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)

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(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%**

General hints:

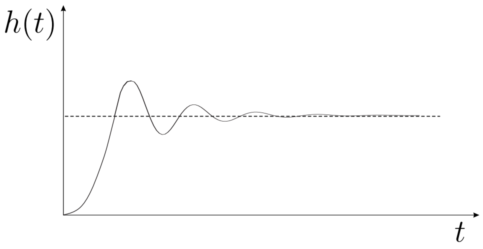
1) For the multiple-choice and multiple-choice-similar tasks the following rules are effective:
   i) For correct answers of exam task parts the desired number of points will be given.
   ii) For noncorrect answers of exam task parts the desired number of points will be counted negative.
   iii) No answering will neither lead to positive nor to negative points.
   iv) The points of the task will be summarized. The whole number can not be smaller than zero.

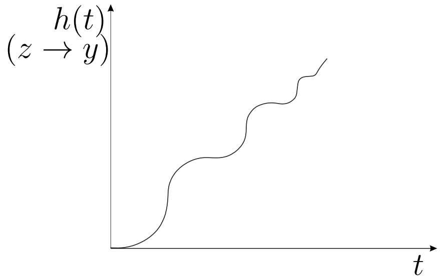
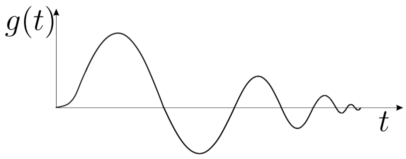
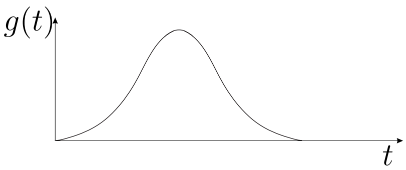
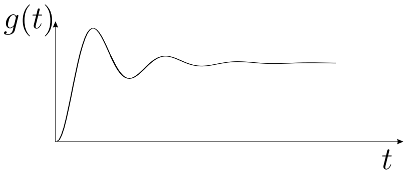
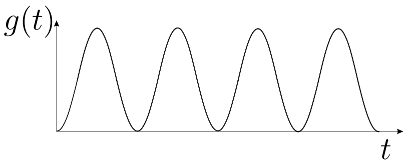
2) If in the exam tasks no information is given for the valid range of numbers for time constants or masses etc. : take for time constants (in sec.), for masses (in kg) positive numbers.

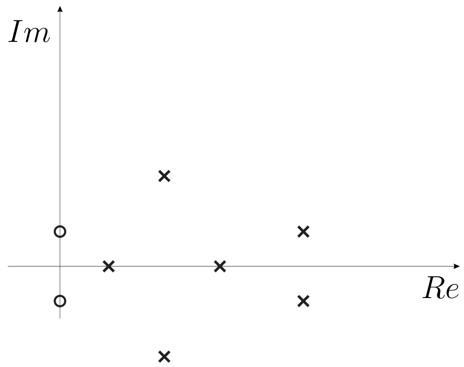
3) If in the exam tasks no information is given for applying negative or positive feedback: use the usual negative feedback.

Problem 1 (15 Points)

1a) (6 points)
Which of the following statements are true and which are false? (The underlying topics are part of lecture/exercise system dynamics).

No.	Task/Question/Judgment	True	False
1)	In linear control technique, the controlled SISO-systems have typically max. two inputs and one output.	○	○
2)	The reference value has to follow the control value.	○	○
3)	Open-loop control systems are technically easier to realize than closed-loop control systems.	○	○
4)	Time delay systems are typical elements in linear control technique.	○	○
5)	The dynamics of a system described by a linear differential equation with constant coefficients is characterized by the fact that the dynamical behavior of the transfer behavior is changing with time.	○	○
6)	Systems of second order with the I/O-behavior $$T_2\ddot{y} + T_1\dot{y} + y = Ku$$ are in principle and independent from the parameters $T_{1,2}$ able to vibrate.	○	○
7)	A system with the step response behavior  is at least I/O-stable.	○	○
8)	The weighting function of a system can be measured technically by applying weights to mechanical systems and is typical for mechanical engineered/mechanical systems.	○	○
9)	Asymptotic stability according to Lyapunov can be easily realized without using sensors, actuators, and controllers (assumption: number of poles = number of eigenvalues).	○	○

10)	The system described by the equation $$a\ddot{y} + b\dot{y} + y = K[w + \frac{1}{T_\mathrm{I}}\int w dt]$$ shows always, independent from the parameters a, b, K, T_I, the following disturbance transfer behavior. 	○	○
11)	Independent from the parameters m, d, k the system behavior described by the equation $$m\ddot{z} + d\dot{z} + kz = \delta(t) \text{ with } m, d, k \geq 0$$ can show the following behaviors.		
		○	○
		○	○
		○	○
		○	○

12)	The system with the eigenvalue distribution shown below is asymptotically stable. 	○	○

□

1b) (5 points)
Give the eigenfrequency $\tilde{\omega_0}$ as well as the damping $\tilde{D}$ for the resulting transfer system in figure 1.1 between the input u_1 and the output f_2.

