Duration: 3 Hours **Total Marks: 80**

Note:

1. **Question one is compulsory.**
2. **Solve any three from remaining and assume suitable data**

Q1. **Solve any four** 20

a. Explain types of stability in details.

b. Draw sinusoidal response of saturation with dead zone nonlinearity and write the response equation.

c. Demonstrate types of physical nonlinearity with its example

d. What is mean by optimal control problem formulation? What are the requirements?

e. Differentiate linear and nonlinear system in details

Q2.a. Derive the describing function for relay with dead-zone nonlinearity 10

Q2. b Give definition of 1,2, and ∞ norm and 10

Compute 2-norm of following,

$$A=\begin{bmatrix} 0.8 & 0 \\ 0 & 1.7 \end{bmatrix} \quad B = \begin{bmatrix} 1 & 0 \\ 0 & 5 \end{bmatrix}$$

Q3.a Design IMC- PI controller for plant model in order to achieve the response with time constant of 1.5 Sec. 10

$$G(s) = \frac{(-s+1)}{(2s+1)}$$

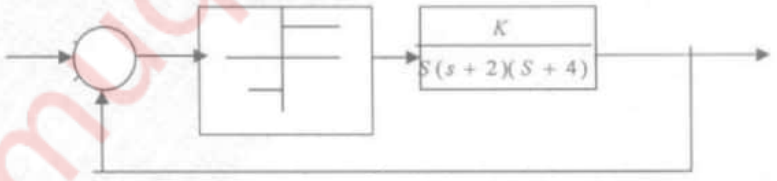
Q3.b. Design the optimal controller via Riccati equation for the system 10

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 2 & -1 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

to minimize the performance index

$$J = \int_0^\infty (x_1^2 + x_2^2 + u^2)\,dt$$

Q4.a. Investigate Stability using Describing function of following system which has unity relay signal as a nonlinearity.



10

Q4.b. Comment on stability using Lyapnov for the nonlinear systems given below , **10**

1.
$$\dot{x}_1 = -x_1 + x_2 + x_1^3 + x_1 x_1^2$$
$$\dot{x}_2 = -x_1 - x_2 + x_1^2 x_2 + x_2^3$$

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

Q5.a. Design the Lyapunov function using Krasovskii's method for the following system. **10**

$$\dot{x}_1 = x_2, \dot{x}_2 = x_1 - x_2^2$$

Q5.b. Using different equilibrium point comment of singular point and draw trajectories **10**

$$\dot{x}_1 = -x_1^3 + x_2$$
$$\dot{x}_2 = x_1 - x_2^3$$

Q6a. Explain limit cycle in detail **06**

Q6b. How to comment on stability using singular point explain in details **08**

Q6c. Explain direct method of Lyapunov stability, design the Lyapunov function for the following system **06**

$$\dot{x} = Ax$$

where A is Hurwitz

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