

M.E. ELECTRICAL ENGINEERING FIRST YEAR FIRST SEMESTER EXAM 2024

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 Any Three Questions

Two marks are reserved for neat and well-organized answers

- Q1a) A nonlinear control system can have multiple equilibrium points. Justify the statement with the help of a suitable example. 4
- Q1b) Explain the phenomenon of bifurcation with the help of Duffing Equation. In this respect establish the physical significance of the Duffing Equation. 4+3
- Q1c) Why Van der Pol equation is considered to be a benchmark problem for understanding the phenomenon of limit cycle? Explain. 5
- Q2a) Explain the notion of equilibrium point/s with the help of suitable example. Also define equilibrium point/s mathematically. 4
- Q2b) Why equilibrium points are called singular points for a second order nonlinear/linear system? Explain. 4
- Q2c) Consider the following nonlinear differential equation
- $$\ddot{y} - \left(0.1 - \frac{10}{3} \dot{y}^2\right) \dot{y} + y + y^3 = 0$$
- i) Find all the singularities of the system.
ii) Identify the nature of the singularities 2+6
- Q3a) Consider the first order system $\dot{x} = f(x) = -x^2 + 2x + 24$. Plot $f(x)$ versus x (a rough sketch would suffice). Find out the equilibrium points. Draw a few representative trajectories. 7

[Turn Over

- Q3b) Draw the vector fields and comment on the stability of the equilibrium points. Justify your answer citing suitable reasons. 5
- Q3c) From the representative trajectory plots explain the notion of “Uniqueness of a solution” of the differential equation. 4
- Q4) Consider a nonlinear element consisting of dead-zone and saturation kind of nonlinearity. Draw the transfer characteristic of the combined nonlinearity. Derive the Describing Function for this nonlinearity. 16
- Q5) Write short notes on any two 8+8
- i) Admissible Control
 - ii) Significance of Forward and Backward Integration
 - iii) Domains of Attraction and Effectiveness

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Use separate answer-scripts for each parts.**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 challenges that occur while analyzing the stability of nonlinear systems.
- b) What is “Equilibrium State” of a nonlinear system?
- c) How the Error Dynamic Model is derived for nonlinear systems and what is the significance of it in the analysis of nonlinear systems?
- d) Explain (i) BIBO Stability, (ii) Local Stability, (iii) Global Stability.

[4+2+4+6=16]

2. a) “Lyapunov’s method of stability analysis is a generalized approach of stability study”- Do you agree with this statement? Justify your answer with reasons.
- b) Explain, with example, the Direct method of Lyapunov for the stability analysis of nonlinear systems.

[4+12=16]

3. a) Explain the basic idea of backstepping control.
- b) “Backstepping based design of nonlinear control law is essentially a nonlinear state feedback control” – Is the above statement correct? Justify your answer with reasons.
- c) 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.

[4+4+8=16]

4. a) Explain the concept of Variable Structure System.
- b) Explain the significant features of Sliding Mode Controllers.
- c) What is Sliding Manifold? How will you choose the Sliding Manifold for a Sliding Mode Controller?
- d) Why “Chattering” is observed in Sliding Mode Controllers? What are the measures to reduce it?

[3+3+5+5=16]

[Turn Over]

5. Write short note on **any two** from the following:

- a) Nonlinear System Modeling.
- b) Jacobian linearization.
- c) Lyapunov Candidate Function.
- d) Basic steps of Sliding Mode Controller design.

[8x2=16]