Control Systems 1/ Control Systems

WS 2022

Student's Name: ____________________

Matriculation Number: ____________________

Allowed materials: Non-programmable pocket calculators only

Unauthorized materials: **any handwritten or printed material (manuscripts, lecture notes, books, etc.), laptops, mobile phones, smart watches, etc.**

Further Instructions:

Check your question paper. You must have 13 pages.

Write your name and matriculation number on the front page and return all the pages at the end of the examination!

Answer the questions within the space provided on the question paper. You are allowed to write on the backside of the paper.

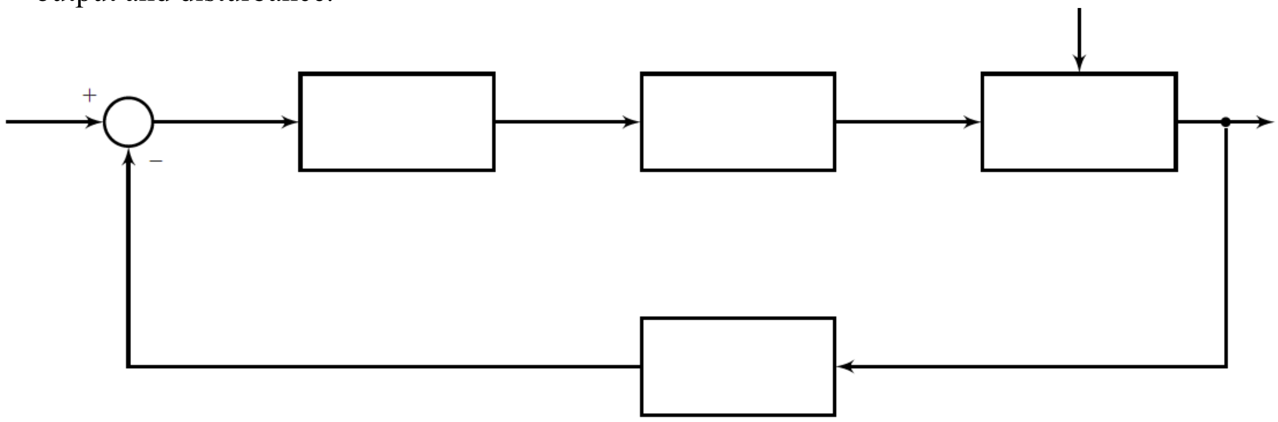
Write your name on the formula sheet and return it along with your question paper.

Problem	Marks	
1	7	
2	5	
3	6	
4	6	
5	6	
6	5	
7	6	
8	2	
9	4	
10	3	
Σ	**50**	

Grade	
1. Examiner	
2. Examiner	

Problem 1 (7)

1.1 Given is the block diagram of a standard feedback control loop. Use the following terms to label the blocks and signals properly: plant, controller, sensor, actuator, reference signal, control signal, plant output and disturbance.



1.2 Given is the following transfer function:

$$G(s) = \frac{5}{2s^2 + 3s + 8}$$

Calculate the following:

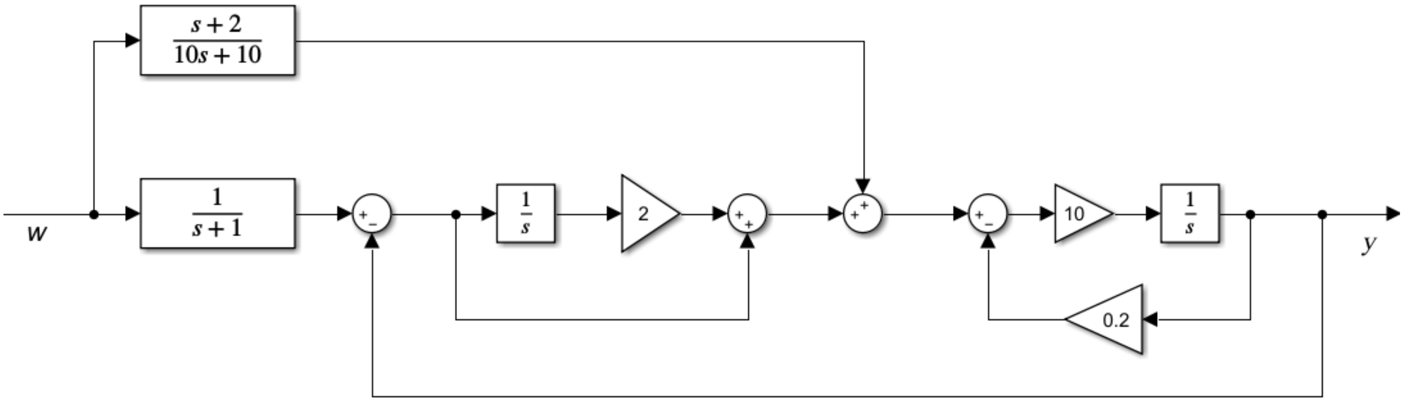
1. Natural frequency
   $\omega_0 =$

2. Damping ratio:
   $D =$

3. Steady-state gain:
   $K_0 =$

Problem 2 (5)

Given is the following block diagram of a plant.