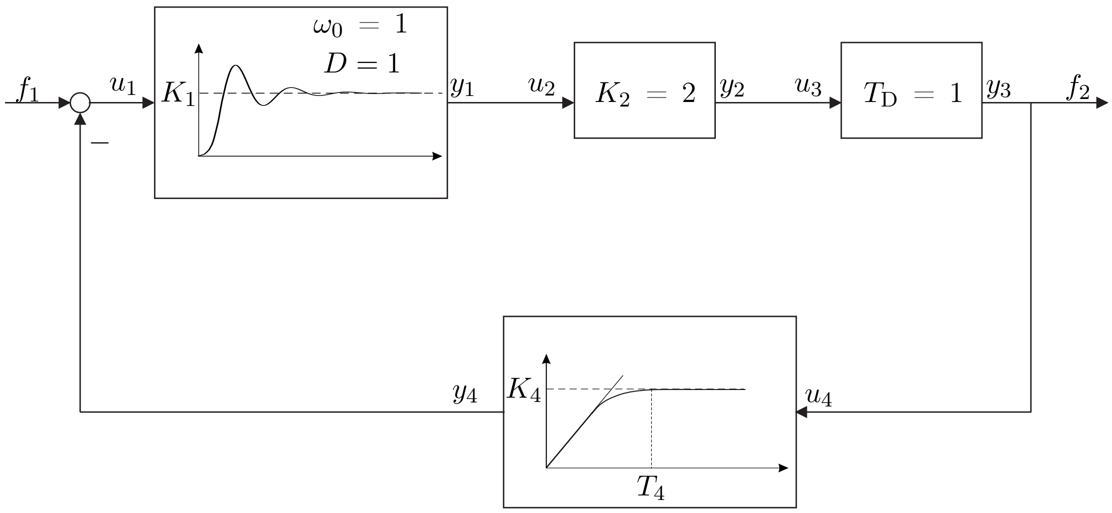


Figure 1.1: System

- Give the transfer behavior of the open-loop system in one equation.
- Give the reference transfer behavior of the system in one equation ($u_4 = y_3 - w$).
- Give the reference and disturbance transfer behavior of the system in one equation.

1c) (4 points)
The eigenvalues of four different systems are graphically illustrated in figure 1.2. The weighting functions of the systems are measured. Evaluate the statements in the following table.

