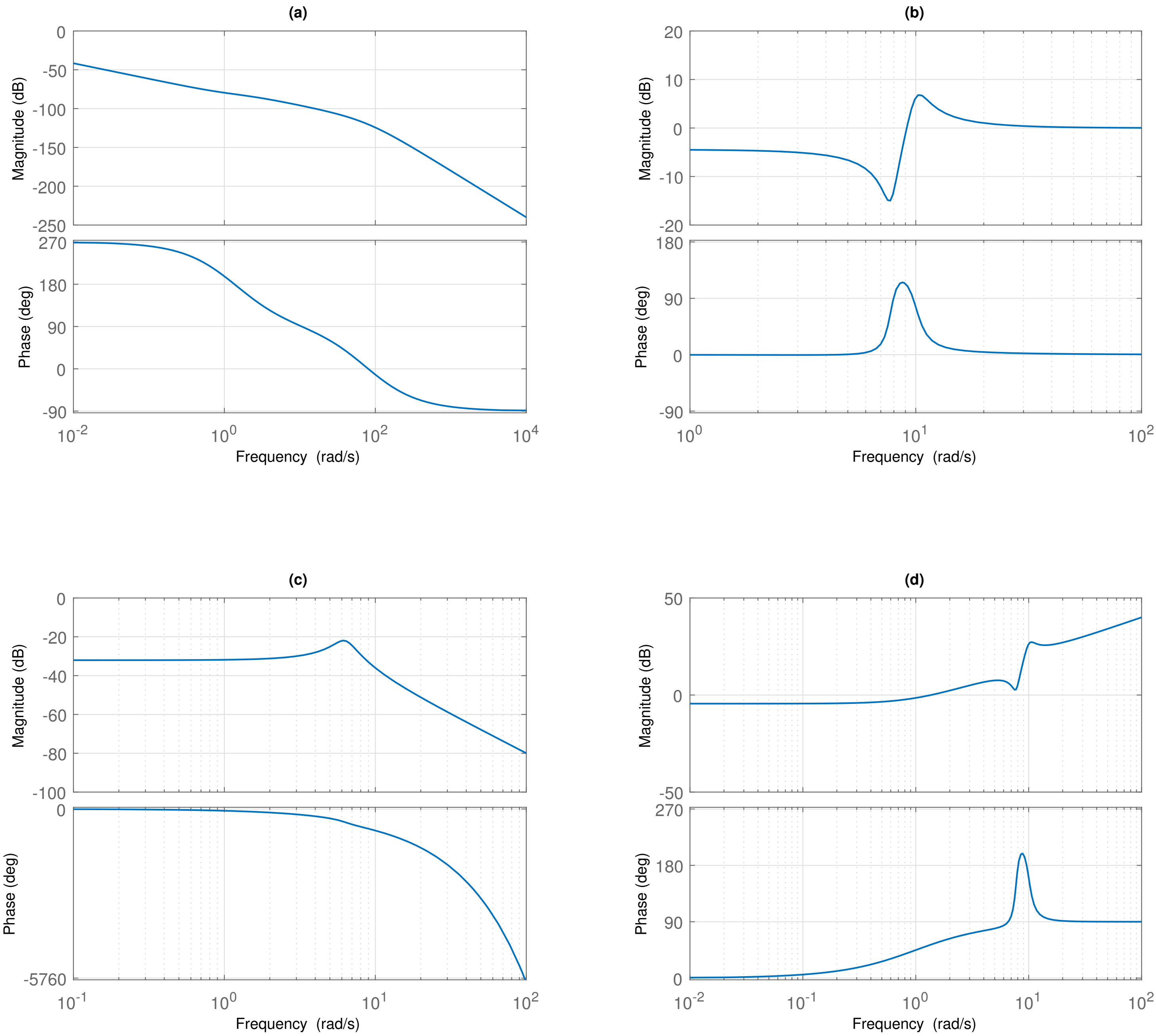


Figure 5: Frequency response of an unknown plants

Note: Use matlab `bode` function for the design problems in the tutorial. Please include relevant bode plots with appropriate labels and calculations while submitting the homework solutions.

