YTU ELECTRICAL & ELECTRONICS FACULTY
DEPARTMENT OF CONTROL & AUTOMATION ENGINEERING
KOM3712 CONTROL SYSTEMS DESIGN, Sections 1 & 2, Homework-2

Student number:	**Section:**
Name and Surname:	**Signature:**
Announced: April 16, 2020	**Due:** April 26, 2020, 23:59

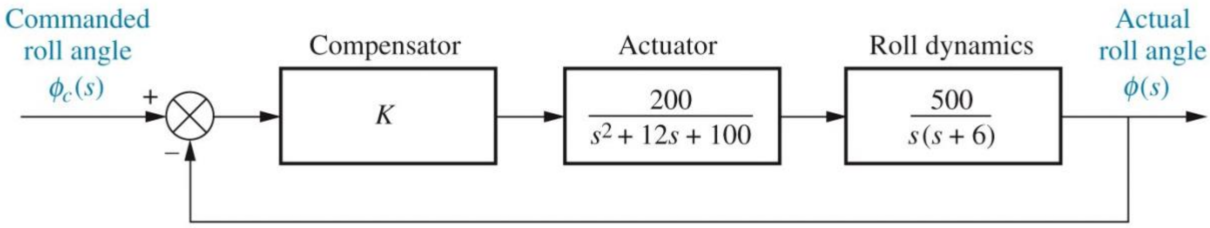
Print out this file if you can, otherwise use blank sheets. Use your hand writing and drawings. Use also MATLAB for Bode and step response plots and other computations for validation purpose. Add extra sheets for each problem and number them logically like 1-1, 1-2, 2-1, 2-2.... Send your converted-to-pdf files to **odevyl.ytu@gmail.com** *with the subject containing your number, name, surname and HW-2.*

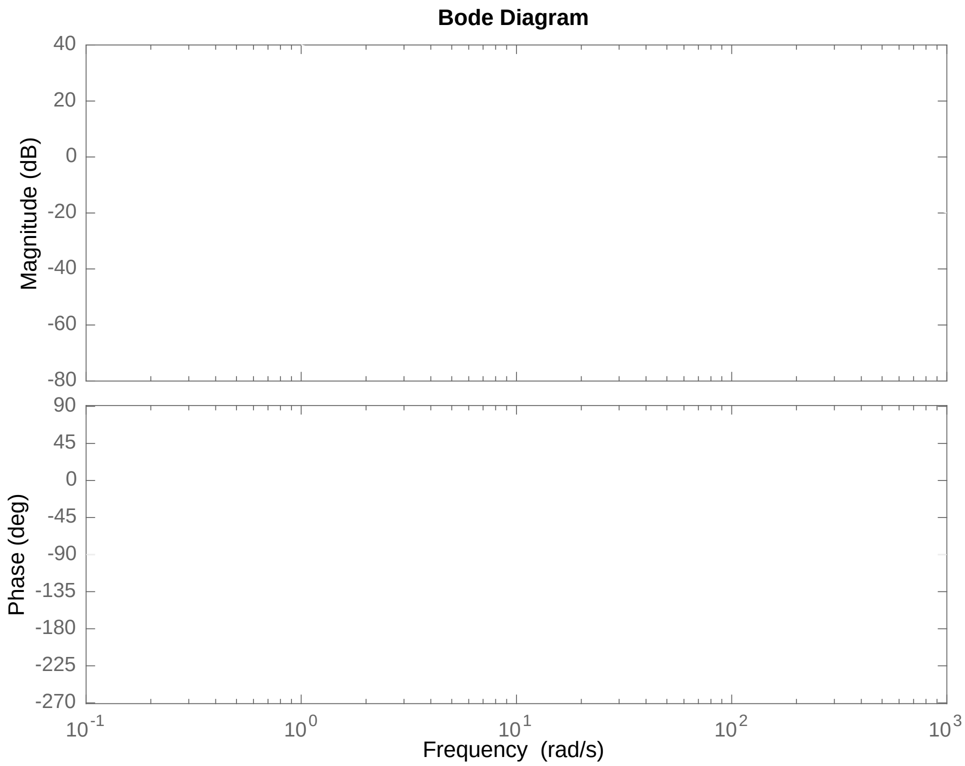
Problem-1. An aircraft roll control system is presented in the figure below. Use frequency response techniques to do the following (Cochran, 1992):

(a) Determine the value of gain, K, to yield a closed-loop step response with 10% overshoot by means of system's open-loop frequency response. *Hint*: Draw Bode diagrams by hand on the blank semi-logarithmic planes provided below. Change the limit values of the axes if needed.