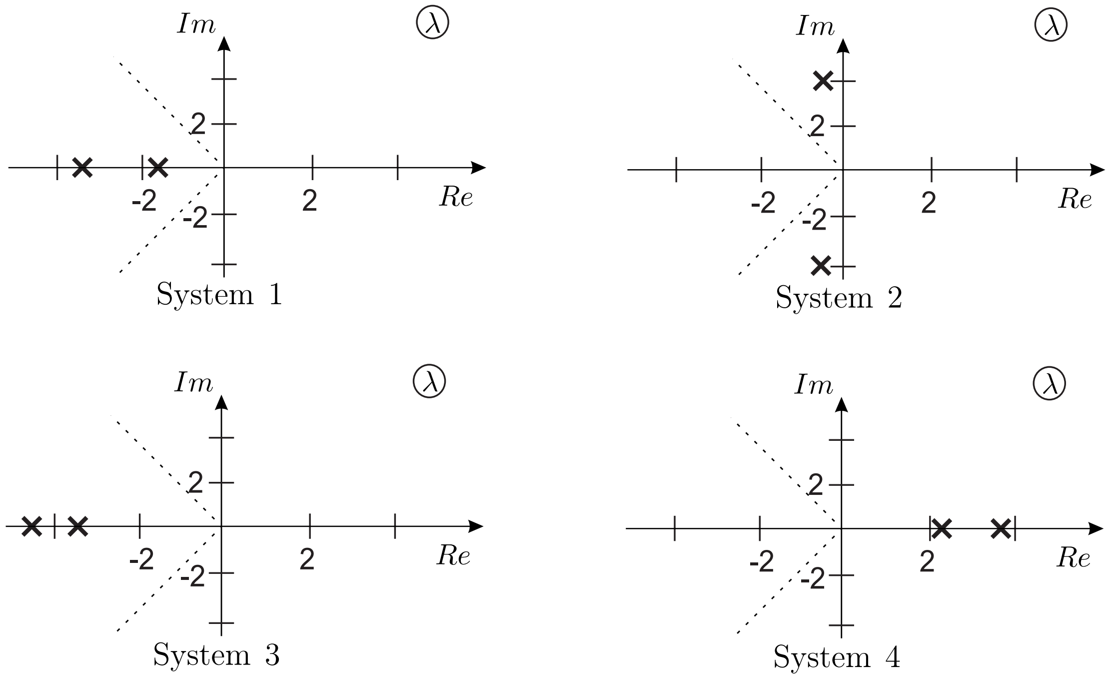


Figure 1.2: Eigenvalue distribution of four different systems

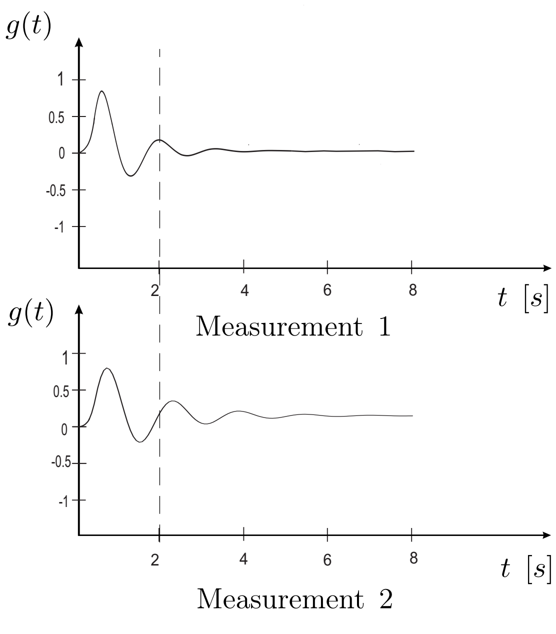


Figure 1.3: Measurements of the dynamic behaviors of two different systems

No.	Task/Question/Judgment	True	False
1)	The distribution of eigenvalues of the systems 3 and 4 show a strong damping behavior.	○	○
2)	The system 2 shows a complex conjugate eigenvalue pair. Due to the weak damping, it could fit both measurement 1 as well as measurement 2.	○	○
3)	The measurements 1 and 2 show typical step response functions of PT_2-systems.	○	○
4)	The behavior of measurement 1 shows a stronger damping of the system than that of measurement 2.	○	○
5)	The behavior of measurement 2 shows a smaller eigenfrequency ω_0 of the system.	○	○
6)	The systems 1 and 2 can have in principle the behavior illustrated in measurements 1 and 2.	○	○
7)	Due to the damping angle $> 45°$, the systems 2 and 4 show unstable behavior.	○	○
8)	The underlying systems of the weighting functions in measurements 1 and 2 are at least BIBO-stable, so that the eigenvalues which are responsible for the I/O-behavior have real parts < 0.	○	○

| □

$\sum$ □

Problem 2 (25 Points)

2a) (1.5 points)
Which of the following statements are true and which are false? (The underlying topics are part of lecture/exercise system dynamics).

No.	Task/Question/Judgment	True	False
1)	Using the convolution integral $$y(t) = \int_{t=0}^{t} c\phi(t-\tau)bu(\tau)d\tau + du(t)$$ the time behavior of the output $y(t)$ to the input signal σ(t) can be calculated.	◯	◯
2)	The eigenvalue analysis of the system described by the matrix $$A = \begin{bmatrix} 0 & 1 \\ -k & -d \end{bmatrix}$$ show that for the control of the stationary behavior of the system, the time-variant behavior is not allowed to be neglected.	◯	◯
3)	To select a controller: For proportional systems a P-controller, for integral systems a PI-controller, for differential systems a PD-controller should be used following Ziegler-Nichols.	◯	◯

☐

2b) (2.5 points)
The I/O-transfer behavior

$$\dddot{y} - 3\ddot{y} + 3\dot{y} - y = -30u + \dot{u} + \ddot{u}$$

has the following poles

- ○ $s_{1,2} = -1 \pm j$, $s_3 = -1$
- ○ $s_{1,2} = -1$, $s_1 = -1$
- ○ $s_1 = +1$, $s_{2,3} = -1$
- ○ $s_{1,2,3} = 1.$