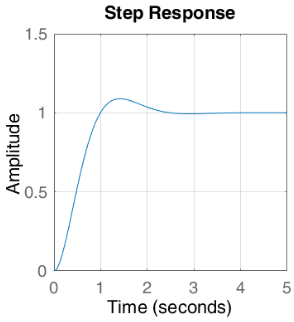
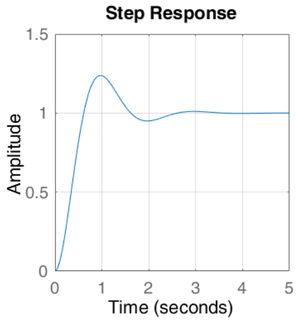
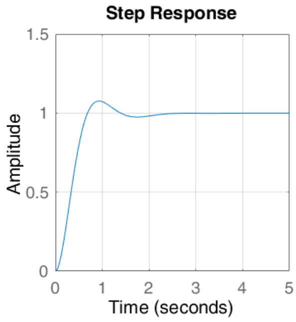
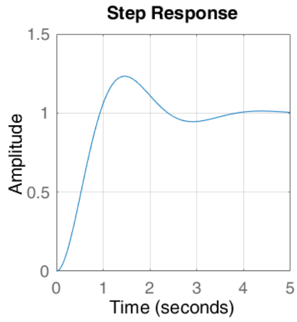


Calculate its transfer function:

$$G_{YW}(s) = \frac{Y(s)}{W(s)}$$

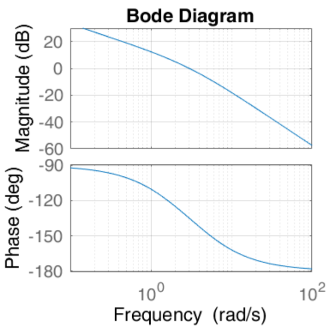
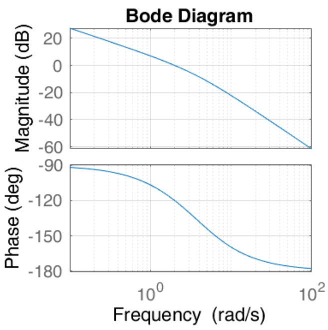
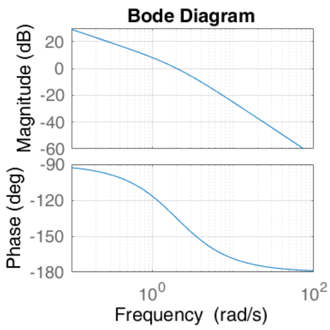
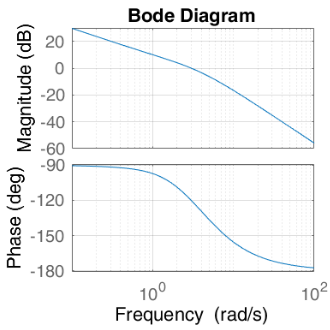
Problem 3 (6)

3.1 The following table shows results and design parameters for 4 different control systems.
First row: closed-loop step responses (tracking control)
Second row: Design parameters i.e. phase margin ϕ_R and gain-crossover frequency ω_{gc}.

			
$\phi_M = 45°$ $\omega_{gc} = 2\,rad/s$	$\phi_M = 60°$ $\omega_{gc} = 3\,rad/s$	$\phi_M = 60°$ $\omega_{gc} = 2\,rad/s$	$\phi_M = 45°$ $\omega_{gc} = 3\,rad/s$

Draw lines to connect step responses (first row) to corresponding design parameters (second row).

3.2 The following table shows 4 Bode plots their characteristics.
First row: Bode plots
Second row: Characteristics phase margin ϕ_R and gain-crossover frequency ω_{gc}.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Draw lines to connect Bode plots (first row) to corresponding characteristics (second row).

