Reading-up-time

For reviewing purposes of the problem statements, there is a "reading-up-time" of **10 minutes** prior to the official examination time. During this period it is **not** allowed to start solving the problems. This means explicitly that during the entire "reading-up-time" no writing utensils, e.g. pen, pencil, etc. at all are allowed to be kept on the table. Furthermore the use of carried documents, e.g. books, (electronic) translater, (electronic) dictionaries, etc. is strictly forbidden. When the supervisor refers to the end of the "reading-up-time" and thus the beginning of the official examination time, you are allowed to take your utensils and documents. Please **then**, begin with filling in the **complete** information on the titlepage and on page 3.

Good Luck!

LAST NAME	
FIRST NAME	
MATRIKEL-NO.	
TABLE-NO.	

Klausurunterlagen

Ich versichere hiermit, dass ich sämtliche für die Durchführung der Klausur vorgesehenen Unterlagen erhalten, und dass ich meine Arbeit ohne fremde Hilfe und ohne Verwendung unerlaubter Hilfsmittel und sonstiger unlauterer Mittel angefertigt habe. Ich weiß, dass ein Bekanntwerden solcher Umstände auch nachträglich zum Ausschluss von der Prüfung führt. Ich versichere weiter, dass ich sämtliche mir überlassenen Arbeitsunterlagen sowie meine Lösung vollständig zurück gegeben habe. Die Abgabe meiner Arbeit wurde in der Teilnehmerliste von Aufsichtsführenden schriftlich vermerkt.

Duisburg, den __________ ______________________________

(Unterschrift der/des Studierenden)

Falls Klausurunterlagen vorzeitig abgegeben: ______________Uhr

Bewertungstabelle

Aufgabe 1	
Aufgabe 2	
Gesamtpunktzahl	
Angehobene Punktzahl	
%	
Bewertung gem. PO in Ziffern	

____

(Datum und Unterschrift 1. Prüfer, Univ.-Prof. Dr.-Ing. Dirk Söffker)

____

(Datum und Unterschrift 2. Prüfer, Dr.-Ing. Yan Liu)

____

(Datum und Unterschrift des für die Prüfung verantwortlichen Prüfers, Söffker)

Fachnote gemäß Prüfungsordnung:

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
1,0	1,3	1,7	2,0	2,3	2,7	3,0	3,3	3,7	4,0	5,0
sehr gut		gut			befriedigend			ausreichend		mangelhaft

Bemerkung: ____

Attention: Give your answers to ALL problems directly below the questions in the exam question sheet.

You are NOT allowed to use a pencil and also NOT red color (red color is used for corrections).

This exam is taken by me as a
☐ mandatory (Pflichtfach)
☐ elective (Wahlfach)
☐ prerequsite (Auflage)
subject (cross ONE option according to your own situation).

Maximum achievable points:	**40**
Minimum points for the grade 1,0:	**95%**
Minimum points for the grade 4,0:	**50%**

Problem 1 (15 Points)

1a) (3 Points)
Linearize by using the Taylor series expansion breaking after the first term the mathematical Input/Output equation

$$R = ae^{3S}S^2, \ \ S \in [0, \pi]$$

around the working point $S_0 = 2$ with S as input and R as output.

1b) (3 Punkte)
Consider the system shown in Figure 1.1

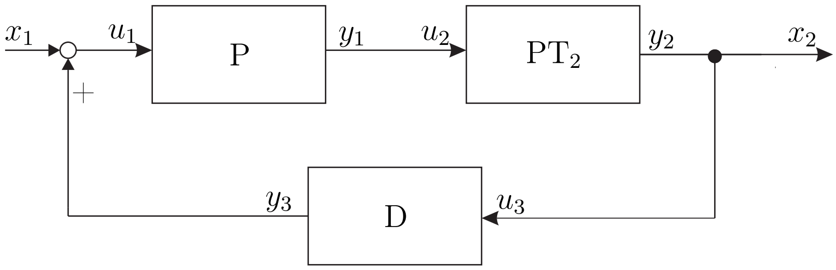


Figure 1.1: Block diagram of the system to be considered

with the given parameters

P : $K_1 = 2$

PT_2 : $K_2 = 2,\ \omega_0 = 2,\ D = 2,$ and

D : $T_D = 2.$

Give the eigenfrequency ω_0^*, the damping D^* for the transmission system with x_1 as input and x_2 as output.

1c) (2 Punkte)

An inventor proposes a new controller for a robust and always stable control for a system with a P-transfer behavior. This system is controlled by a transfer element with PT_1-behavior ($T = 1, K_2 = 1$) using negative feedback as illustrated in Figure 1.2. Explain (for example by calculating eigenvalues) whether the proposed solution guarantees a stable system behavior (the eigenvalues have to be calculated in detail, here K_1 is always positive). Is the given controller suitable according to its objective? [Yes, No]. State reasons.

