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.

THE ABOVE REQUIRED STATEMENTS AS WELL AS THE SIGNATURE ARE MANDATORY AT THE BEGINNING OF THE EXAM.

Duisburg, ______________ (Date) ________________________________ (Student's signature)

Falls Klausurunterlagen vorzeitig abgegeben: ______________Uhr

Bewertungstabelle

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

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

____
(Datum und Unterschrift 2. Prüfer, Prof. Dr.-Ing. Mohieddine Jelali, Priv.-Doz.)

____
(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:	**70**
Minimum points for the grade 1,0:	**95%**
Minimum points for the grade 4,0:	**50%**

General hints:

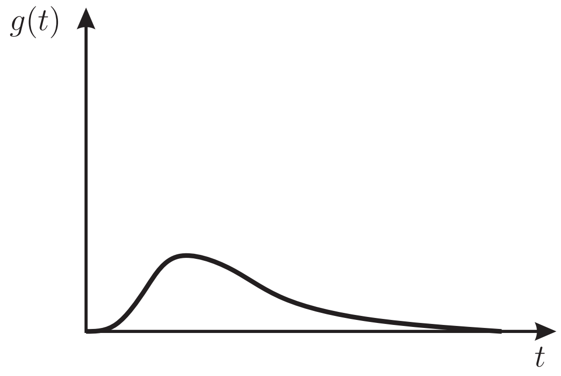
1) For the multiple-choice and multiple-choice-similar tasks the following rules are effective:
   i) For correct answers of exam task parts the desired number of points will be given.
   ii) For noncorrect answers of exam task parts the desired number of points will be counted negative.
   iii) No answering 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.

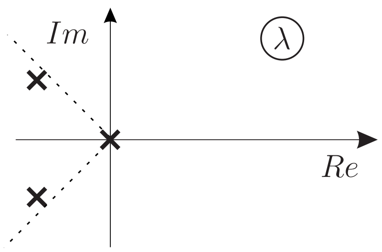
3) If in the exam tasks no information is given for applying negative or positive feedback: use the usual negative feedback.

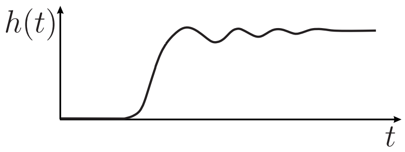
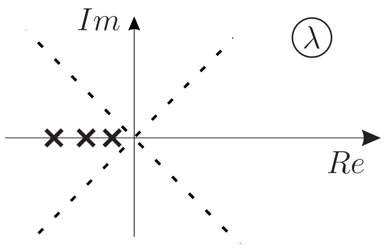
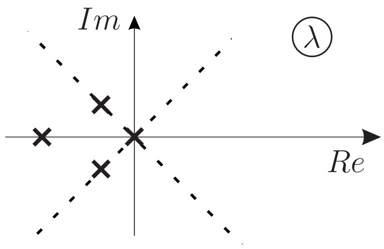
Problem 1 (40 Points)

1a) (3 × 5 × 1 Point, 15 Points)
Which of the following statements are true and which are false?

No.	Task/Question/Judgment	True	False
A.1)	The weighting function is the response of a system to the dirac delta function $u(t) = \delta(t)$ as input.	○	○
A.2)	The algorithm for the calculation of eigenvectors is $$Av_i = \lambda_i v_i,$$ with the system matrix A and the eigenvalues λ_i.	○	○
A.3)	The step response is a typical input signal.	○	○
A.4)	A linear system of second order with damping $D > 1$ can belong to the following step response. 	○	○
A.5)	The linearization of the equation $$f(x,y) = -\frac{1}{2}\sin(x)y + 2y^2 - \frac{1}{3}x$$ around the working point $(x_0, y_0) = (0, 0)$ results in $$f(x,y) = -\frac{1}{3}x.$$	○	○