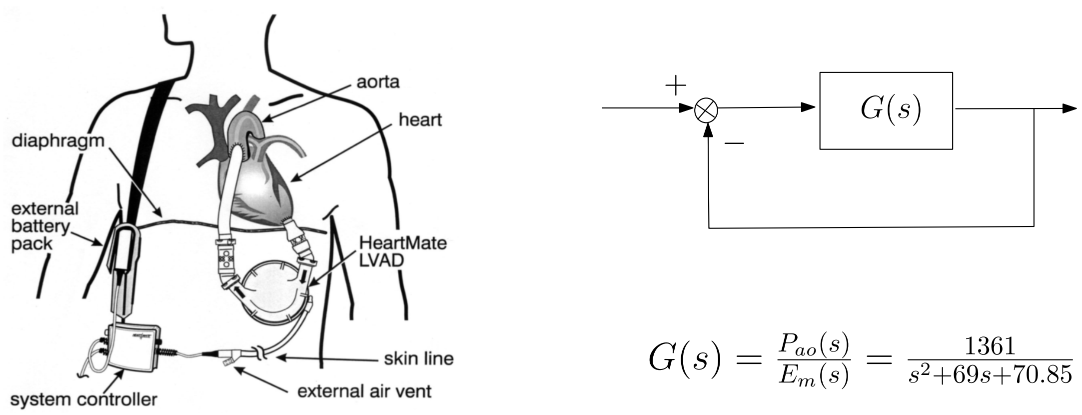
7. Determine the value of gain, K, in the unity feedback system for the following systems
   a) $G(s) = \frac{K}{(s+4)(s+10)(s+15)}$ for gain margin 10 dB
   b) $G(s) = \frac{K}{s(s+4)(s+10)}$ for phase margin $40°$
   c) $G(s) = \frac{K(s+2)}{s(s+4)(s+6)(s+10)}$ for gain crossover frequency $\omega_{\text{gc}} = 1$ rad/sec
   d) $G(s) = \frac{Ke^{-0.6s}}{s(s+20)}$ for phase margin $40°$

8. Consider a unity feedback closed loop system with $G(s) = \frac{K}{s(0.1s+1)(s+1)}$. Design a lead compensator such that phase margin is $45°$, gain margin not less than 8dB, and the static velocity error constant K_v is 4 sec^{-1}. Plot unit step and unit ramp response curves of the compensated system.

9. Consider a unity feedback closed loop system with $G(s) = \frac{K(s+7)}{s(s+5)(s+15)}$. Design a lead compensator for the following performance specifications: 15% overshoot, settling time = 0.1 second, and $K_v = 1000$. Plot unit step and unit ramp response curves of the compensated system.

10. Consider a unity feedback closed loop system with $G(s) = \frac{K(s+10)(s+11)}{s(s+3)(s+6)(s+9)}$. Design a lag compensator for the following performance specifications: 15% overshoot for step input and $K_v = 1000$. Plot unit step and unit ramp response curves of the compensated system.

11. An electric ventricular assist device (EVAD) that helps pump blood concurrently to a defective natural heart in sick patient can be shown to have a transfer function $G(s)$; see figure 6. The

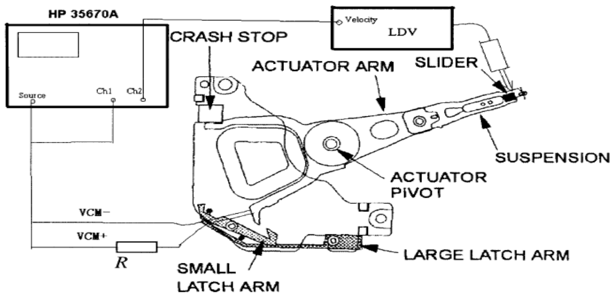


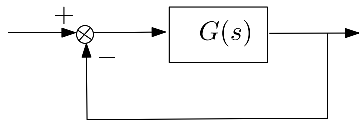
$$G(s) = \frac{P_{ao}(s)}{E_m(s)} = \frac{1361}{s^2+69s+70.85}$$