(b) Estimate peak time and settling time using the gain-compensated systems frequency response (Bode diagrams). *Hint*: estimate the closed-loop bandwidth frequency, which is equal to the angular frequency when the open-loop magnitude is about -7.5 dB, then use the response speed and closed-loop frequency relationships.

(c) Plot the step response using MATLAB to check if the $\%OS$ requirement is met and speed estimations are close enough. Report the comparison results.

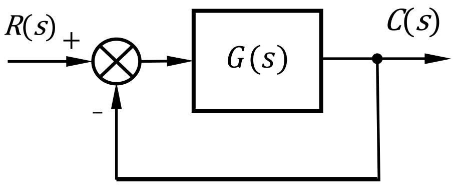




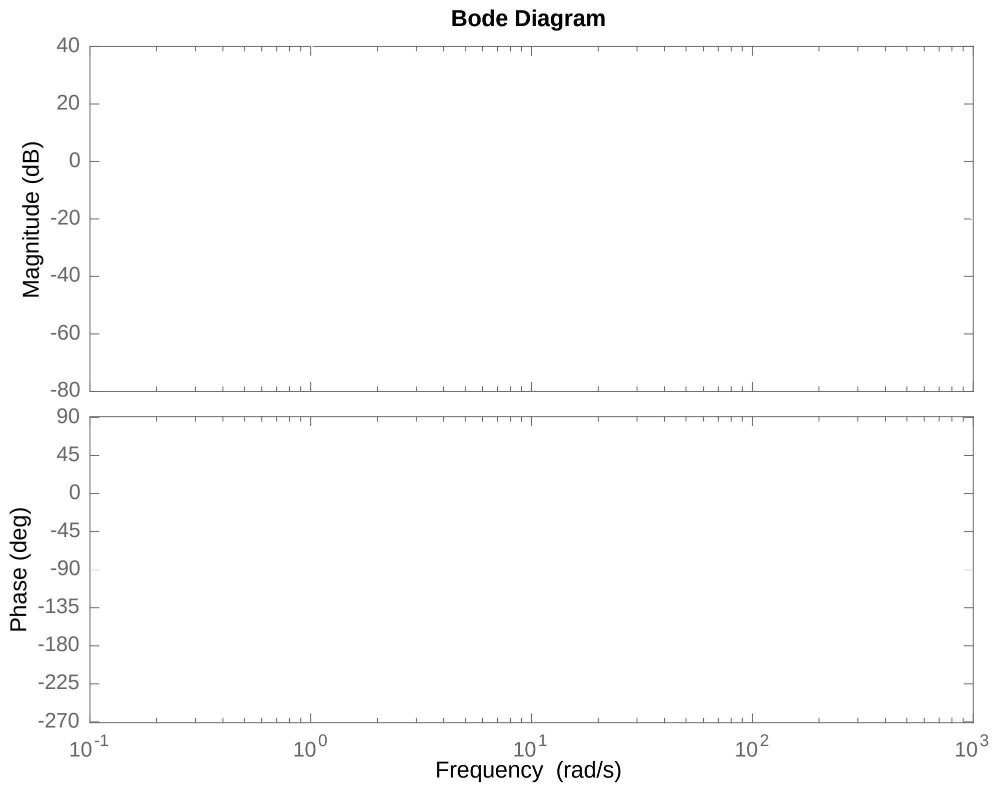
Strictly individual and original work is expected!