□

No.	Task/Question/Judgment	True	False
B.1)	The differential equation $$T_2 y = K(u + T_\mathrm{D}\dot{u}),$$ describes a PDT_2-behavior.	○	○
B.2)	Second order transfer elements described by $$\frac{1}{\omega_0^2}\ddot{y} + \frac{2D}{\omega_0}\dot{y} + y = K[u + T_\mathrm{D}\dot{u}]$$ have a double real eigenvalue for $D = 1$.	○	○
B.3)	For $D > 1$ the system described in 1a)B.2) has two different eigenvalues without imaginary part.	○	○
B.4)	The reference value has to follow the state variable.	○	○
B.5)	A system with the eigenvalue distribution  has conjugate complexe eigenvalues.	○	○

No.	Task/Question/Judgment	True	False
C.1)	A linear differential equation with constant coefficients describes the time variant transfer behavior of the system.	○	○
C.2)	A system with the step response behavior  describes a system of second order with $D > 1$.	○	○
C.3)	A system with the eigenvalue distribution  is asymptotically stable.	○	○
C.4)	A system with the eigenvalue distribution  is unstable.	○	○
C.5)	An open loop control is a process in which the control variable is continuously measured and compared with the reference variable. The control variable is influenced in the way to follow the reference variable.	○	○

□

1b) (2 × 5 × 1 Point, 10 Points)

The transfer behavior of a technical system with u as input value, x_1 as output value, and $x = \begin{bmatrix} x_1 \\ \dot{x}_1 \end{bmatrix}$ as the state space vector is described by the differential equation

$$\ddot{x}_1 + 3\dot{x}_1 + 2x_1 = u.$$

Evaluate the statements in the following tables.

No.	Task/Question/Judgment	True	False
A.1)	The transfer behavior can be classified as PDT_2-behavior.	◯	◯
A.2)	The considered technical system has the following state space representation $$\begin{bmatrix} \dot{x}_1 \\ \ddot{x}_1 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ \dot{x}_1 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u,$$ $$y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ \dot{x}_1 \end{bmatrix}.$$	◯	◯
A.3)	The direct transmission matrix D has an influence on the ability of a system to oscillate.	◯	◯
A.4)	The eigenvalues are $\lambda_1 = 1$ and $\lambda_2 = 2$.	◯	◯
A.5)	The system can have the eigenvectors $$v_1 = \begin{bmatrix} 1 \\ -1 \end{bmatrix} \quad \text{and}$$ $$v_2 = \begin{bmatrix} 1 \\ -2 \end{bmatrix}.$$	◯	◯

☐

No.	Task/Question/Judgment	True	False
B.1)	The modal matrix V is $$V = \begin{bmatrix} 1 & 1 \\ 1 & 2 \end{bmatrix}.$$	○	○
B.2)	Due to the modal canonical form, the state space vector is transformed in such a way, that the motions of the new state variables are affecting each other.	○	○
B.3)	After the modal transformation the sytem matrix $\tilde{A}$ results in $$\tilde{A} = \begin{bmatrix} -1 & 0 \\ 0 & -2 \end{bmatrix}.$$	○	○
B.4)	The algorithm for the modal transformation of the output matrix C to $\tilde{C}$ is $\tilde{C} = CV$.	○	○
B.5)	Assume that the output matrix C is $$C = \begin{bmatrix} 0 & 1 \end{bmatrix}$$ and the modal matrix V is $$V = \begin{bmatrix} 0 & 1 \\ 1 & -1 \end{bmatrix}.$$ The transformed matrix $\tilde{C}$ results in $$\tilde{C} = \begin{bmatrix} 1 & -1 \end{bmatrix}.$$	○	○

☐

1c) (3 × 5 × 1 Point, 15 Points)
The eigenvalues of the I/O-behavior from four different linear systems without time delay are illustrated in Figure 1.1. Four measured step response functions $h(t)$ are shown in Figure 1.2. Evaluate the statements in the following tables.

