Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/B.Tech (EE-N)/SEM-8/EE-801D/2010

2010

NON-LINEAR CONTROL SYSTEMS

Time Allotted : 3 Hours | Full Marks : 70

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following : $10 \times 1 = 10$

   i) Which of the following property/properties hold(s) for non-linear systems ?

      a) The response to a particular test input is no guide to their behaviour to other inputs

      b) Obeys superposition theorem

      c) Highly insensitive to input amplitude

      d) Both (a) and (b).

   ii) The equation governing a spring-mass-damper system is given by $m\ddot{x} + f\dot{x} + k_1 x + k_2 x^3 = F \cos \omega t$. The non-linearity is due to

      a) $k_2 x^3$ b) F cos ωt

      c) $k_1 x$ d) both (a) and (b).

iii) The phase-plane trajectories are generally restricted to

a) 1st order system b) 2nd order system

c) 3rd order system d) n order system.

iv) A system is represented by $\dot{X} = F(x)$. It is called

a) autonomous system

b) non-autonomous system

c) non-linear system

d) both (b) and (c).

v) The correct statement about limit cycle is/are

a) the limit cycle describes the oscillation of non-linear system

b) the limit cycle describes the oscillation of linear system

c) the existence of a limit cycle corresponds to an oscillation of fixed amplitude and period

d) both (a) and (c).

vi) The describing function technique

a) heuristically linearizes the non-linearity

b) replaces the non-linearity by a complex function and phase shift

c) assumes sinusoidal input to non-linearity

d) all of these.

vii) The characteristic of chaos is

a) aperiodic behaviour of non-linear system

b) periodic behaviour of non-linear system

c) insensitive to initial condition

d) have all Lyapunov exponent as negative.

viii) The direct method of Lyapunov for stability analysis is based on

a) the concept of energy

b) the relation of stored energy with system stability

c) value of state variables at $t \rightarrow \alpha$

d) both (a) and (b).

ix) The bifurcation in a system means

a) the change of topological phase portrait structure as a parameter of the system is varied

b) the stability of the system

c) frequency response of the system

d) time domain analysis of the system.

x) The feedback linearization amounts to

a) adding non-linearity to the feedback loop

b) cancelling the non-linearities in a non-linear system

c) utilizing the feedback to render the given system a linear input-output dynamics.

d) both (a) and (b).

xi) Sliding mode control is meant

a) to regulate a dynamic system subject to parameter uncertainties and non-linearities

b) to confirm the dynamical behaviour of the system to a surface within the state space

c) to regulate a dynamic system with fixed parameters and linearities

d) both (a) and (b).

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. 3 × 5 = 15

2. Explain the following terms with example :

a) Stable focus

b) Stable node.

3. A non-linear system is described by

$\dot{x}_1 = x_2$

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

Check the stability of the system.

4. A dynamic system is defined by $\dot{X} = F(x)$. With reference to this system, what are meant by

a) stable at the origin ?

b) asymptotically stable ?

c) asymptotically stable at large ?

d) unstable ?

5. Show how the state equation $\dot{X} = f(X, u)$ of a general time invariant system can be linearized for small variation about equilibrium point (n_o, u_o).

6. A spring-mass-damper system is shown in the following figure :

Fig.

a) Derive state variable model of the system.

b) Show that the total energy is positive unless the system is at rest. 2 + 3

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. 3 × 15 = 45

7. a) Derive the describing function for the non-linearity shown in the figure :

Fig.

b) Investigate the stability of the non-linear system shown in the figure.

Fig.

5 + 10

8. a) State Lyapunov's stability theorem. Can this theorem be applied to linear system ?

b) Explain with an example, the bifurcation phenomena in a non-linear system.

c) Discuss concepts of stability for non-autonomous systems. Can Lyapunov's stability analysis be extended for non-autonomous systems ? 4 + 5 + 6

9. a) Define positive real transfer functions. State passivity formalism.

b) State and explain Popov's criterion.

c) Discuss how Nyquist criterion can be extended to determine stability of non-linear systems. 4 + 5 + 6

10. a) Discuss stabilization problem of a pendulum.

b) Explain with an example the concept of feedback linearization of a system.

c) Discuss with example the modelling of non-linear systems.

5 + 5 + 5

11. a) Explain the principle of sliding mode control with suitable example.

b) Discuss the advantages and disadvantages of sliding mode control technique.

c) Explain algorithm for sliding mode control of a system.

5 + 5 + 5

12. Write short notes on any *three* of the following : 3 × 5

i) Common non-linearities in control systems.

ii) Limit cycles.

iii) Invariant set theorem.

iv) Input-output linearization.