Problem 4 (6)

Consider a standard feedback control loop with the following transfer functions:

Controller: $G_R(s) = K_R\left(1 + \frac{1}{T_I s}\right)$ Plant: $G_S(s) = \frac{1}{(0.1s+2)(0.01s+1)}$

Determine the value of the controller parameters K_R und T_I to fulfil the following conditions:

1. The slowest pole of the plant is compensated with the controller zero.
2. The phase margin ϕ_M should be 65°.

Problem 5 (6)

Draw asymptotic approximation of the Bode plot of the following transfer function.

$$G(s) = \frac{100s + 20}{s + 2}$$

Do not forget to scale and label all the axes.

Problem 6 (5)

Given are the following transfer functions for a compensation controller design:

Plant model: $G_S(s) = \frac{s+3}{(s+1)(s^2+s+1)}$

Please design a minimum-order compensation controller, which satisfies the following conditions:

1. Der denominator of the closed loop tracking system $K_W(s)$ should be in binomial form.
2. After a step-like change, the system output should achieve 80% of the new set-point within 1 second ($t_{80} = 1$s).

Problem 7 (6)

Consider a standard feedback control loop with the following transfer functions:

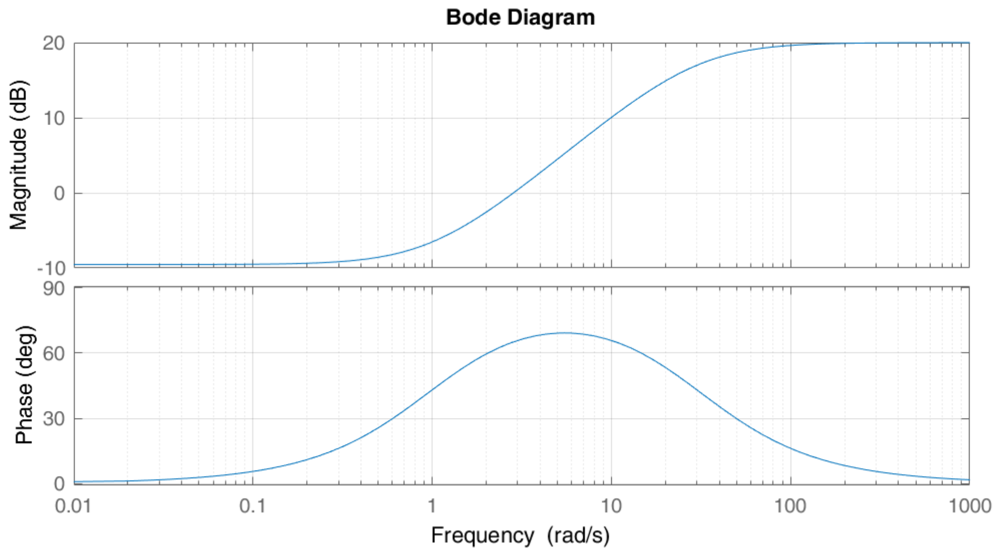
Controller: $G_R(s) = K_P + \frac{K_I}{s}$ Plant: $G_S(s) = \frac{5}{2s-1}$

Calculate the values of controller parameters K_P and K_I so that the closed loop hast he following poles:

$s = -2 \pm j$.

Problem 8 (2)

Given is the following Bode-Diagram:



The following sinusoidal signal is attached to the input of the system:

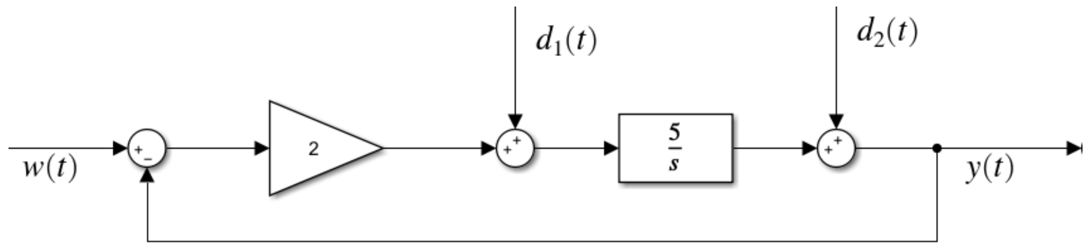
$$u(t) = 5 \cdot \sin(\omega t) \quad \text{with} \quad \omega = 10\frac{rad}{s}$$

Write an expression fort he output signal y(t)

Hint: Ignore the switching transients. Assume that the system is in this state for a very long time.