2c) (2 points)
The measurement of the step response behavior of an open-loop system is given in the figure below:

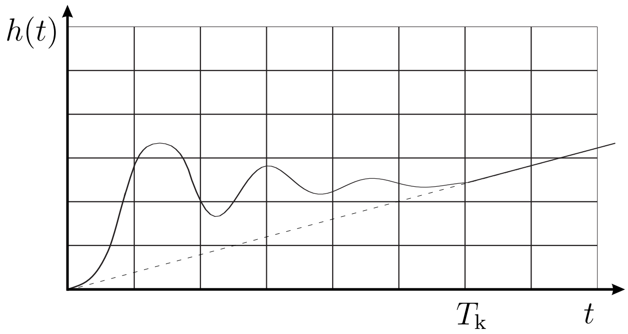


Figure 2.1: Open-loop system

What can be concluded from the figure?

No.	Task/Question/Judgment	True	False
1)	It is definitively a non-linear system.	○	○
2)	It is a stable system behavior, in the case of a linear system, therefore, a stable system.	○	○
3)	Until the time point $t = T_k$, the behavior can be classified as a PT_1-system behavior.	○	○
4)	The description as a proportional system acting parallel to a time-delay integral system classifies the system as PIT_t-system.	○	○

☐

2d) (6 points)
The block diagram of a system with four transfer elements is given in figure 2.2. The input is denoted as u and the output as y.

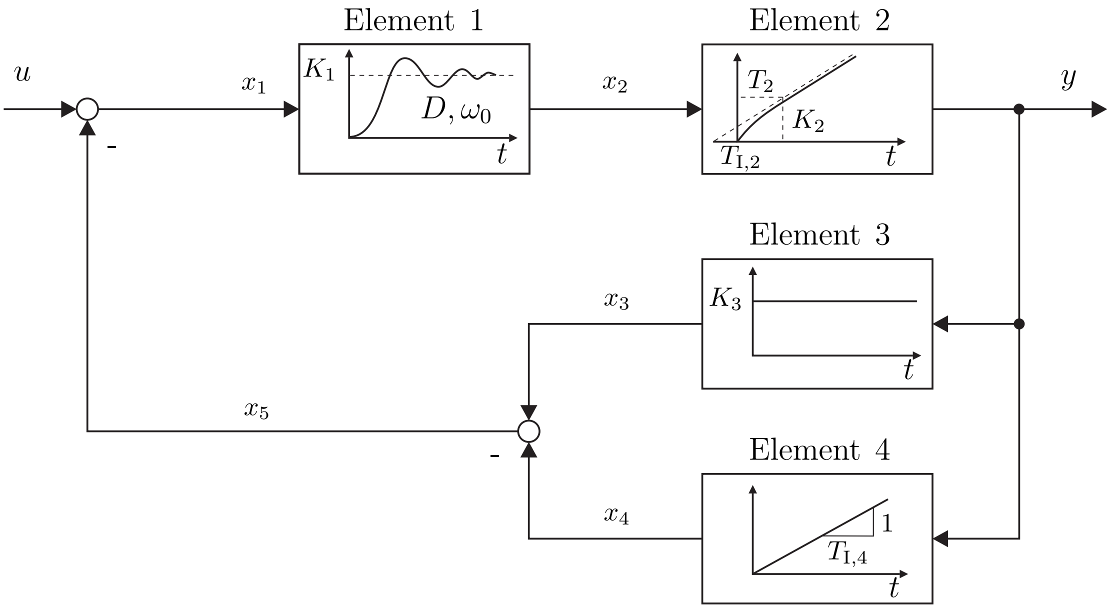


Figure 2.2: Block diagram of the system

i) (3 points)
Combine the elements 3 and 4 (type of the individual transfer behavior). Give the corresponding differential equation in a suitable form for classification using the given denotations. If classification is possible, classify the resulting behavior of which type of $\mathrm{PIDT_nT_t}$ behaviors.

ii) (3 points)

How much energy storages are included within the series network of elements 1 and 2? The system behavior of the combined elements 1 and 2 can be classified without the use of mathematical equations, therefore consider the number of included energy storages as well as the causal chain. Classify the resulting behavior of the combined elements 1 and 2?

