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

Note:

1. Question one is compulsory.

2. Solve any three from remaining and suitable data

Q1. **Solve any four** 20

a. Investigate in detail Physical nonlinearity which has memory.

b. Demonstrate Saturation and dead-zone in detail with sinusoidal input.

c. Differentiate linear and nonlinear system in detail

d. Explain Lyapnov theorem in details

e. Derive classical control "c" from the IMC controller 'q'

Q2. a Investigate the following system around the equilibrium point (0,0) and derive its linear model. 10

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

2. $x_1 = -x_1 + x_2 + x_1^3 + x_1 x_2^2,$
   $x_2 = -x_1 - x_2 + x_2^3 + x_1^2 x_2$

Q2. b Design IMC- PI controller for the following plant model in order to achieve the response with time constant of 1.5 Sec. 10

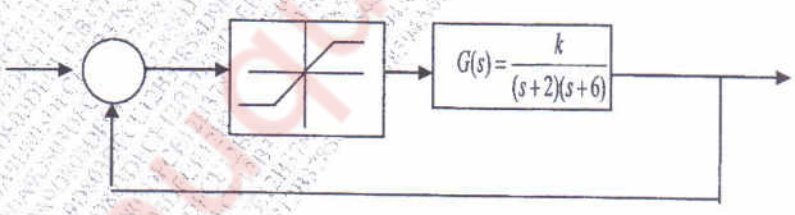
$$G(s) = \frac{(-s+1)}{(2s+1)}$$

Q3.a Derive the Lyapunov function using Variable Gradient method for the system given , 10

$x_1 = -9x_2, x_2 = -x_1^2 - x_2$

Q3.b. Formulate the describing function for relay with dead zone 10

Q4.a. Investigate Stability using Describing function of following system which has unity saturation signal as a nonlinearity and find out frequency and magnitude where system has limit cycle



10

Q4.b. Investigate stability of the following nonlinear system using Lyapunov's method

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

Q5.a. Explain in details IMC based PID controller Design/tuning. **10**

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

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

2. $\dot{x}_1 = x_2$
   $\dot{x}_2 = -x_1 + x_2(1 - x_1^2 + 0.1x_1^4)$

Q6a. How would you classify the following physical nonlinearities and sketch their input-output characteristics? **04**

a. Saturation b. Dead-zone c. Relay d. Friction

Q6b Explain in details Jump resonance for nonlinear system **06**

Q6c What is limit cycle? Explain in details contrast between stable and unstable limit cycles using Van der Pol equation **10**

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