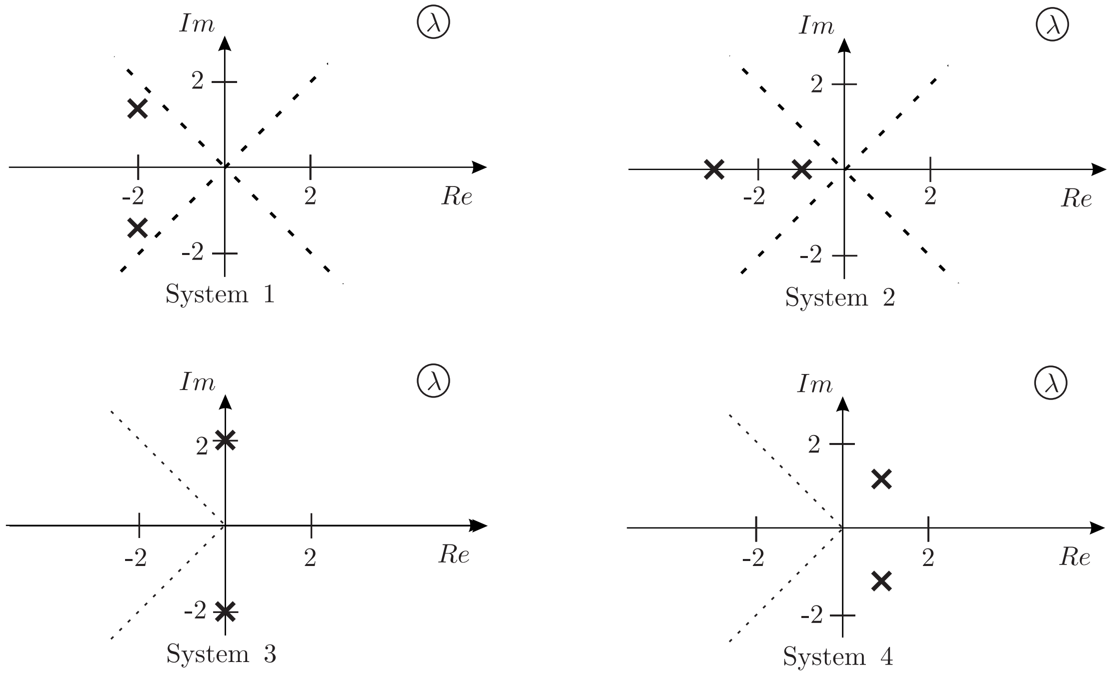


Figure 1.1: Eigenvalue distribution of four different systems

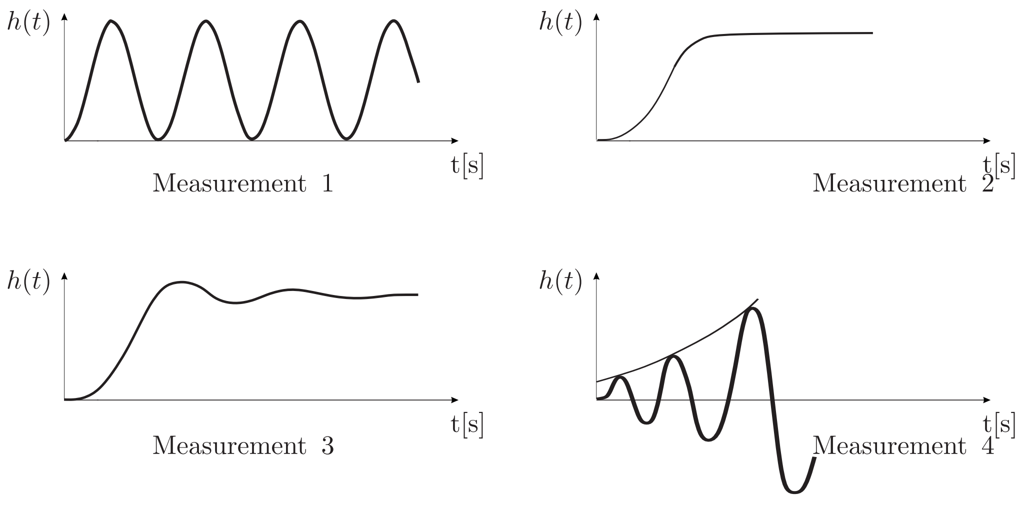


Figure 1.2: Step response functions of four different systems

No.	Task/Question/Judgment	True	False
A.1)	System 1 can be described by $\frac{1}{\omega_0^2}\ddot{y} + \frac{2D}{\omega_0}\dot{y} + y = Ku$.	◯	◯
A.2)	The eigenvalue distribution of the Systems 2 and 3 shows a strong damping behavior respectively.	◯	◯
A.3)	System 2 corresponds to a system with a damping $D > 1$.	◯	◯
A.4)	System 1 is asymptotically stable.	◯	◯
A.5)	From the eigenvalue distribution of the Systems 1 and 2 it can be concluded clearly that they have an identical static gain K in stationary behavior.	◯	◯

No.	Task/Question/Judgment	True	False
B.1)	The Measurements 2 and 3 show typical step response functions of PT_2-systems.	◯	◯
B.2)	The behavior of Measurement 3 shows a stronger damping than the behavior of Measurement 2.	◯	◯
B.3)	Measurement 3 shows time delay behavior.	◯	◯
B.4)	Measurement 2 could correspond to the behavior of a PT_1-system.	◯	◯
B.5)	Measurement 4 shows a damping behavior with $D < 0$.	◯	◯

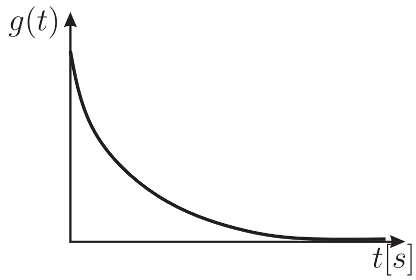
