



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 × 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 $m\ddot{x} + f\dot{x} + k_1x + k_2x^3 = F \cos \omega t$. The non-linearity is due to
 - a) k_2x^3
 - b) $F \cos \omega t$
 - c) k_1x
 - 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 $t \rightarrow \infty$
 - 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. $3 \times 5 = 15$

2. Explain the following terms with example :

- a) Stable focus
- b) Stable node.

3. A non-linear system is described by

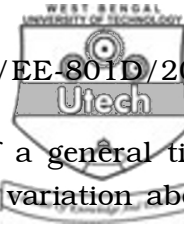
$$\dot{x}_1 = x_2$$

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

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.

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