B. E. ELECTRICAL ENGINEERING THIRD YEAR SECOND SEMESTER EXAMINATION 2024

NON-LINEAR AND OPTIMAL CONTROL (HONS.)

Part-I

Time: Three hours **Full Marks 100 (√50 marks for each part)**

Use a separate Answer-Script for each part

Answer all the questions.

Q1) Explain the phenomenon of bifurcation with the help of Duffing Equation. In this respect establish the physical significance of the Duffing Equation. (CO1, K2) **8**

Q2a) Prove that if the origin of the state space is not the equilibrium point then with the help of suitable transformation the equilibrium point can be shifted to the origin. (CO2, K3) **4**

Q2b) Draw the phase portrait of the system governed by the dynamics. Consider a suitable initial condition of your choice.

$$\ddot{x} + 0.2(x^2 - 1)\dot{x} + x = 0$$

Construct the phase trajectory using the method of Isoclines. Construct at least three representative isoclines. (CO2, K3) **12**

OR

2a) Distinguish between a stable focus and a stable node. Sketch representative phase trajectories around the origin of the phase plane. Justify the nature of the respective phase trajectories citing suitable reasons. (CO2, K3) **8**

Q2b) What do you understand by the term Bang-Bang Control. Explain. (CO2, K3) **8**

Q3) Draw the input-output characteristic of an on-off nonlinearity with hysteresis. Determine the magnitude and phase characteristics of the describing function for this non-linearity. (CO2, K3) **16**

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OR

Q3a) Draw the input-output characteristic of an ideal relay. Derive the describing function for the nonlinearity. (CO2, K3) **6**

Q3b) Consider a relay controlled system where the plant is a type 1 system having following open-loop transfer function

$$G(s) = \frac{K}{s(s+2)(s+3)}$$

Draw the block diagram representing the closed loop configuration. Consider the reference input to be constant. Investigate the stability of the controlled system using describing function based method. (CO2, K3) **10**

Q4a) Prove that Lyapunov's direct method can be applied for ascertaining the stability of a linear system. (CO3, K4) **4**

Q4b) Ascertain the stability of the following linear system using Lyapunov's direct method. (CO3, K4) **6**

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -1 & -1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

OR

Q4a) Write short note on Lyapunov's First Method. (CO3, K4) **5**

Q4b) State the sign definiteness of the following quadratic scalar function F(x). (CO3, K4)

$$F(x) = x_1^2 + 4x_2^2 + x_3^2 + 2x_1x_2 - 6x_2x_3 - 2x_1x_3$$

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Ref. No. : **Ex/EE/PE/H/T/326A/2024**

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(50 Marks for this part)

Part-II

Answer any THREE questions.

Different parts of the same question should be answered together. Two marks will be given for neat and well organized answer.

1. a) State the advantages and disadvantages of optimal control.

b) What are the basic requirements for the design of an optimal control law for a system?

c) Explain the following with proper diagram: (i) Control history, (ii) State trajectory, (iii) Admissible control, (iv) Admissible trajectory

[6+2+8=16]

2. State and explain with suitable example the various steps for the formulation of a constrained optimal control problem.

[16]

3.a) What is performance measure and what is its role in optimal control problem?

b) Describe the classification of optimal control problems based on various performance measures.

[2+2+12=16]

4. a) Explain the Principle of Optimality.

b) Explain with suitable example, how the Principle of Optimality may be applied for optimal decision making.

[6+10=16]

5. Write short note on ***any two*** from the following: [8x2=16]

(a) Selection of the mathematical model for the design of the optimal control law.

(b) Basic approach of Dynamic Programming.

(c) Formulation of a generalized cost function for optimal control.