Problem-2. Design a lag compensator so that the system given in the figure below, where

$$G(s) = \frac{K(s+4)}{(s+2)(s+6)(s+8)}$$



operates with a 45° phase margin (corresponding to ~23% overshoot) and a static error constant of 100 (corresponding to $e_{ss} = 0.0099$). Draw Bode diagrams by hand on the blank semi-logarithmic planes provided below (change the limit values of the axes if needed). You may also obtain and add the Bode diagrams of the compensated system with "bode" or "bodeplot" function in MATLAB on an extra sheet. Plot the step responses for the P-controlled and then lag-compensated cases to validate the results.



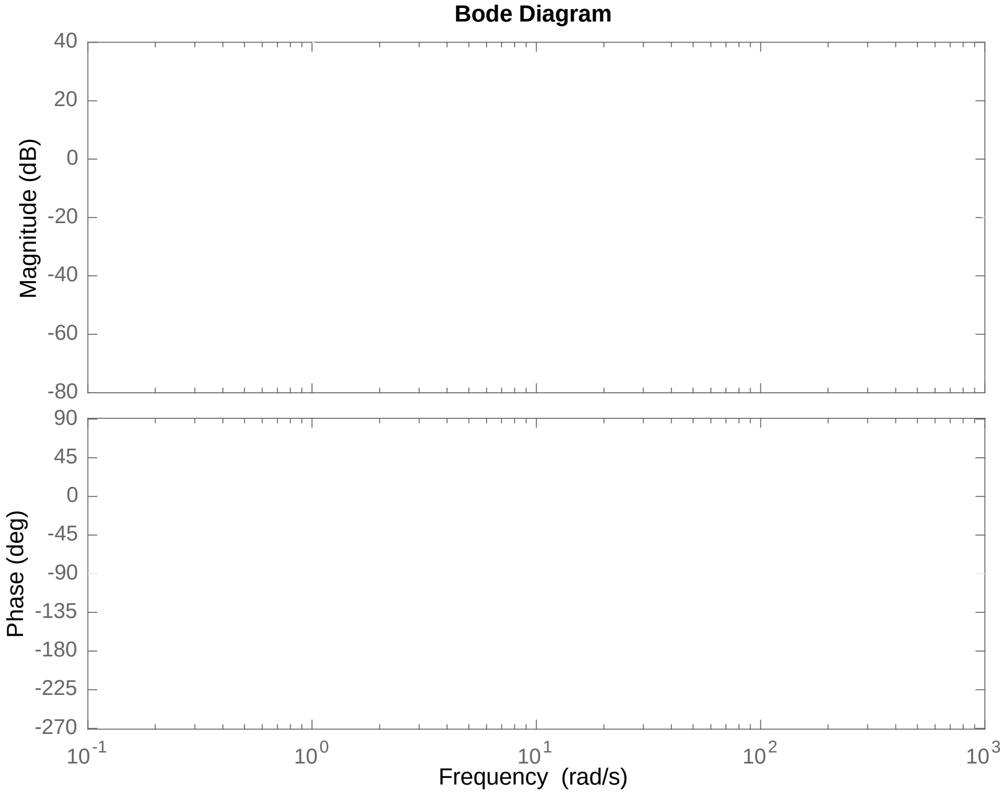
Problem-3. Consider the same unity feedback system of **Problem-2**, with

$$G(s) = \frac{K}{s(s+5)(s+20)}$$

The uncompensated system has about 55% overshoot and a peak time of 0.5 second when $K_v = 10$. Do the following:

(a) Use frequency response methods to design a lead compensator to reduce the percent overshoot to 10%, while keeping the peak time and steady-state error about the same. Make any required second-order approximation. Use the blank semi-logarithmic planes provided below. Change the limit values of the axes if needed.

(b) Use MATLAB or any other computer program to test your second-order approximation by simulating the system for the determined value of K and lead-compensated system (i.e. plot step responses). Make sure that the maximum overshoot is reduced from 55% to around 10% while the peak time is still about the same or even shorter.