No.	Task/Question/Judgment	True	False
C.1)	Measurement 2 corresponds to system 2.	◯	◯
C.2)	Measurement 1 corresponds to system 3.	◯	◯
C.3)	Measurement 4 corresponds to system 4.	◯	◯
C.4)	Connecting a time delay system in series after system 1, measurement 4 can be obtained.	◯	◯
C.5)	Measurement 2 shows, that the underlying system has no dynamic (in the sense of delay or inertia).	◯	◯

□

$\sum$ □

Problem 2 (30 Points)

2a) (4 × 1 Point, 4 Points)
Which of the following statements are true and which are false?

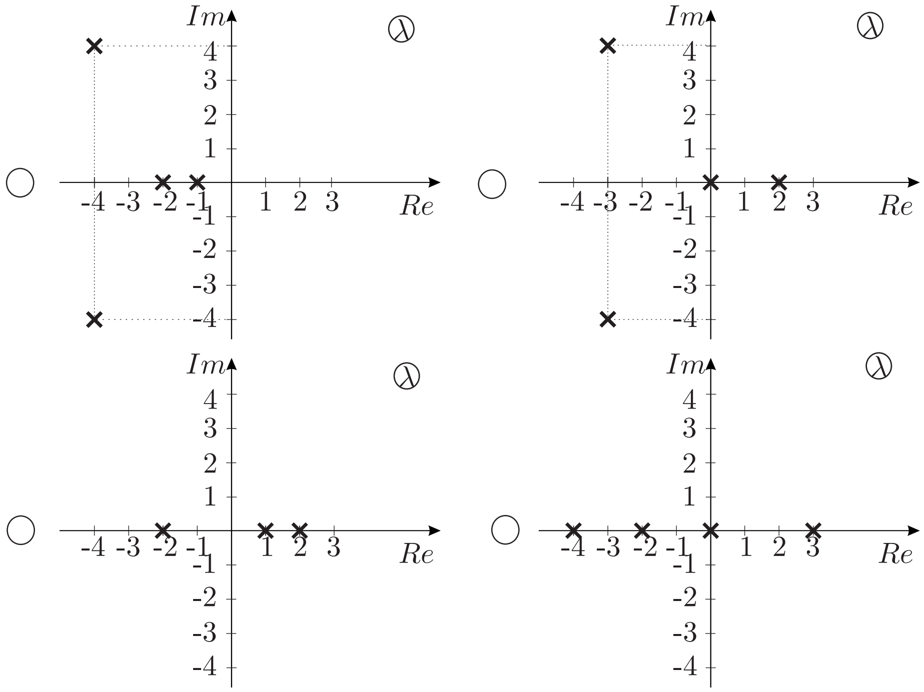
No.	Task/Question/Judgment	True	False
1)	From the description of the state behavior given by $x(t) = \phi(t)x_0(t=0) + \int_{t=0}^{t} \phi(t-\tau)bu(\tau)d\tau,$ the time response of the output $y = Cx(t)$ can be derived with the input value $u(t)$.	○	○
2)	In a system with time delay, the value of the output signal $y(t)$ at the time t depends on the input variable $u(t)$ at the previous time with the fixed time difference T_t.	○	○
3)	To design a controller: For proportional systems a PI-controller can be used.	○	○
4)	A system with DT_1-behavior has the following weighting function: 	○	○