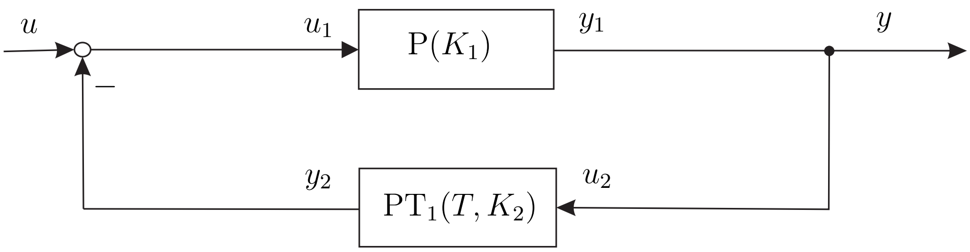


Figure 1.2: System

1d) (1 Punkte)
Is the controller design in combination with positive feedback an innovation? [Yes, No]. State reasons.

1e) (3 Points)

A system in state space description with

$$A = \begin{bmatrix} 0 & 1 \\ -1 & -1 \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, \quad C = \begin{bmatrix} 1 & 0 \end{bmatrix} \quad \text{and} \quad D = 0$$

is controlled by a transfer element with P-behavior using negative feedback ($K = K_\mathrm{R}$). For which values of the parameter K_R is the controlled system stable? Mark with a cross the correct answer(s). Several answers are possible.

The controlled system is

- ◯ Stable for $K_\mathrm{R} \geq -1$.
- ◯ Asymptotic stable for $K_\mathrm{R} > -1$.
- ◯ Unstable for $K_\mathrm{R} = 2$.
- ◯ Stable for $K_\mathrm{R} = 2$.

☐

1f) (3 Punkte)
Two systems are arranged according to Figure 1.3.
The dynamic behavior of system 1 is

$$u_1 = K_2 y, \quad \text{and} \tag{1.1}$$

of the total system in case of the closed switch

$$u = K_1 y + T_D K_2 \dot{y}. \tag{1.2}$$

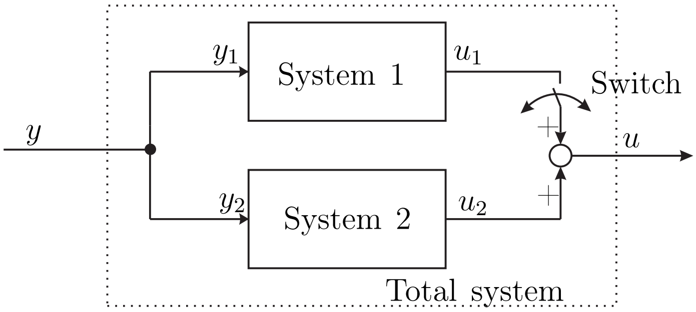


Figure 1.3: Block diagram

Classify the resulting transfer behavior of the total system in case of the opened switch. Mark with a cross the correct answer(s). Several answers may be possible.

The system is a

- ◯ PDT_1
- ◯ PD
- ◯ PT_1
- ◯ $PIDT_1$

system.

□

$\sum$ □

Problem 2 (25 Points)
Given is the following closed-loop control system (see Figure 2.1).

