PP2

TECHNICAL UNIVERSITY OF MOMBASA

School of Engineering and Technology

Department of Electrical and Electronic Engineering

UNIVERSITY EXAMINATION FOR:

Bachelor of Science in Electrical and Electronic Engineering

EEE 4517: CONTROL ENGINEERING IV

END OF SEMESTER EXAMINATION

SERIES: NOVEMBER 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) State the advantages and disadvantages of feedback and feed forward controllers (4 marks)

(b) Explain why derivative mode of control is not recommended for a noisy process (2 marks)

(c) A PI controller has 20% proportional band and integral time of 10 seconds. for a constant error of 5%., determine the controller output after 10 seconds if the controller offset is 25%. (2 marks)

(d) Draw and explain process control loops for Supervisory and Direct digital control (DDC) (4 marks)

(e) Explain with sketches the following types of singular nodes (6 marks)

i) Stable node

ii) Saddle point

iii) Stable focus.

(f) Explain what is meant by limit cycles and Finite escape time in nonlinear systems (4 marks)

(g) Explain Sampling theorem (2 marks)

(h) Explain bilinear transformation (2 marks)

(i) The 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)

Question TWO

(a) Distinguish between linear and nonlinear systems (2 marks)

(b) State any two advantages and two disadvantages of phase plane analysis (4 marks)

(c) Figure Q2 (c) whose governing differential equation is given as: $\ddot{x} + x = 0$ is a mass attached to a spring.

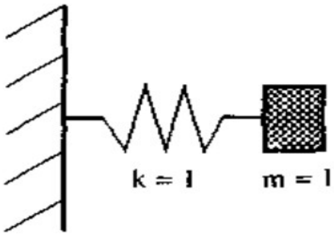

Figure Q2 (c)

Assume that the mass is initially at rest, at length x_o. Obtain the equations of the trajectories and hence construct the phase portrait. (6 marks)

(d) The characteristics of a hardening spring are given by:

$$f(x)=x+\frac{x^3}{2}$$

Given the input $x=A\sin(\omega t)$ obtain the describing function of the spring (8 marks)

Question THREE

(a) State the effects of the following control actions on system performance.

i) Integral action and

ii) Derivative action

(4 marks)

(b) A unity feedback control system has a proportional controller of gain K_p and a forward transfer function:

$$G(s)=\frac{1}{s^2+2s}$$

A derivative controller of gain constant K_d is introduced into the closed loop system. Show that the damping factor increases but the natural frequency of the system remains unchanged

(7 marks)

(c) Briefly describe the open loop reaction method of controller tuning (5 marks)

(a) In an application of the Zeigler-Nichol's method of controller tuning, a process begins oscillations with a 30% proportional band in an $11.5\ \text{min}$ period. Find the nominal three-term controller settings given the following data: $K_p=0.6K_c,\ \ T_i=T_c/2,\ \ T_d=T_c/8$; The notations have the usual meanings. (4 marks)

Question FOUR

(a) Describe the Sample & Hold operation (4 marks)

(b) Find the z-transform of a unit ramp signal (4 marks)

(c) Define the initial and final value of the system's impulse when

$$Y(z)=\frac{2z^2}{(z-1)(z-\alpha)(z-\beta)},|\alpha|,|\beta|>1$$

(4 marks)

(d) Implement digital PID controller algorithm using the position and the velocity versions. (8 marks)

Question FIVE

(a) Determine the z- transforms for the following continuous functions:

i) step function $f_1(t)=u(t)$

ii) ramp input $f_2(t)=at$

(6 marks)

(b) For the transfer function $G(s)=\dfrac{1}{(s+1)(s+2)}$ obtain the pulse transfer function $G(z)$ (10 marks)

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

$$\begin{bmatrix} x_1(k+1) \\ x_2(k+1) \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 2 & 5 \end{bmatrix} \begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u(k)$$

$$y(k) = \begin{bmatrix} 8 & -7 \end{bmatrix} \begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix}$$

(4 marks)

Table of Laplace and Z-transforms

	$X(s)$	$x(t)$	$x(kT)$ or $x(k)$	$X(z)$
1.	–	–	Kronecker delta $\delta_0(k)$ 1 $\quad k = 0$ 0 $\quad k \neq 0$	1
2.	–	–	$\delta_0(n-k)$ 1 $\quad n = k$ 0 $\quad n \neq k$	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	$\frac{Tz^{-1}}{\left(1-z^{-1}\right)^2}$
6.	$\frac{2}{s^3}$	t^2	$(kT)^2$	$\frac{T^2z^{-1}\left(1+z^{-1}\right)}{\left(1-z^{-1}\right)^3}$
7.	$\frac{6}{s^4}$	t^3	$(kT)^3$	$\frac{T^3z^{-1}\left(1+4z^{-1}+z^{-2}\right)}{\left(1-z^{-1}\right)^4}$
8.	$\frac{a}{s(s+a)}$	$1-e^{-at}$	$1-e^{-akT}$	$\frac{\left(1-e^{-aT}\right)z^{-1}}{\left(1-z^{-1}\right)\left(1-e^{-aT}z^{-1}\right)}$
9.	$\frac{b-a}{(s+a)(s+b)}$	$e^{-at}-e^{-bt}$	$e^{-akT}-e^{-bkT}$	$\frac{\left(e^{-aT}-e^{-bT}\right)z^{-1}}{\left(1-e^{-aT}z^{-1}\right)\left(1-e^{-bT}z^{-1}\right)}$
10.	$\frac{1}{(s+a)^2}$	te^{-at}	kTe^{-akT}	$\frac{Te^{-aT}z^{-1}}{\left(1-e^{-aT}z^{-1}\right)^2}$
11.	$\frac{s}{(s+a)^2}$	$(1-at)e^{-at}$	$(1-akT)e^{-akT}$	$\frac{1-(1+aT)e^{-aT}z^{-1}}{\left(1-e^{-aT}z^{-1}\right)^2}$
12.	$\frac{2}{(s+a)^3}$	t^2e^{-at}	$(kT)^2e^{-akT}$	$\frac{T^2e^{-aT}\left(1+e^{-aT}z^{-1}\right)z^{-1}}{\left(1-e^{-aT}z^{-1}\right)^3}$
13.	$\frac{a^2}{s^2(s+a)}$	$at-1+e^{-at}$	$akT-1+e^{-akT}$	$\frac{\left[\left(aT-1+e^{-aT}\right)+\left(1-e^{-aT}-aTe^{-aT}\right)z^{-1}\right]z^{-1}}{\left(1-z^{-1}\right)^2\left(1-e^{-aT}z^{-1}\right)}$
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}	$\frac{z^{-1}}{\left(1-az^{-1}\right)^2}$
21.	–	–	k^2a^{k-1}	$\frac{z^{-1}\left(1+az^{-1}\right)}{\left(1-az^{-1}\right)^3}$
22.	–	–	k^3a^{k-1}	$\frac{z^{-1}\left(1+4az^{-1}+a^2z^{-2}\right)}{\left(1-az^{-1}\right)^4}$
23.	–	–	k^4a^{k-1}	$\frac{z^{-1}\left(1+11az^{-1}+11a^2z^{-2}+a^3z^{-3}\right)}{\left(1-az^{-1}\right)^5}$
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, $k = 0, 1, 2, 3, \ldots$