Figure 6: Control of EVAD system

input, $E_m(s)$, is the motor's armature voltage, and the output is $P_{ao}(s)$, the aortic blood pressure. The EVAD will be controlled in the closed loop configuration shown in figure 6. Design a phase lag compensator to achieve a tenfold improvement in the steady state error to step inputs without appreciably affecting the transient response of the uncompensated system. Plot unit step response curves of the compensated system.

12. The transfer function from applied force to arm displacement for the arm of a hard disk drive has been identified as $G(s)$, see figure 7. The position of the arm will be controlled using the unity feedback gain system. Design a lead compensator to achieve closed loop stability with a transient response of 16% overshoot and a settling time of 2 milli seconds for a step input. Plot unit step response curves of the compensated system.

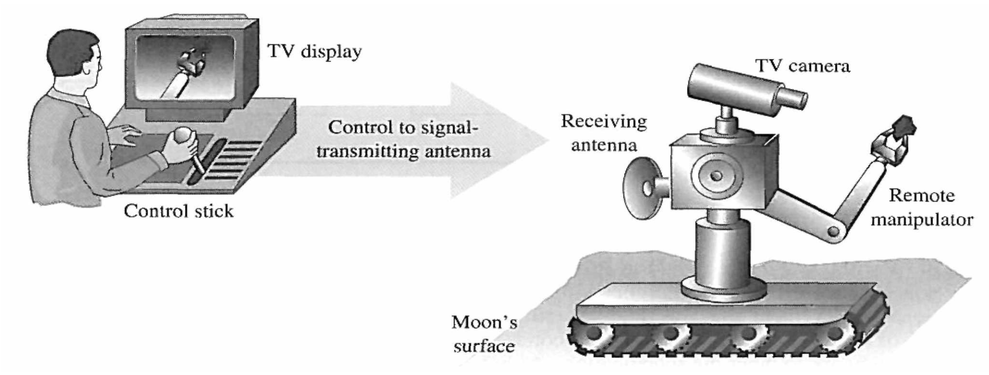




$$G(s) = \frac{10^5}{3s^2}$$

Figure 7: Control of hard disk drive arm

13. ISRO is developing remote manipulators that can be used to extend the hand and the power of humankind through space by means of radio. A concept of a remote manipulator and the associated closed loop schematic is shown in Figure 8. Assuming an average distance of $382,168$ kilometers from Earth to the Moon, the time delay T in transmission of a communication signal is 1.28 seconds. The operator uses a control stick to control remotely the manipulator placed on the Moon to assist in geological experiments, and the TV display to access the response of the manipulator. The time constant of the manipulator is $\tau = 0.25$ seconds.



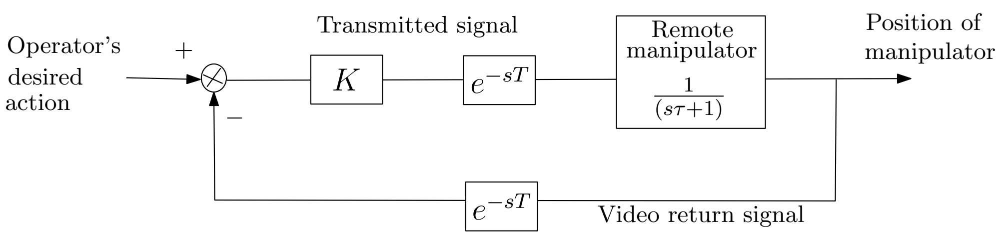


Figure 8: Control of remote robot manipulator

a) Set the gain K so that the system has a phase margin of approximately $30°$. Evaluate the percentage steady-state error for this system for a step input.

b) To reduce the steady-state error for a position command input to 5% and to achieve a phase margin of approximately $50°$ add a lag compensation network in cascade with K. Plot the step response.