2b) (2 Points)

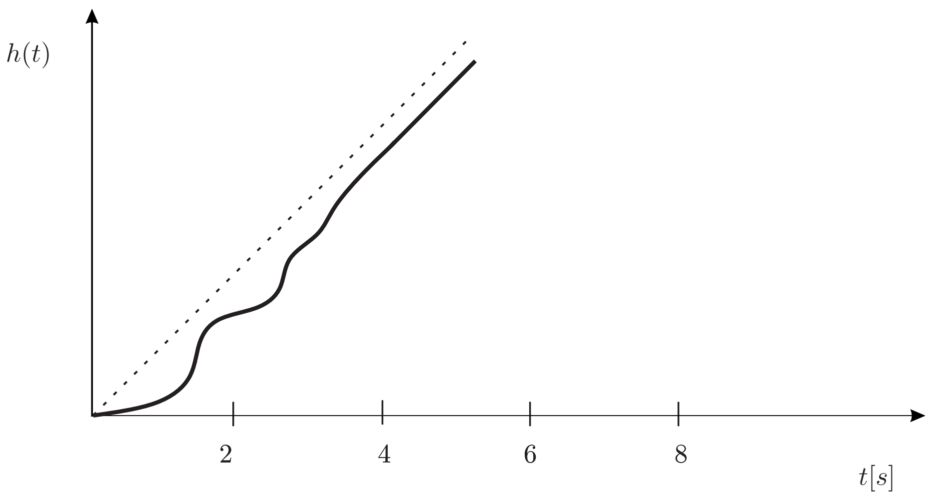
The I/O-transfer behavior

$$\dddot{y} - \ddot{y} - 4\dot{y} + 4y = 45u + \dot{u},$$

has the following eigenvalue distribution:



2c) (4 × 1 Point, 4 Points)
The measurement of the step response behavior of an open loop system is given in the figure below:



No.	Task/Question/Judgment	True	False
1)	It is definitively a non-linear system.	○	○
2)	There is no time delay behavior in the system response.	○	○
3)	The instationary behavior occurs, because the free motion of the system is influenced by the input variable $u(t)$.	○	○
4)	There is no doubt that this is an IT_1-behavior.	○	○

2d) (10 Points)
For the illustrated hydraulic cylinder in Figure 2.1 the equation of motion is given by: $\dot{y}(t) = \frac{q_e(t)}{A}$.

