PP2

TECHNICAL UNIVERSITY OF MOMBASA

School of Engineering and Technology

Department of Electrical and Electronic Engineering

UNIVERSITY EXAMINATION FOR:

Bachelor of Technology in Applied Physics (Electronics and Instrumentation)

EEE 4450: CONTROL III

END OF SEMESTER EXAMINATION

SERIES: JULY 2025 EXAM

TIME: 2 HOURS

DATE : July 2025

Instructions to Candidates

You should have the following for this examination

-Answer Booklet, examination pass and student ID

This paper consists of **five** Questions; Attempt any THREE Questions.

Do not write on the question paper.

Question ONE

(a) Compare and contrast classical control system design techniques with the state space approach to controller design (4 marks)

(b) Briefly explain the concept of state of a system (2 marks)

(c) State the different methods available in representing the system using state-space model (4 marks)

(d) Obtain the state-space model of the system whose transfer function is given by $G(s)=\frac{1}{(s+2)^2(s+1)}$ in Jordan canonical form (6 marks)

(e) Determine the state-space model of the system whose differential equation is given by $\frac{d^3y(t)}{dt^3}+4\frac{d^2y(t)}{dt^2}+7\frac{dy(t)}{dt}+2y(t)=5u(t)$ (4 marks)

Question TWO

(a) Define state transition matrix. (2 marks)

(b) Distinguish between singularity and non-singularity matrix (2 marks)

(c) State what is meant by Eigen values and Eigen vectors (4 marks)

(d) State what is meant by homogenous and non-homogenous state equations (2 marks)

(e) The state equation for a homogeneous system is given as $\begin{bmatrix}\dot{x}_1(t)\\ \dot{x}_2(t)\end{bmatrix}=\begin{bmatrix}1 & 0\\ 1 & 1\end{bmatrix}$. Determine the solution of the system when $\begin{bmatrix}x_1(0)\\ x_2(0)\end{bmatrix}=\begin{bmatrix}1\\ 0\end{bmatrix}$ (10 marks)

Question THREE

(a) Explain the terms controllability and observability (4 marks)

(b) A plant is represented by the state equations: $\dot{x}(t) = Ax(t) + Bu(t)$;, where

$A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$, $B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$, $C = \begin{bmatrix} 3 & 1 \end{bmatrix}$

State whether it is completely controllable and observable. (6 marks)

(c) For the state space model of (b) if an input $r(t) = 1(t)$ Find the full state feedback matrix H which place the poles of the closed loop system at positions $s_1 = (-2, +j2),\ s_2 = (-2, -j2)$ (10 marks)

Question FOUR

(a) A sampled data system has the following transfer function: $G(s) = \dfrac{1}{s+1}$. If the sampling time is 1second and the system is subjected to a unit step input, determine the discrete time response. Note that the system has no zero-order hold included. (6 marks)

(b) Figure Q4 (b) shows a digital control system. When the controller gain K is unity and the sampling time is 0.5 seconds, determine:

i) Open loop pulse transfer function
ii) Closed loop pulse transfer function
iii) The difference equation for the discrete time response
iv) The steady state value of the system output

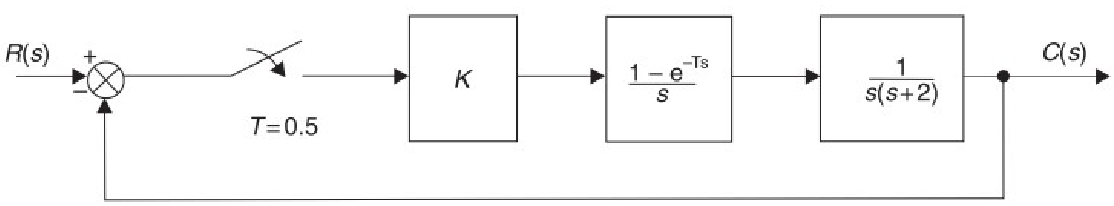

Figure Q4 (b) (14 marks)

Question FIVE

(a) Draw the block diagram and signal flow graph of discrete state-space model (4 marks)

(b) Determine the state equations of a discrete-time LTI system with system function

$G(z) = \dfrac{z}{2z^2 - 3z + 1}$ (6 marks)

(c) Sketch a block diagram of a discrete-time system with the state space representation

$x(k+1) = \begin{bmatrix} 0 & 1 \\ 2 & 5 \end{bmatrix} x(k) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(k)$

$y(k) = \begin{bmatrix} 8 & -7 \end{bmatrix} x(k)$ (4 marks)

(d) A discrete time system is to have the identical time response to the continuous system. State the desired closed loop poles and characteristic equations in

i) the s plane and
ii) the z plane

(4 marks)

(e) State the conditions of stability in the z-domain for the closed loop system of Figure Q 5(e). (2 marks)

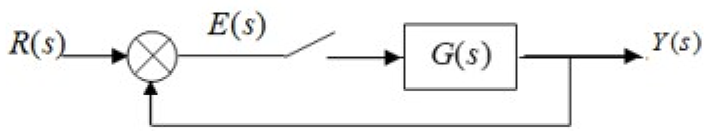

Figure Q 5(e)

