B. E. ELECTRICAL ENGINEERING THIRD YEAR SECOND SEMESTER EXAMINATION 2023

NON-LINEAR AND OPTIMAL CONTROL (HONS.)

Part-I

Full Marks 100

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

Use a separate Answer-Script for each part

Q1) With the help of suitable diagrams explain the phenomenon of jump response. (CO1) **8**

Q2a) Consider a second order linear system that has non-repeated conjugate root pair on the imaginary axis of the s-plane. Prove that the phase portrait of the system will be a set of closed curves. Draw the phase portraits and name the equilibrium point. (CO2) **5**

Q2b) A linear second order servo system is described by the equation

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

$\zeta = 0.15, \omega_n = 1\, unit$

$e(0) = 1.5, \dot{e}(0) = 0$

where the symbols carry their usual meanings.

Determine the singular point/s. What are the nature/s of the singular point/s? Justify your answer.

Construct the phase trajectory using the method of Isoclines. Derive all the steps that you use. Construct at least five representative isoclines. (CO2) **4+7**

OR

Q2a) With a suitable example of a plant and a block diagram representing the controlled system, explain how the attitude of a satellite may be controlled using on-off type thrusters.

Construct the phase portrait of the system. Derive all the expressions that you use for constructing the phase trajectory. (CO2) **5+6**

[Turn over

Q2b) Explain, why is dead zone necessary for such controllers. Justify your answer citing suitable reasons. (CO2) **5**

Q3) Draw the input-output characteristic of a backlash non-linearity. Determine the magnitude and phase characteristics of the describing function for this non-linearity. (CO2) **16**

OR

Q3a) Non-linear spring characteristic can be approximated by two piecewise linear gains as shown in Fig. P-3. Derive the expression for its describing function. (CO2) **10**

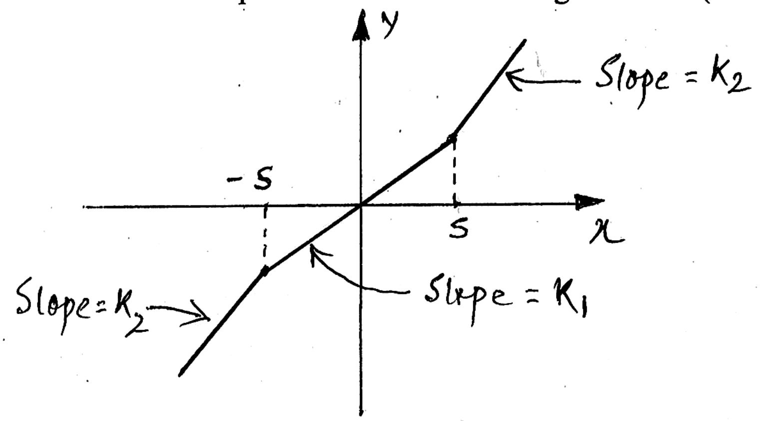

Fig. P-3: Input-Output Characteristic of the spring

Q3b) Enumerate the limitations of the describing function method, if any. (CO2) **6**

Q4) Define and explain the notions of Stability in the sense of Lyapunov, Asymptotic Stability and Exponential Stability. (CO3) **10**

<u>OR</u>

Q4) Consider the non-linear system described by the state equations given below.

$$\dot{x}_1 = x_2^2 + x_1 \cos x_2$$
$$\dot{x}_2 = x_2 + (x_1 + 1)x_1 + x_1 \sin x_2$$

Ascertain the stability of the system using Lyapunov's first method. (CO3) **10**

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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 major challenges for the design of optimal control law.

c) "Accuracy of the controlled output from an optimal controller depends on the accuracy of the plant model adopted for the formulation of the optimal control problem."- Justify whether the statement is True or False with suitable example.

[8+8=16]

2. a) Explain the following with proper diagram:

(i) Control history, (ii) State trajectory, (iii) Admissible control, (iv) Admissible trajectory

b) Explain the various steps to design an optimal controller for the speed control system of the electric drive of a conveyer belt.

[6+10=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. Write a note, with suitable example, on the application of the Principle of Optimality.

[16]

5. a) Explain the following with example:

(i) Closeness of Functions, (ii) Increment of Functional (iii) Variation of a Functional

b) Explain how to derive the extreme values of the functions and functionals. Hence derive the fundamental theorem of the Calculus of Variations.

[3x2+10=16]