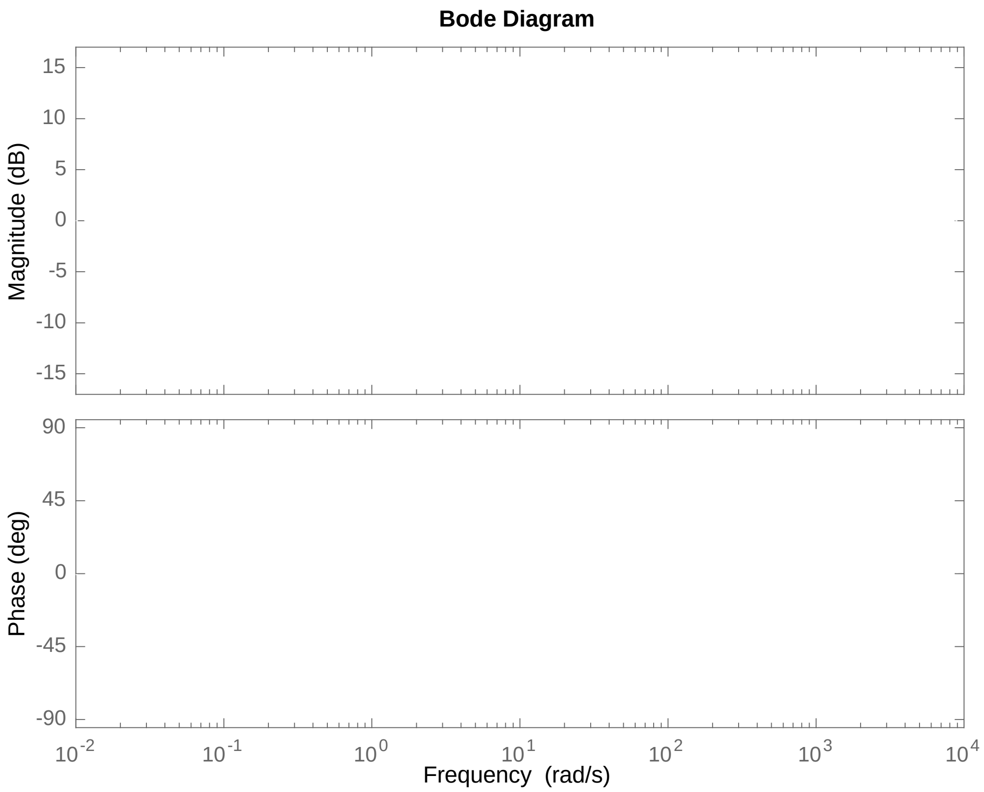


Problem-4. In order to assess the magnitude and phase response characteristics of the phase compensators,

(a) Design Lead, Lag and Lead-Lag Compensators whose general expressions are given below for the parameters of $\gamma = 5,\ T_1 = 0.05,\ T_2 = 0.2$. K, K_1 and K_2 gains are to be determined to yield 0 dB at low frequencies.

(b) Draw Bode plots of three compensators obtained in **(a)** on the same plane. Label the compensators' Bode magnitude and phase plots as G_{LG}, G_{LD} and G_{LL}. Use line width of 2.

$$G_{LL}(s) = K\left(\frac{s+\frac{1}{T_1}}{s+\frac{\gamma}{T_1}}\right)\left(\frac{s+\frac{1}{T_2}}{s+\frac{1}{\gamma T_2}}\right), G_{LX}(s) = K_1\left(\frac{s+\frac{1}{T_1}}{s+\frac{\gamma}{T_1}}\right), G_{LY}(s) = K_2\left(\frac{s+\frac{1}{T_2}}{s+\frac{1}{\gamma T_2}}\right)$$



Problem-5. Consider again the same unity feedback system of **Problem-2**, with

$$G(s) = \frac{20(s+2)}{s(s+5)(s+7)}$$

Design a controller to yield a 10% overshoot and a settling time of 2 seconds. Place the third pole 10 times as far from the imaginary axis as the dominant pole pair.

Required Steps:

1. Use controllable canonical form for full state-variable feedback.
2. Obtain the gain matrix of **K** by means of coefficient matching method and Ackermann's formula.
3. Validate your results with the "acker" or "place" function in MATLAB.
4. Plot the unit step responses of the systems with output feedback and state-variable feedback on the same plane for comparison.