Table of Laplace and Z-transforms

	$X(s)$	$x(t)$	$x(kT)$ or $x(k)$	$X(z)$
1.	–	–	Kronecker delta $\delta_0(k)$ 1 $k = 0$ 0 $k \neq 0$	1
2.	–	–	$\delta_0(n-k)$ 1 $n = k$ 0 $n \neq k$	z^{-k}
3.	$\frac{1}{s}$	$1(t)$	$1(k)$	$\frac{1}{1-z^{-1}}$
4.	$\frac{1}{s+a}$	e^{-at}	e^{-akT}	$\frac{1}{1-e^{-aT}z^{-1}}$
5.	$\frac{1}{s^2}$	t	kT	$\frac{Tz^{-1}}{(1-z^{-1})^2}$
6.	$\frac{2}{s^3}$	t^2	$(kT)^2$	$\frac{T^2z^{-1}(1+z^{-1})}{(1-z^{-1})^3}$
7.	$\frac{6}{s^4}$	t^3	$(kT)^3$	$\frac{T^3z^{-1}(1+4z^{-1}+z^{-2})}{(1-z^{-1})^4}$
8.	$\frac{a}{s(s+a)}$	$1-e^{-at}$	$1-e^{-akT}$	$\frac{(1-e^{-aT})z^{-1}}{(1-z^{-1})(1-e^{-aT}z^{-1})}$
9.	$\frac{b-a}{(s+a)(s+b)}$	$e^{-at}-e^{-bt}$	$e^{-akT}-e^{-bkT}$	$\frac{(e^{-aT}-e^{-bT})z^{-1}}{(1-e^{-aT}z^{-1})(1-e^{-bT}z^{-1})}$
10.	$\frac{1}{(s+a)^2}$	te^{-at}	kTe^{-akT}	$\frac{Te^{-aT}z^{-1}}{(1-e^{-aT}z^{-1})^2}$
11.	$\frac{s}{(s+a)^2}$	$(1-at)e^{-at}$	$(1-akT)e^{-akT}$	$\frac{1-(1+aT)e^{-aT}z^{-1}}{(1-e^{-aT}z^{-1})^2}$
12.	$\frac{2}{(s+a)^3}$	t^2e^{-at}	$(kT)^2e^{-akT}$	$\frac{T^2e^{-aT}(1+e^{-aT}z^{-1})z^{-1}}{(1-e^{-aT}z^{-1})^3}$
13.	$\frac{a^2}{s^2(s+a)}$	$at-1+e^{-at}$	$akT-1+e^{-akT}$	$\frac{[(aT-1+e^{-aT})+(1-e^{-aT}-aTe^{-aT})z^{-1}]z^{-1}}{(1-z^{-1})^2(1-e^{-aT}z^{-1})}$
14.	$\frac{\omega}{s^2+\omega^2}$	$\sin \omega t$	$\sin \omega kT$	$\frac{z^{-1}\sin\omega T}{1-2z^{-1}\cos\omega T+z^{-2}}$
15.	$\frac{s}{s^2+\omega^2}$	$\cos \omega t$	$\cos \omega kT$	$\frac{1-z^{-1}\cos\omega T}{1-2z^{-1}\cos\omega T+z^{-2}}$
16.	$\frac{\omega}{(s+a)^2+\omega^2}$	$e^{-at}\sin \omega t$	$e^{-akT}\sin \omega kT$	$\frac{e^{-aT}z^{-1}\sin\omega T}{1-2e^{-aT}z^{-1}\cos\omega T+e^{-2aT}z^{-2}}$
17.	$\frac{s+a}{(s+a)^2+\omega^2}$	$e^{-at}\cos \omega t$	$e^{-akT}\cos \omega kT$	$\frac{1-e^{-aT}z^{-1}\cos\omega T}{1-2e^{-aT}z^{-1}\cos\omega T+e^{-2aT}z^{-2}}$
18.	–	–	a^k	$\frac{1}{1-az^{-1}}$
19.	–	–	a^{k-1} $k = 1, 2, 3, \ldots$	$\frac{z^{-1}}{1-az^{-1}}$
20.	–	–	ka^{k-1}	$\frac{z^{-1}}{(1-az^{-1})^2}$
21.	–	–	k^2a^{k-1}	$\frac{z^{-1}(1+az^{-1})}{(1-az^{-1})^3}$
22.	–	–	k^3a^{k-1}	$\frac{z^{-1}(1+4az^{-1}+a^2z^{-2})}{(1-az^{-1})^4}$
23.	–	–	k^4a^{k-1}	$\frac{z^{-1}(1+11az^{-1}+11a^2z^{-2}+a^3z^{-3})}{(1-az^{-1})^5}$
24.	–	–	$a^k\cos k\pi$	$\frac{1}{1+az^{-1}}$

$x(t) = 0$ for $t < 0$
$x(kT) = x(k) = 0$ for $k < 0$
Unless otherwise noted, $k = 0, 1, 2, 3, \ldots$