Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

A Constituent Institution of Manipal University

SIXTH SEMESTER B.TECH. (INSTRUMENTATION & CONTROL ENGG.)

END SEMESTER EXAMINATIONS, JUNE 2017

SUBJECT: NONLINEAR CONTROL SYSTEMS [ICE 4008]

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer **ALL** questions.
- Missing data may be suitably assumed.

1A. Consider the system with an ideal relay as shown Fig. Q1A. Determine the singular point. Design the phase trajectories, corresponding to initial conditions (i) c(0) = 2, $\dot{c}(0) = 1$. Take r=2 volts and M = 1.2 volts. **5**

1B. Illustrate the phase trajectory by delta method for any second order nonlinear system represented by the differential equation. Choose the initial conditions as x(0) = 1.0 and x(0) =0. **3**

1C. Explain jump resonance characteristics exhibited by non-linear system. **2**

2A. Draw the input output waveform for backlash nonlinearity and derive the describing function of backlash nonlinearity. **7**

2B. What do you mean by limit cycle? Write down the van der pole equation and explain how limit cycle exist in it. **3**

3A. Determine whether the system shown in Fig. Q3A exhibits a self-sustained oscillation (limit cycle). If so, determine the stability, frequency, and amplitude of the oscillation. **6**

3B. Examine the stability of the system (Lyapunov's method) described by **4**

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

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

4A. Perform input-output linearization for the system given by, **5**

$$\dot{x} = \begin{bmatrix} 0 \\ x_1 + x_2^2 \\ x_1 - x_2 \end{bmatrix} + \begin{bmatrix} e^{x_2} \\ e^{x_2} \\ 0 \end{bmatrix} u$$

$$y = h(x) = x_3$$

4B. Find $L_{g^2}h$, $L_g L_f h$ and $\left[ad_{f^0}g \; ad_{f^1}g \; ad_{f^2}g \right]$ for the following vector fields f, g and function h. **3**

$$h(x) = \frac{1}{2}(x_1^{\ 2} + x_2^{\ 2})$$

$$f(x) = \begin{bmatrix} x_2 \\ -x_1 - \mu x_2(1-x_1^2) \end{bmatrix} and, g(x) = \begin{bmatrix} -x_1 - x_1 x_2^2 \\ -x_2 + x_1^2 x_2 \end{bmatrix}$$

4C. Define diffeomorphism and lemma to find diffeomorphism. **2**

5A. Consider the fluid level control in a spherical tank and explain the concept of feedback linearization. **4**

5B. With an example explain the steps in design of sliding mode controller. Also comment on the chattering effect in sliding mode controller. **4**

5C. Define zero dynamics and comment on its importance. **2**

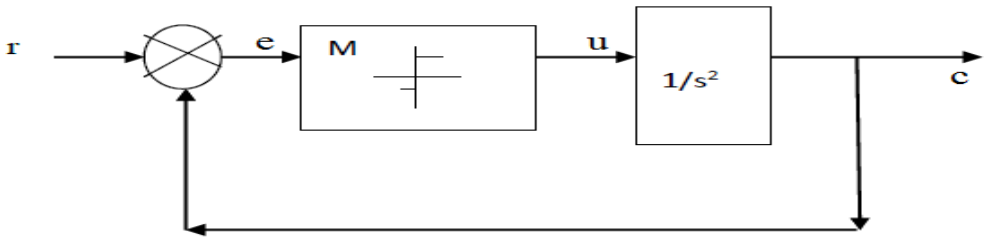

Fig. Q1A

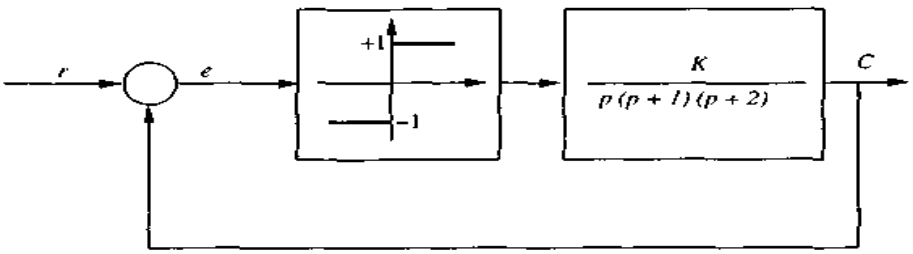

Fig. Q3A