Problem 9 (4)

Consider the following control loop with a P controller:



Please calculate the steady-state value oft he system output y_∞ in following cases:

a. $w(t) = 0 \qquad d_1(t) = 2\epsilon(t) \qquad d_2(t) = 0$

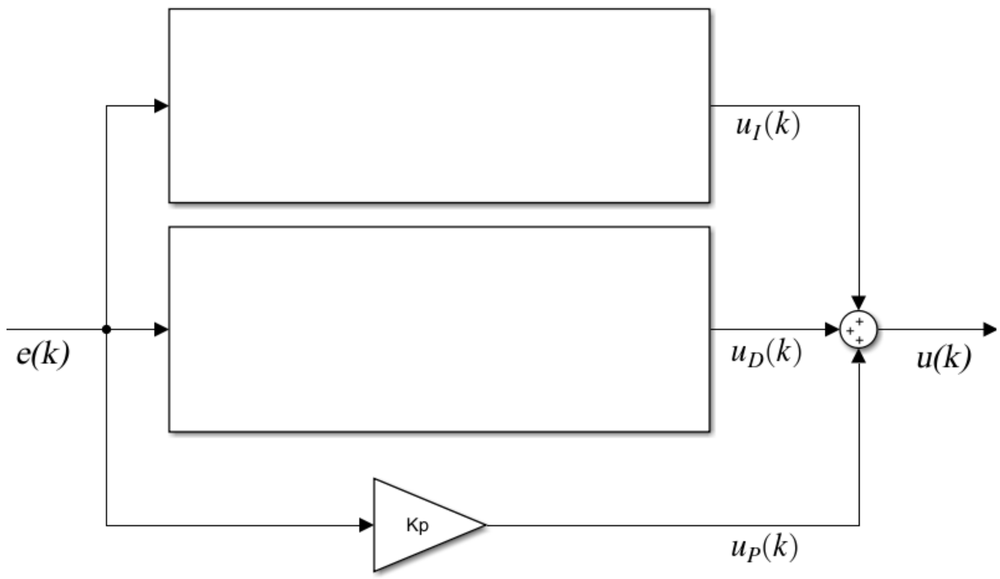
b. $w(t) = 0 \qquad d_1(t) = 0 \qquad d_2(t) = 2\epsilon(t)$

Problem 10 (3)

The mathematical expressions for a discrete-time PID controller are given below:

$$u_I(k) = u_I(k-1) + K_I e(k)$$
$$u_D(k) = K_D\big(e(k) - e(k-1)\big)$$
$$u_P(k) = K_P e(k)$$
$$u(k) = u_P(k) + u_I(k) + u_D(k)$$

Complete the following block diagram by filling the empty blocks for the calculation of $u_I(k)$ and $u_D(k)$. Use a z^{-1}block to represent the unit delay.



Problem 1

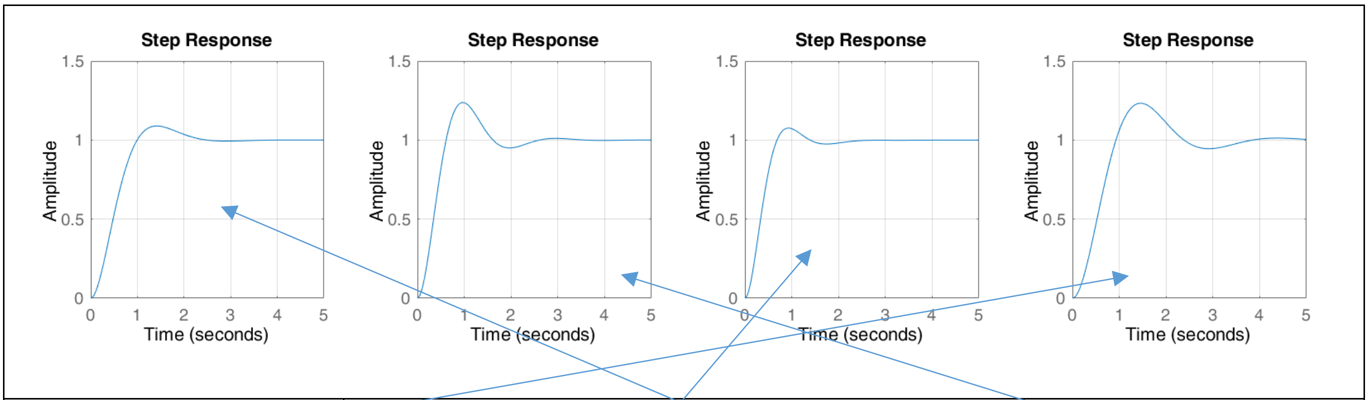
1.2 $\omega_0 = 2$ $\quad D = 3/8;$ $\quad K_0 = 5/8$