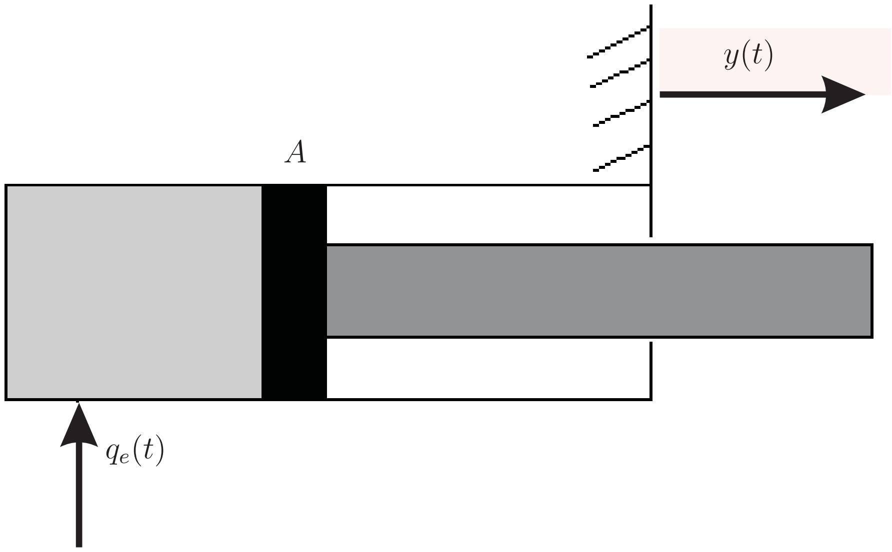


Figure 2.1: Model of a hydraulic cylinder

The cylinder model is the plant (refer to Figure 2.2). The plant should be controlled with negative feedback by a $\mathrm{PIT_1}$-controller with the parameters T_1 and T_I.

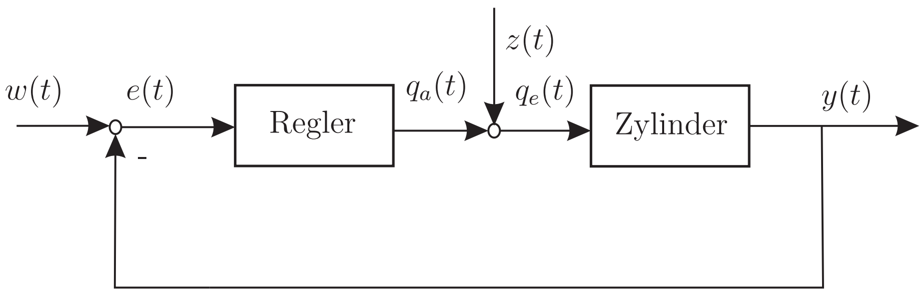


Figure 2.2: Regelkreis

i) (2 Points)
Give the corresponding differential equation for the controller in a suitable form for classification (standard form) using the given notations from Figure 2.2.

For further calculations, assume the following differential equation for the controller as

$$\text{controller:} \quad \dot{q_a} + q_a = K[e + \int e\, dt].$$

ii) (3 Points)
Determine the differential equation of the transfer behavior with respect to the desired value ($w \to y$) in standard form.

iii) (3 Points)
Determine the differential equation of the transfer behavior with respect to the disturbance ($z \to y$) in standard form.

iv) (2 Points)
Is the used controller suitable for a stationary accurate fixed value control ($\omega(t) = \text{constant}$)? State reasons.

2e) (2 × 5 × 1 Point, 10 Points)
The block diagram of a system with transfer elements is given (see Figure 2.3). Answer the following questions related to the mentioned system.

