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: MARCH 2025 EXAM

TIME: 2 HOURS

DATE: Pick DateSelect MonthPick Year

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 Question ONE any other TWO Questions.

Do not write on the question paper.

Question ONE

(a) Draw a block diagram of a simple process-control loop and identify each element. (5 marks)

(b) Distinguish between supervisory and direct digital control as applied in process control systems (2 marks)

(c) Draw process control loops for:

i) Supervisory control

ii) Direct digital control (DDC)

(4 marks)

(d) Classify with examples, the following types of nonlinearities

i) Inherent nonlinearities, and

ii) Intentional nonlinearities.

(4 marks)

(e) Describe the characteristics of the following nonlinearities

i) Saturation

ii) Friction

iii) Dead zone

(6 marks)

(f) Find the z-transform of the unit step function $f(t)=1$ (3 marks)

(g) Given that: $U(z)=\frac{z}{(z-2)(z-4)}$, Expand $U(z)$ into partial fraction form and find its time domain representation using inverse z-transform . (6 marks)

Question TWO

(a) Linearize the nonlinear equation $z = xy$ in the region $5 \le x \le 7; 10 \le y \le 12$ (6 marks)

A system is described by the following second-order nonlinear differential equation:

$$\frac{d^2x}{dt^2} + x^2\left(\frac{dx}{dt} - 1\right) + x = 0,$$

Investigate the stability of the system near the point of equilibrium. (7 marks)

(b) A nonlinear continuous system represented by:

$$\frac{d^2x}{dt^2} + \frac{dx}{dt} + \left(\frac{dx}{dt}\right)^3 + x = 0$$

. Prove that the system is stable according to the function of Lyapunov $V(x) = (x_1^2 + x_2^2)$. (7 marks)

Question THREE

(a) Consider the second order system: $\ddot{x} + \alpha\dot{x} - x + x^3 = 0$. Determine:

i) The equilibrium points
ii) the eigenvalues
iii) The corresponding eigenvectors

(6 marks)

(b) Describe the following frequency response methods of nonlinear systems analysis

i) Describing function
ii) Nyquist stability criterion

(8 marks)

(c) Define the following with reference to nonlinear system

i) Singular points
ii) Limit cycles
iii) Autonomous system

(6 marks)

Question FOUR

(a) For the system of Figure Q 4(a) with $G(s) = \frac{1}{s+1}$ and $T = 0.1$ s, Derive the controller $D(z)$ that satisfies the steady-state error requirement¿0.01, when a unit ramp function is applied.

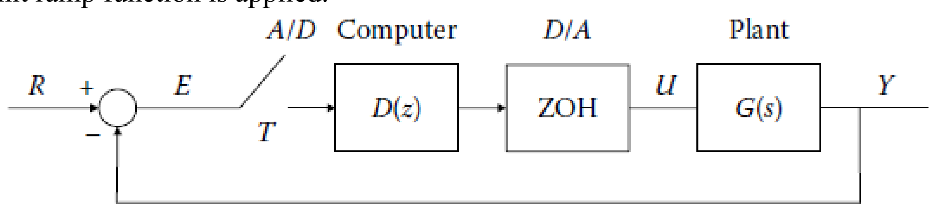

Figure Q4 (a) (14 marks)

(a) Derive the difference equations of the systems with transfer functions:

i) $G(z) = \frac{z^4 + 3z^3 + 2z^2 + z + 1}{z^4 + 4z^3 + 5z^2 + 3z + 2}$ and

ii) $H(z) = \frac{z}{5z^2 - 1.7z + 0.72}$ (6 marks)

Question FIVE.

(a) A three-term controller is described by the equation

$$\theta_c(t) = 20\left[e(t) + \frac{1}{T_r}\int_0^t e(t)\,dt + T_d\frac{de(t)}{dt}\right]$$

Where, θ_c is controller output, T_r is the integral reset time., $e(t)$ is system error and T_d is the derivative time. This controller is used to control a process with transfer function

$$G(s)=\frac{40}{10s^2+80s+800}.$$

Unity feedback is used. If the integral action is not employed, find the derivative time required to make the closed loop damping ratio unity. (10 marks)

(b) Explain how a Deadbeat Digital Controller works (4 marks)

(c) Briefly explain the Stability limit method of digital PID controller tuning (6 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, $k = 0, 1, 2, 3, \ldots$