2e) (4 points)

The mathematical model of a thermodynamical system is described by the equations

$$\dot{x}_1(t) + x_1(t) = Ku \text{ and}$$
$$x_1 = T_1\ddot{y} + T_2\dot{y} + \int y dt$$

Use the given equations to determine the scalar differential equation of the whole system (with input u and output y) and classify - if possible - the resulting transfer behavior of the system. Which controller type is suitable for realizing stationary accuracy of the whole system?

2f) (4 points)
The block diagram of a system of transfer elements is given (see figure 2.3).

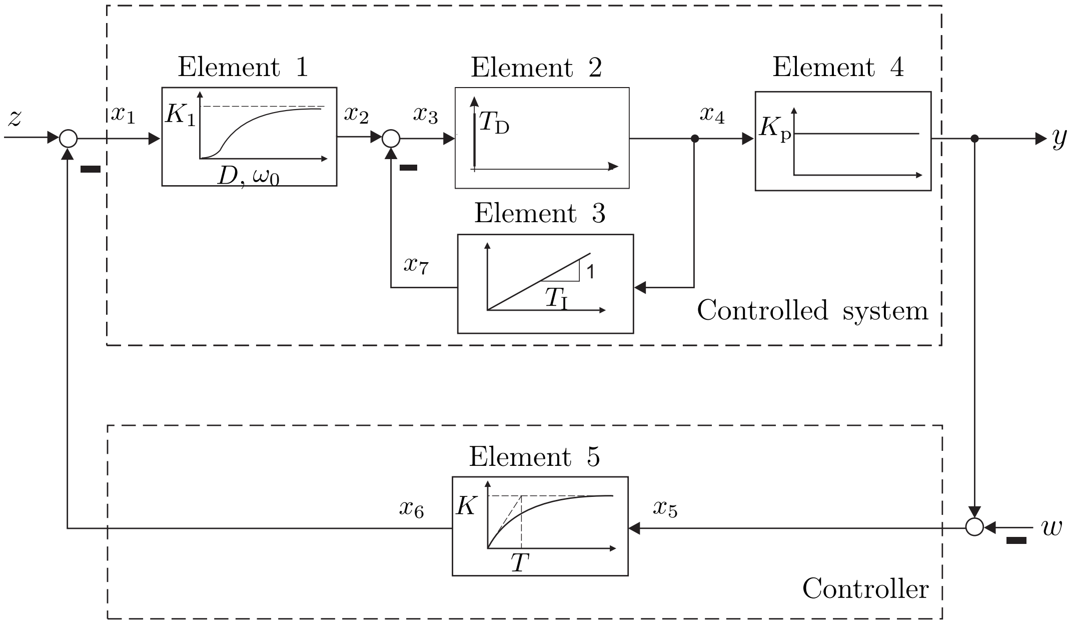


Figure 2.3: Block diagram

Answer the following questions related to the mentioned system.

No.	Task/Question/Judgment	True	False
1)	Element no. 1 is a system with proportional behavior.	◯	◯
2)	Element no. 3 is a system with steady behavior, where such systems are characterized as they have continous behavior without jump.	◯	◯
3)	The system behavior from x_2 to x_4 is classified as ID-behavior.	◯	◯
4)	The system behavior from x_2 to x_4 is classified as PDT_1-behavior.	◯	◯
5)	The associated differential constant $\widetilde{T}_D$ is: $$\widetilde{T}_D = \frac{T_I + T_D}{T_D T_I} \quad (2.1)$$	◯	◯
6)	Depending on the parameters (K, T) element no. 5 can has unstable behavior.	◯	◯
7)	The characterized system is a classical MISO-system (Multi-Input, Single-Output).	◯	◯
8)	Due to the complexity of the system (5 elements, 2 feedback loops), such systems can not be described by classical design methods, they have to be solved with the help of modern tools of numerics and simulation (Matlab/Simulink/Phyton/Mathematica).	◯	◯

2g) (5 points)

The dynamical behavior of the controlled system is described by the following equation

$$\tilde{T}_3\dot{y} + \tilde{T}_2 y + \tilde{T}_1 \int y dt = K_1 \int \left[x_1 + \frac{1}{T_{\mathrm{I}}} \int x_1 dt\right] .dt$$

Classify the resulting disturbance behavior ($z \rightarrow y$).
Classify the resulting system behavior of the whole system and give the static gains $K_{\mathrm{s},w}$ and $K_{\mathrm{s},z}$.
Use the parameter $T = 0$ for the controller.

☐

$\sum$ ☐