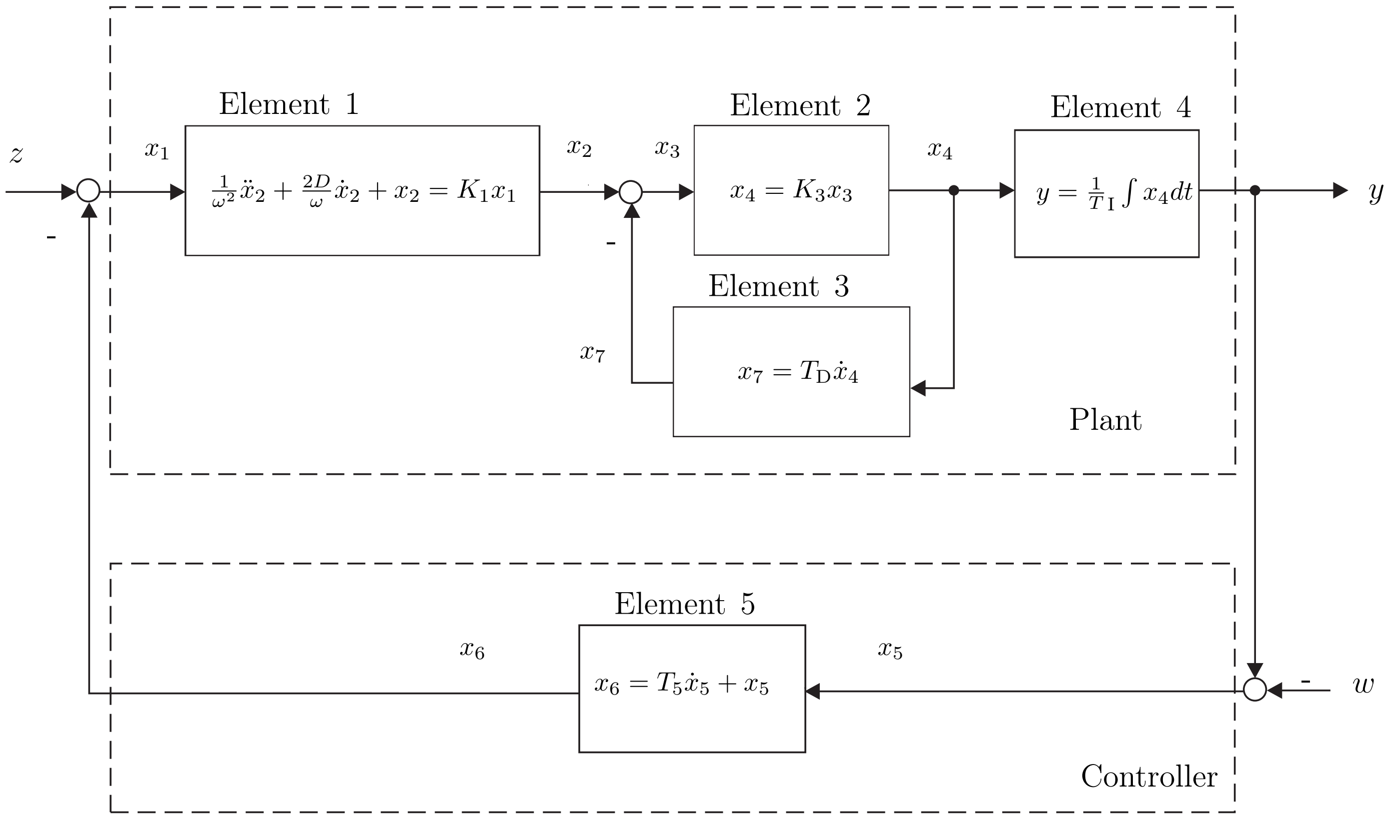


Figure 2.1: Block diagram

2a) (4 Points)
Classify the transfer behavior of the elements 1 to 4 and draw the corresponding step responses.

2b) (3 Points)
Classify the transfer behavior of the plant?

(Note: Transform the differential equation into a suitable representation for classification. The parameters are given as $\omega = D = K_1 = T_\mathrm{D} = K_3 = T_5 = T_\mathrm{I} = 1$.)

2c) (3 Points)
The dynamics of the plant to be controlled is now given by the differential equation

$$\tilde{T}_3\dddot{y} + \tilde{T}_2\ddot{y} + \tilde{T}_1\dot{y} = K_1 x_1.$$

Classify the disturbance behavior of the closed-loop system ($z \rightarrow y$).
Classify the reference behavior of the closed-loop system ($w \rightarrow y$).

2d) (2 Points)
The reference behavior of a system is described by

$$3\ddot{y} + \dot{y} - 2y = Ku - 2.$$

Classify the stability of the system. Cross the correct answer(s). Several solutions may be possible.

◯ Stable	◯ Asymptotic stable
◯ Unstable	◯ Boundary stable

☐

For the following tasks a new system is described by

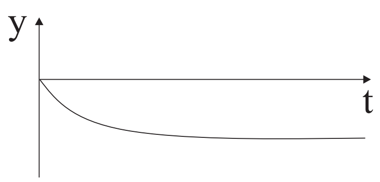
$$4\dot{y} + 2y = -u,$$

where y denotes the measured output and u the input.

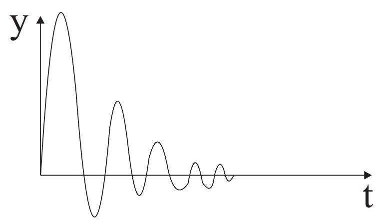
2e) (3 Points)
Give the state space representation of the system. Here the coefficient of the c-matrix has to be chosen equal to one, there does not exist any direct transmission.

2f) (3 Points)
Is the system given in problem 2e) able to oscillate? State reasons.