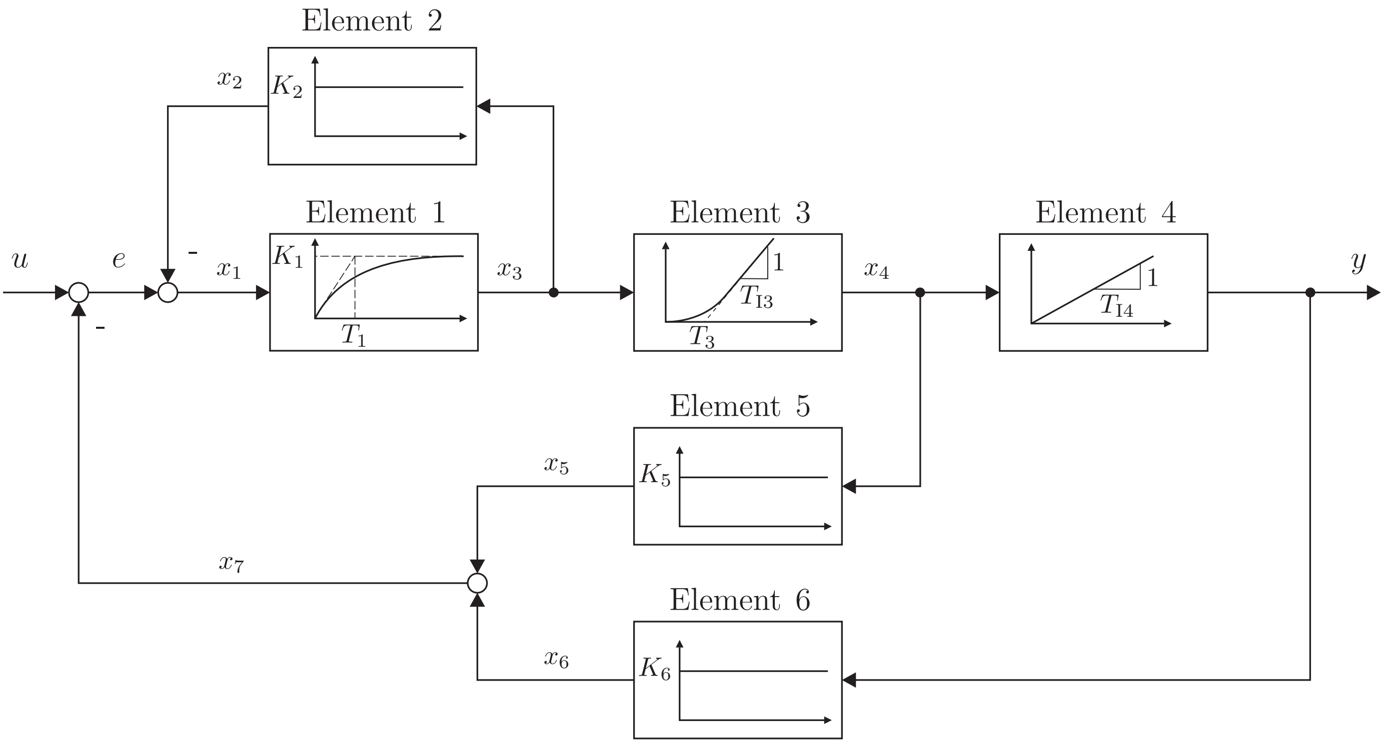


Figure 2.3: Block diagram of the system

No.	Task/Question/Judgment	True	False
A.1)	Element 6 is a system with proportional behavior.	○	○
A.2)	Element 3 is an IT_3-system.	○	○
A.3)	The system behavior from x_3 to x_7 contains time delay.	○	○
A.4)	The system behavior from x_3 to x_5 can be described by $$T_3\dot{x}_5 + x_5 = \frac{K_5}{T_{I3}} \int x_3 \, dt.$$	○	○
A.5)	Element 3 is boundary stable.	○	○

No.	Task/Question/Judgment	True	False
B.1)	Depending on the parameter T_{I4}, Element 4 can be able to oscillate.	○	○
B.2)	The system behavior from e to x_3 (Element 1 and Element 2) can be described by $$\frac{T_1}{1+K_1K_2}\dot{x}_3 + x_3 = \frac{K_1}{1+K_1K_2}e.$$	○	○
B.3)	Element 4 can be described by $$x_4 = \frac{1}{T_{\mathrm{I4}}}\int y\,dt.$$	○	○
B.4)	Proportional elements are dynamic transfer elements, which have a stationary final value in output proportional to a constant input $u(t)$.	○	○
B.5)	A block diagram describes the structure of a considered dynamic system.	○	○

☐

Σ ☐