University of Eswatini
Faculty of Science and Engineering
Department of Electrical and Electronic Engineering

Main Examination 2021

Title of Paper:	Control Engineering II
Course Number:	EEE533
Time Allowed:	3 hrs

Instructions:

1. Answer all four (4) questions.
2. Each question carries 25 marks.

This paper should not be opened until permission has been given by the invigilator.

This paper contains four (4) pages including this page.

Question 1

a) Show the block diagram of a state-space system with full state-feedback, a state observer and reference input. And briefly describe the design procedure for a controller/observer in state-space systems.

[10]

b)

i) Convert the following transfer function into phase-variable form

[8]

$$G(s) = \frac{10}{(s^2+2)(s+100)}$$

ii) Determine if it is observable.

[7]

Question 2

a) Discuss 4 common behaviours of non-linear systems.

[8]

b) For the system $\dot{x} = Ax$, using the Lyapunov equation $AP + A^T P = -Q$, determine the stability of the system. Use the identity matrix as Q.

[7]

$$A = \begin{bmatrix} 0 & 4 \\ -8 & -2 \end{bmatrix}$$

c) Use Krasovskii's theorem to find a Lyapunov function candidate for the system below:

[10]

$$\dot{x}_1 = -8x_1 + 3x_2$$
$$\dot{x}_2 = -3x_1 - 4x_2 - 2x_2^3$$

Question 3

a) Discuss 3 advantages of implementing digital control systems over analogue systems.

[6]

b) For the system of Figure 1, find the sampled-data transfer function $G(z) = \frac{Y(Z)}{R(Z)}$ if the sampling time, $T = 0.5$s.

[10]

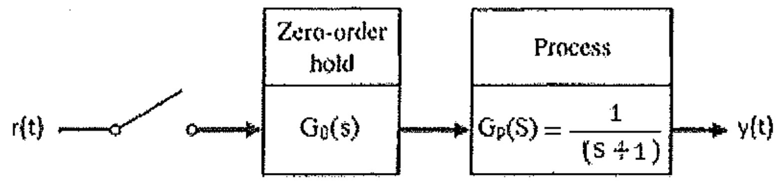

Figure 1

c) For the given system below, find the steady-state error for a ramp and parabolic input. [9]

$$G(z) = 20\left(\frac{T}{z-1} - 1 + \frac{z-1}{z-e^{-T}}\right)$$

Question 4

Determine the stability of the following systems.

i)

$$G(s) = \frac{6s+4}{2s^2+6s+4}$$

[5]

ii)

$$\dot{\mathbf{x}}(\mathbf{t}) = \begin{bmatrix} 3 & 0 \\ 1 & 2 \end{bmatrix} \mathbf{x}(\mathbf{t}) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} \mathbf{u}(\mathbf{t})$$

$$\mathbf{y}(\mathbf{t}) = \begin{bmatrix} 1 & 1 \end{bmatrix} \mathbf{x}(\mathbf{t})$$

[5]

iii)

$$\dot{x} = 9x - x^3$$

(hint: find the equilibrium points first)

[7]

iv)

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

Sampling time, $T = 0.001$s

[8]

APPENDIX

z-Transforms

$x(t)$	$X(s)$	$X(z)$
$u(t)$, unit step	$1/s$	$\dfrac{z}{z-1}$
t	$1/s^2$	$\dfrac{Tz}{(z-1)^2}$
e^{-at}	$\dfrac{1}{s+a}$	$\dfrac{z}{z-e^{-aT}}$
$1-e^{-at}$	$\dfrac{1}{s(s+a)}$	$\dfrac{(1-e^{-aT})z}{(z-1)(z-e^{-aT})}$
$\sin(\omega t)$	$\dfrac{\omega}{s^2+\omega^2}$	$\dfrac{z\sin(\omega T)}{z^2-2z\cos(\omega T)+1}$
$\cos(\omega t)$	$\dfrac{s}{s^2+\omega^2}$	$\dfrac{z(z-\cos(\omega T))}{z^2-2z\cos(\omega T)+1}$
$e^{-at}\sin(\omega t)$	$\dfrac{\omega}{(s+a)^2+\omega^2}$	$\dfrac{(ze^{-aT}\sin(\omega T))}{z^2-2ze^{-aT}\cos(\omega T)+e^{-2aT}}$
$e^{-at}\cos(\omega t)$	$\dfrac{s+a}{(s+a)^2+\omega^2}$	$\dfrac{z^2-ze^{-aT}\cos(\omega T)}{z^2-2ze^{-aT}\cos(\omega T)+e^{-2aT}}$

Final Value Theorem for discrete signals:

$$e(\infty) = \lim_{z\to 1} 1 - z^{-1}\frac{R(z)}{1+G(z)}$$