M.E. ELECTRICAL ENGINEERING FIRST YEAR FIRST SEMESTER EXAM 2025

NONLINEAR CONTROL (CS)

Time: Three hours **Part-I** **Full Marks 100**
(50 marks for each part)✓

Use a separate Answer-Script for each part

Answer Question No. 1 and any Two from the rest.

Two marks are reserved for neat and well-organized answers

Q1) Answer any four questions 4X4=16

i) With the help of an example prove the fact that a nonlinear system can have multiple non isolated equilibrium points.

ii) What is an equilibrium point? Define mathematically.

iii) State, whether the following claim is True or False. Justify your answer citing suitable reasons.

"Undamped oscillation exhibited by a marginally stable linear system is not a robust sustained oscillation".

iv) Explain the phenomenon of Chaos in brief.

v) What do you understand by the term "non-autonomous system".

Q2) Write short notes on any two 8+8

i) Phenomenon of Bifurcation
ii) Limit Cycle Oscillation
iii) Reachability and Controllability Sets

Q3a) Consider the first order system $\dot{x} = f(x) = -x^2 + 2x + 15$. Plot f(x) versus x (a rough sketch would suffice). Find out the equilibrium points. 5

Q3b) Draw the vector fields and comment on the stability of the equilibrium points. Justify your answer citing suitable reasons. 5

Q3c) Draw a few representative trajectories. From the representative trajectory plots explain the notion of "Uniqueness of a solution" of the differential equation. 6

Q4a) What is an Isocline? With the help of a suitable diagram explain the method of Isoclines for constructing phase trajectories. 8

Q4b) Consider the following linear mass-spring system. Construct three isoclines. Choose a suitable initial condition.

$$\ddot{x} + x = 0$$

With the help of the constructed isoclines construct a portion of a phase trajectory 8

Q5) Consider an on-off nonlinearity with dead-zone. Draw the transfer characteristic of the combined nonlinearity. Derive the Describing Function for this nonlinearity. 16

Ref. No. : **Ex/PG/EE/T/115B/2025**

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Part-II

Answer any three questions. Two marks reserved for neatness.

Answer all parts of a question in the sequential order.

1. a) Explain the following with suitable diagram:

i) Equilibrium state

ii) Local Stability

iii) Global Stability

iv) Asymptotic stability

b) Explain, with example, the Direct method of Lyapunov for the stability analysis of nonlinear systems.

[8+8=16]

2. a) Explain the important features of Lyapunov Candidate Functions.

b) Explain Krasovskii's method of finding Lyapunov Candidate function. What are its limitations?

[4+10+2=16]

3. Derive the feedback control law for the following system employing Integrator Backstepping:

$$\dot{\eta} = f(\eta) + g(\eta)\xi$$
$$\dot{\xi} = u$$

Where η and ξ are the system states and u is the control input.

Why is it called "Integrator Backstepping"?

[14+2=16]

4. a) How does the Sliding Mode Controller in closed loop render a system to work as a Variable Structure System?

b) Explain the various steps to design a Sliding Mode Controller for nonlinear system with known bounds of model uncertainties.

[6+10=16]

5. Write short note on **ANY TWO** from the following:

a) Strict Feedback Form model of nonlinear systems.

b) Strengths and weaknesses of feedback linearization.

c) Methods to reduce chattering in Sliding Mode Control.

d) Indirect method of Lyapunov for stability analysis.

[8+8=16]