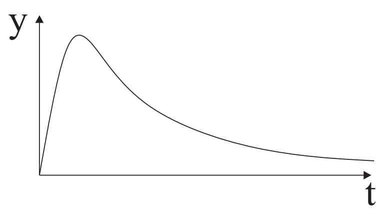
A step function is applied to the system. Which behavior do you expect on the output y? Cross the correct answer(s). Several solutions may be possible.

○ 

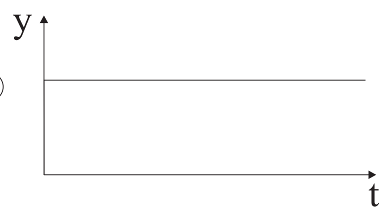
(a)

○ 

(b)

○ 

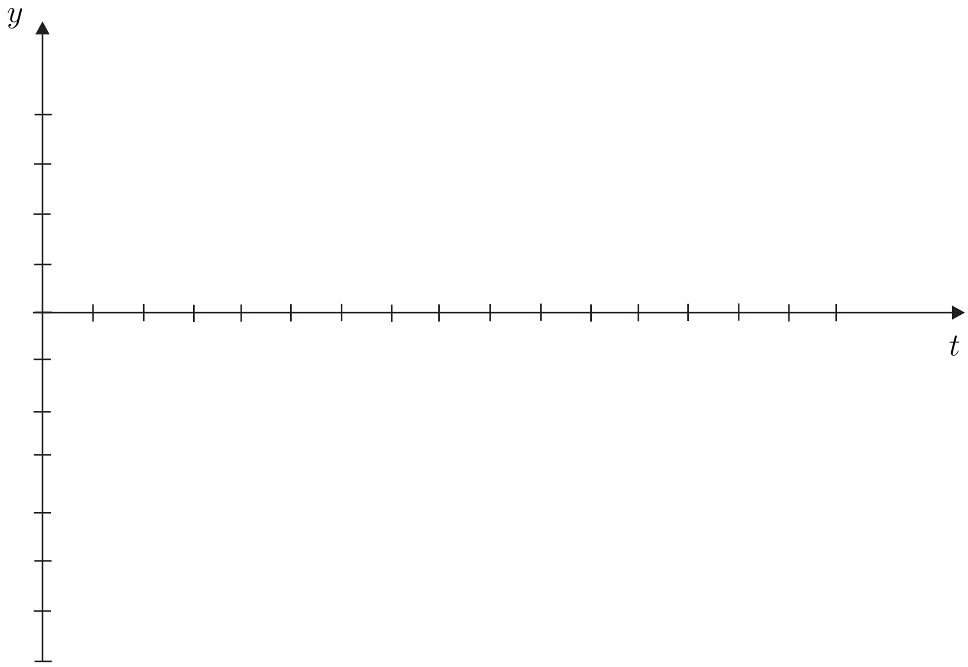
(c)

○ 

(d)

2g) (4 Points)

Draw in the following diagram quantitatively the output behavior $y(t)$ of the system, when the input is $u(t) = 4 \cdot \delta(t)$. Draw - if applicable - the static final value and the time constant T explicitly.



2h) (3 Points)
The following modified system

$A = \begin{bmatrix} 0,1b & 1 \\ 0 & b \end{bmatrix}$, $B = \begin{bmatrix} 0 \\ 2 \end{bmatrix}$ und $C = \begin{bmatrix} 1 & 0 \end{bmatrix}$ is given.

Calculate the eigenvalues λ_1, λ_2 and the corresponding eigenvectors $v_1 = [1\, v_{12}]^T$, $v_2 = [1\, v_{22}]^T$ of the system matrix A. Cross the correct answer(s). Several solutions may be possible.

Eigenvalues:

○ $\lambda_1 = b$ and $\lambda_2 = -0,1b$

○ $\lambda_1 = 0,1b$ and $\lambda_2 = b$

○ $\lambda_1 = -0,1b$ and $\lambda_2 = b$

○ $\lambda_1 = b$ and $\lambda_2 = 0,1b$

Eigenvectors:

○ $v_1 = [1 \;\; 0]^T$ and $v_2 = [1 \;\; -0,1b]^T$

○ $v_1 = [1 \;\; b]^T$ and $v_2 = [1 \;\; 1,1b]^T$

○ $v_1 = [1 \;\; 0]^T$ and $v_2 = [1 \;\; -0,9b]^T$

○ $v_1 = [1 \;\; 0]^T$ and $v_2 = [1 \;\; 0,9b]^T$

Which values of the parameter b have to be chosen to realize an asymptotic stable system behavior?

○ $b = 0$

○ $b \neq 0$

○ $b < 0$

○ $b > 0$

$\sum$ □