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(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

SUPPLEMENTARY/SPECIAL UNIVERSITY EXAMINATIONS

2021/2022 ACADEMIC YEAR

FIFTH YEAR FIRST SEMESTER EXAMINATIONS

FOR THE DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL AND COMMUNICATION ENGINEERING

COURSE CODE: ECE 513

COURSE TITLE: NON-LINEAR AND MULTIVARIABLE CONTROL

DATE: OCTOBER 3RD, 2022 **TIME: 3:00PM - 5:00PM**

INSTRUCTIONS TO CANDIDATES

ANSWER QUESTION ONE AND ANY OTHER TWO QUESTIONS.
QUESTION ONE CARRIES 30 MARKS AND ALL OTHERS 20 MARKS EACH.

TIME: 2 Hours

MMUST observes ZERO tolerance to examination cheating

QUESTION ONE (COMPULSORY) (30 MARKS)

1. Differentiate the following types of nonlinearities using appropriate examples.
   i. Inherent nonlinearities and intentional nonlinearities
   ii. Static nonlinearities and dynamic nonlinearities
   iii. Functional nonlinearities and piece-wise nonlinearities.

[6 Marks]

2. State at least 4 differences between linear and nonlinear systems.

[4 Marks]

3. A 2nd order system is represented by $\dot{x} = Ax$. Where, $A = \begin{bmatrix} -1 & 1 \\ -2 & -4 \end{bmatrix}$, using Lyapunov theorems determine the stability of the system at the origin.

[4 Marks]

4. Derive the describing function of a simple dead zone

[8 Marks]

5. The response of a system is $y = ax^3 + e^{bx}$. Test whether the system is linear or nonlinear.

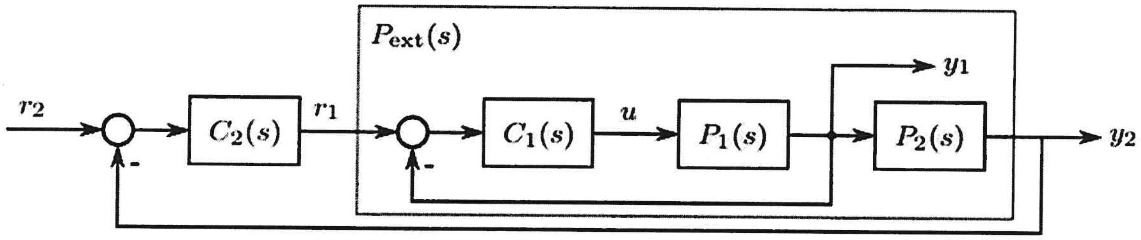
[4 Marks]

6. Discuss the terms stability in the large and stability in the small

[4 Marks]

QUESTION TWO (20 MARKS)

1. The control system of a SISO system is given below



Where the plant P_1 is given as $P_1 = \frac{1}{s+1}$ and the inner controller C_1 is given as $C_1(s) = 5$. To design the outer controller C_2, calculate the transfer function of the extended plant P_{ext} which includes the inner control loop and P_2, where $P_2 = \frac{1}{5s+1}$.

[4 Marks]

2. A nonlinear second order servo is described by the equation below

$$\ddot{e} + 2\zeta\omega_n\dot{e} + 2\omega_n e + e^2 = 0$$

Where $\zeta = 0.25$, $\omega_n = 1$ rad/sec.
   i. Find all the singularities of the system
   ii. Classify all singularities
   iii. Sketch the phase portrait in the neighborhood of the equilibrium points

[10 Marks]

3. What are the desirable characteristics of the nonlinear element while performing a describing function analysis?

[4 Marks]

4. State at least two disadvantages of linearization to solve non-linear systems.

[2 Marks]

QUESTION THREE (20 MARKS)

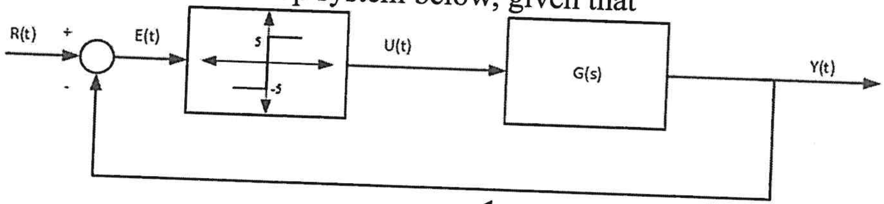
1. State the Aizerman's and Kalman's conjecture.

[4 Marks]

2. Using phase plane diagrams, differentiate between the following:
   i. Stable node and unstable node
   ii. Stable focus and unstable focus
   iii. Saddle point and vortex

[6 Marks]

3. Consider a nonlinear closed loop system below, given that



$$G(s) = \frac{1}{s(1+s)(s+6)}$$

   i. Determine if a limit cycle exist
   ii. if so determine if the limit cycle is a sustained oscillation
   iii. find the amplitude and frequency of the limit cycle.

[10 Marks]

QUESTION FOUR (20 MARKS)

1. Consider a nonlinear system given by $\ddot{y} + \dot{y} + y = 0$. Construct the phase trajectory, using the method of Isoclines. Choose slope as $N = \{-4, -3, -2, -1, 0, 1, 2, 3\}$.

[8 Marks]

2. Discuss stability with reference to Linear Time Invariant systems

[2 Marks]

3. Given a scalar function $V(x) = 4x_1^2 + 2x_2^2 + x_3^2 + 2x_1x_2 + x_2x_3 + 2x_1x_3$ represent it in quadratic form and based on Sylvester's Theorem determine its definiteness.

[6 Marks]

4. State and explain Popov's hyperstability theorem.

[4 Marks]

QUESTION FIVE (20 MARKS)

1. An input $x(t)$ and an output $y(t)$ of a nonlinear system are related through a nonlinear differential equation. Find the describing function of the system.

$$y = x^2\frac{dx}{dt} + 2x$$

[6 Marks]

2. Discuss the following terms using appropriate equations and drawings

   i. Lyapunov stability

   ii. Asymptotic stability

   iii. Quasi-asymptotic stability

[6 Marks]

3. For the system described by the equation below, determine the equilibrium point and check for its stability using Lyapunov's stability theorem.

$$\dot{x}_1 = -x_1 - x_2(x_1^2 + x_2^2)$$
$$\dot{x}_2 = x_2 - x_1(x_1^2 + x_2^2)$$

[8 Marks]