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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

SEMESTER M.TECH DEGREE EXAMINATION, MAY-JUNE 2019

Branch: Electrical and Electronics Engineering

Stream(s):

1. **Control Systems**
2. ***Guidance and Navigational Control***

Course Code & Name: 01EE6104 Nonlinear Control Systems

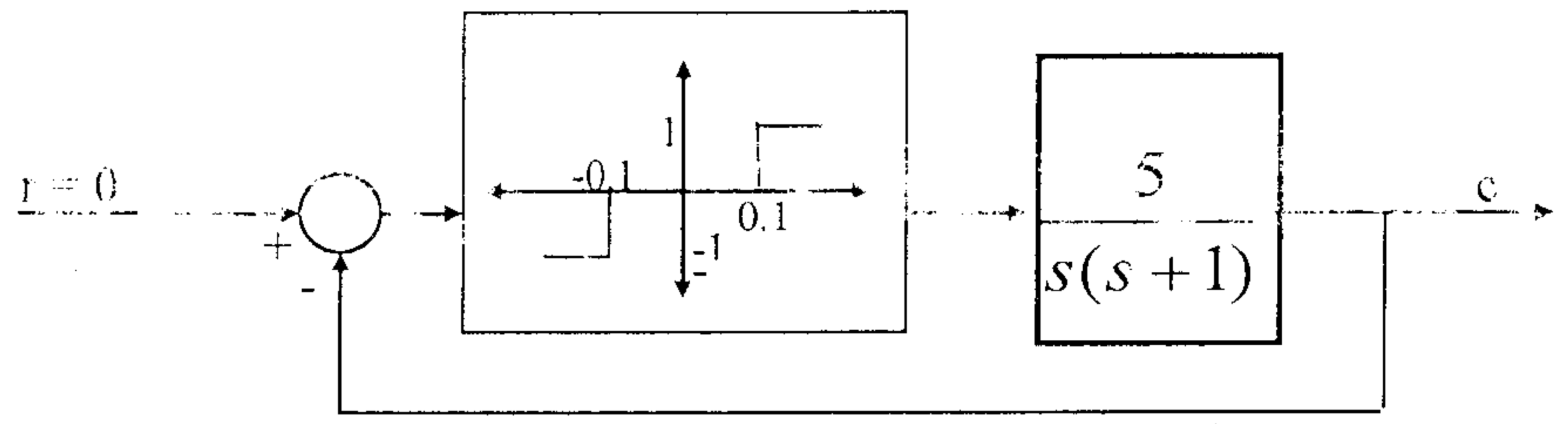
Answer *any **two full*** questions from ***each*** **part**

Limit answers to the required points.

Max. Marks: 60 Duration: 3 hours

PART A

1. Construct an approximate phase trajectory for the following system with nonlinear system starting from (2,0). 9



2. a. Briefly explain the properties exhibited by nonlinear systems. 4

   b. How do you identify the existence and stability of limit cycle from phase portraits? Give example of a system exhibits stable limit cycle. 5

3. a. State existence and uniqueness theorem. 4

   b. Identify the Lipschitzness of the function $f(x) = \begin{bmatrix} x_1 + sat(x_2) \\ x_1 + \sin(x_2) \end{bmatrix}$. 5

PART B

4. a. Apply instability and prove that the system is unstable $\dot{x}_1 = (x_1 - x_2)(1 - x_1^2 - x_2^2)$ $\dot{x}_2 = (x_1 + x_2)(1 - x_1^2 - x_2^2)$. 4

   b. Apply Lyapunov stability and prove that the equilibrium point at the origin for the system $\dot{x}_1 = x_2$, $\dot{x}_2 = -x_2 - \sin(x_1)$ is asymptotically stable. 5

5. a. Define Lyapunov stability theorem. 3

b. Define Popov stability criterion. 3

c. Define L-stability 3

6. Applying circle criterion determine the sector over which the system $\dot{x}_1 = x_2,\ \dot{x}_2 = x_3,\ \dot{x}_3 = 10x_1 - 3x_2 - 6x_3 + u,\ y = 10x_1 + x_2\ and\ u = -\Psi(y)$ with feedback nonlinearity is absolutely stable. If the nonlinearity is saturation identify the domain of output y for which the system is absolutely stable. 9

PART C

7. a. What is gain scheduling? When do we need gain scheduling controller? 3

b. Consider the system $\dot{x}_1 = x_1 x_2,\ \dot{x}_2 = x_1 + u$ Apply back-stepping to design a state feedback control law to globally stabilise the origin. 9

8. Applying linearization to design an output feedback controller with integral action to track the output of the system $\dot{x}_1 = x_2,\ \dot{x}_2 = -\sin(x_1) - x_2 + u,\ y = x_1$ to a specified value y_R. Assume sufficient stable pole locations for the design. 12

9. Consider the system
$$\begin{aligned}\dot{x}_1 &= -x_1 + x_2 - x_3\\ \dot{x}_2 &= -x_1 x_3 - x_2 + u\\ \dot{x}_3 &= -x_1 + u\end{aligned}$$
Find a feedback control and a change of variable that linearize the system. 12