Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

A Constituent Institution of Manipal University

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

END SEMESTER EXAMINATIONS, APRIL/MAY 2017

SUBJECT: NONLINEAR CONTROL SYSTEMS [ICE 4008]

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

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

1A. A unity feedback system is given in Fig. Q1A. Draw the isocline and the phase trajectory for a step input of r(t) = u(t) assuming the initial condition to be c(0)= -1 and $\dot{c}(0) = 0$ where r(t) is the input and c(t) is the output. **5**

1B. Mathematical model of a nonlinear system is given by the equation below. Where f(t) is the input and x(t) is the output of the system. Find the equilibrium points for f=80 and linearize the system for small deviations from the equilibrium points and comment on the stability. **3**

$$2\ddot{x} + 18\dot{x} + 128000\frac{x^2}{(x+2)} = 0.03f$$

1C. Explain common nonlinear system behavior. **2**

2A. Derive the describing function of relay with dead-zone and hysteresis. What will be the describing function if nonlinearity is relay with hysteresis? **7**

2B. Consider the Van der pol equation and explain the describing function analysis method for nonlinear systems. **3**

3A. Consider the nonlinear system shown in Fig. Q3A. Determine the largest *K* which preserves the stability of the system. If *K = 2Kmax,* find the amplitude and frequency of the self-sustained oscillation. **5**

3B. Construct Lyapunov function using variable gradient method for the system described by the equations, **3**

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

$$\dot{x}_2 = -x_1^3 - x_2$$

3C. Define stability and asymptotic stability in the sense of Lyapunov. **2**

4A. Perform input-state linearization for the system described by the equations below and show that the designed nonlinear control law cancel the nonlinearities. **6**

$$\dot{x}_1 = x_2 + x_1^3 + u$$

$$\dot{x}_2 = -u$$

4B. Consider the vector field defined by f and g and prove skew commutativity and Jacobi identity lemmas. **4**

$$f = \begin{bmatrix} -2x_1 + ax_2 + \sin x_1 \\ -x_2 \cos x_1 \end{bmatrix} \qquad g(x) = \begin{bmatrix} 0 \\ \cos(2x_1) \end{bmatrix}$$

5A. Perform input-output linearization for the system given below. **5**

$$\dot{x}_1 = x_1^2 x_2$$

$$\dot{x}_2 = 3x_2 + u$$

$$y = h(x) = -2x_1 - x_2$$

5B. Define internal dynamics. Find the internal dynamics and its characteristics for the system given by the following equations: **3**

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} x_2^3 + u \\ u \end{bmatrix}$$

$$y = x_1$$

5C. With an example explain the steps in design of sliding mode controller. **2**

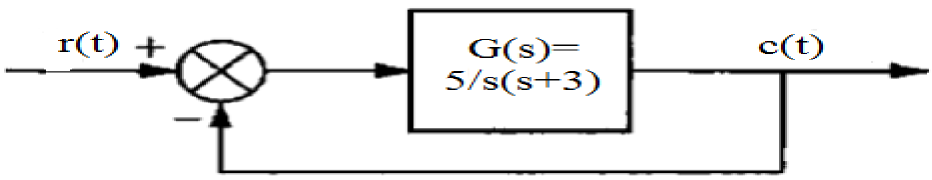

Fig. Q1A

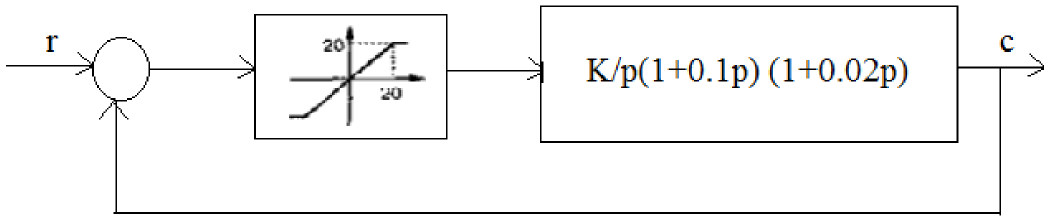

Fig. Q3A