Problem 2

$$G_{YW}(s) = \frac{1}{s+1}$$

Problem 3

3.1



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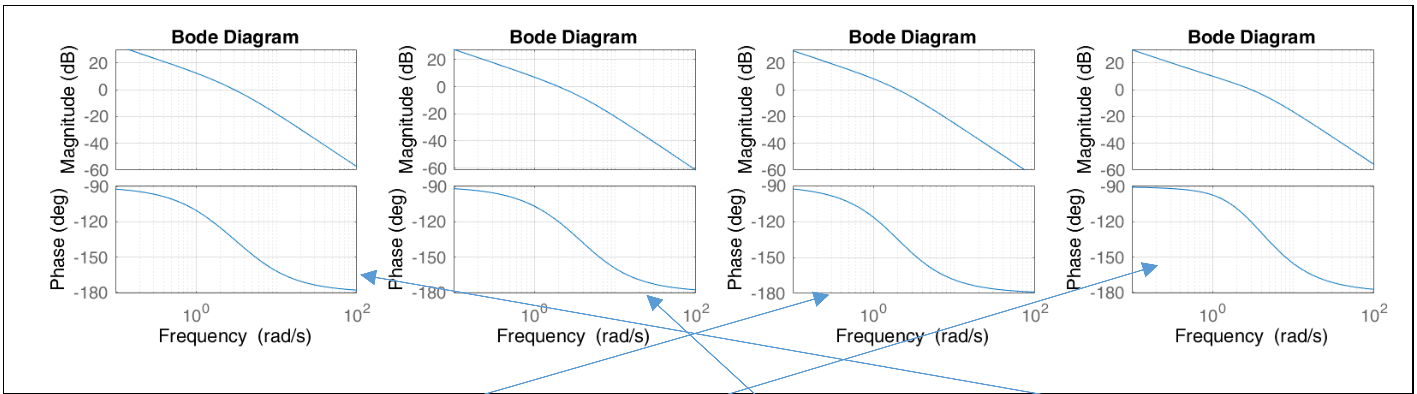
3.2.

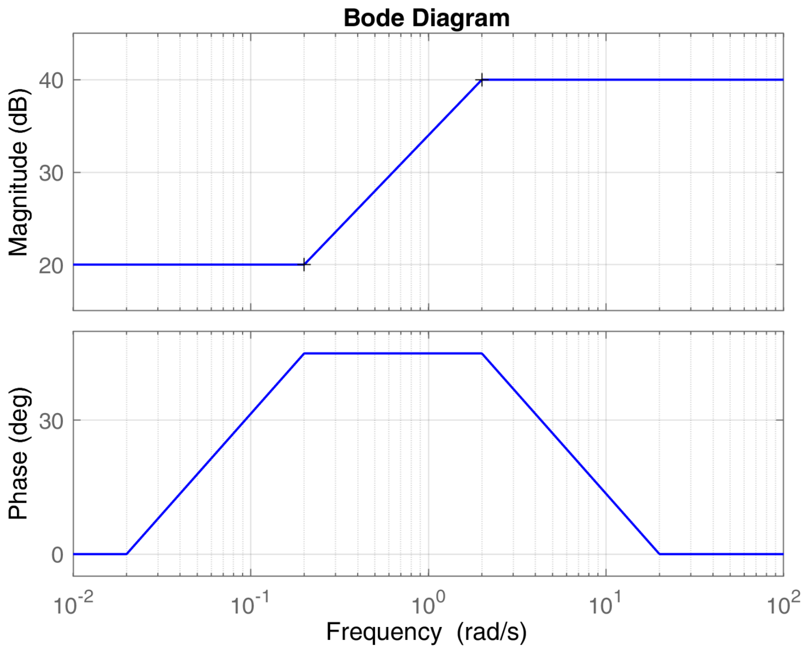


$\phi_M = 45°$ $\omega_{gc} = 2\,rad/s$	$\phi_M = 60°$ $\omega_{gc} = 3\,rad/s$	$\phi_M = 60°$ $\omega_{gc} = 2\,rad/s$	$\phi_M = 45°$ $\omega_{gc} = 3\,rad/s$

Problem 4

$T_I = 0.05;$ $\quad K_R = 5.15.$

Problem 5



Problem 6

$G_R(s) = \frac{9(s+1)(s^2+s+1)}{s(s+6)(s+3)}$

Problem 7

$K_P = 1.8 \qquad K_I = 2$

Problem 8

$y(t) = 15.8 \cdot \sin(10t + 65°)$

Problem 9

a. $y_\infty = 1$; b. $y_\infty = 0$

Problem 10