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# MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

A Constituent Institution of Manipal University

## VII SEMESTER B.TECH (ELECTRICAL & ELECTRONICS ENGINEERING)

## END SEMESTER EXAMINATIONS NOV/DEC 2016

## SUBJECT: ADVANCED CONTROL SYSTEMS [ELE 431]

REVISED CREDIT SYSTEM

**Time: 3 Hours** **Date: 30 November 2016** **MAX. MARKS: 50**

**Instructions to Candidates:**

- Answer **ANY FIVE FULL** questions.
- Missing data may be suitable assumed.
- Use of ordinary graph sheet is permitted.

**1A.** Describe the following nonlinear behavior in a dynamical system: i) Jump resonance ii) limit cycle and iii) Asynchronous quenching. ***03***

**1B.** A bead of mass m sliding on a rotating circular hoop of radius R is described by

$$\ddot{\theta} + \frac{g}{R}\sin\theta - \omega^2 \sin\theta\cos\theta = 0;$$

Where $\theta$ is the angular position of bead on the hoop, g is the acceleration due to gravity, $\omega$ the angular velocity of the hoop. Linearize the system about the origin for the following cases i) $\omega^2 < \frac{g}{R}$ ii) $\omega^2 > \frac{g}{R}$ . Determine the stability of the origin in both the cases. ***04***

**1C.** What are equilibrium points? Compute the equilibrium point(s) for the system given by $\dot{x}_1 = x_2;\ \dot{x}_2 = x_1 - x_1^3 - x_2$. ***03***

**2A.** With neat sketches, Derive the describing function for combined dead-zone and saturation nonlinearity. ***03***

**2B.** Consider a system with saturating amplifier s=1 and having slope K in its linear region with describing function N=$(\frac{2K}{\pi})(sin^{-1}\left(\frac{S}{X}\right) - \left(\frac{S}{X}\right)\sqrt{1-\left(\frac{S}{X}\right)^2})$.The transfer function of the linear part is G(s)=$\frac{2}{s(s+0.5)(s+1)}$. Determine the range of slope K for the system to have limit cycle. What would be the frequency, amplitude and nature of the limit cycle for K=3. ***07***

**3A.** Draw phase trajectory (3 quadrants) of a mechanical system with nonlinear damping which is represented by $\ddot{x} + 2x + 2\dot{x} + 2\dot{x}|\dot{x}| = 0$ . Use Delta method and take the initial state $(x, \dot{x}) = (0,3)$. Comment on the stability of the origin. ***05***

**3B.** Explain Pell's method of drawing phase trajectory of a system whose differential equation is of the form $\ddot{x} + \emptyset(\dot{x}) + g(x) = 0$ ***03***

**3C.** What is the difference between Lyapunov's first method and second method of stability analysis? ***02***

**4A.** Find the optimal control vector ***u*(t)*** using dynamic programming which minimizes the performance index **J = 0.5**$\int_0^\infty x^2 + u^2\, dt$ for the system described by $\dot{x} = u$. ***04***

**4B.** A spin-stabilized satellite is wobbling slightly, with components of angular velocity due to the wobble being $x_1(t)$ and $x_2(t)$. The state equations are given by $\dot{x}_1 = -x_2 + u_1$; $\dot{x}_2 = x_1 + u_2$. Using Pontryagin's Minimum Principle, obtain the optimal control vector u*(t) which drives the state from x(0)=1 to x(2)=0 while minimizing the control energy **J =** $\int_0^2 (u_1^2 + u_2^2)\,dt$ with u(t) unrestricted. ***06***

**5A.** Consider a nonlinear system described by the following equations. Investigate the stability and region of stability of origin using i) direct method of Lyapunov and ii) Krasovskii's method taking [P] to be identity matrix.

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

$$\dot{x}_2 = x_1 - x_2 - x_2^3$$ ***06***

**5B.** Discuss the need and design procedure of state feedback controller with integrator. ***04***

**6A.** State clearly the assumptions made while designing a Kalman Filter. Mention any two applications of Kalman filter. ***02***

**6B.** Consider a system given by the following state space model

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & -2 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u + \begin{bmatrix} 0 \\ 1 \end{bmatrix} w;\ y = \begin{bmatrix} 1 & 0 \end{bmatrix} x + v;$$

i) Design an optimal control law using Algebraic Riccati equation so that **J =0.5** $\int_0^\infty (y^2 + u^2)\,dt$ is minimized.

ii) Design a Kalman Filter for the above system, when the noise co-variance $Q_N$=0.6 and $R_N$=2. Draw the state diagram of the system with Kalman filter. ***08***