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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

VII SEMESTER B.TECH (ELECTRICAL & ELECTRONICS ENGINEERING)
END SEMESTER EXAMINATIONS, NOVEMBER 2022

CONTROL SYSTEM DESIGN [ELE 4076]
REVISED CREDIT SYSTEM

Time: 3 Hours **Date: 23 NOV 2022** **Max. Marks: 50**

Instructions to Candidates:
- Answer **ALL** the questions.
- Missing data may be suitably assumed.

1A. Compute the eigenvalues, Modal matrix & state transition matrix for a system with system matrix

A= $\begin{bmatrix} \mathbf{0} & \mathbf{1} \\ \mathbf{-12} & \mathbf{-7} \end{bmatrix}$. ***(04)***

1B. The state model of a linear time invariant system is given below.

$$\dot{\boldsymbol{x}} = \begin{bmatrix} \mathbf{5} & \mathbf{1} \\ \mathbf{-1} & \mathbf{-2} \end{bmatrix} \boldsymbol{x} + \begin{bmatrix} \mathbf{0} \\ \mathbf{1} \end{bmatrix} \boldsymbol{u};\ \boldsymbol{y} = [\mathbf{1} \quad \mathbf{1}]\boldsymbol{x};$$

i)Check whether the system is completely observable and completely state controllable or not.

ii)Design a state feedback controller so as to place the closed loop poles at -3±j10. ***(06)***

2A. Derive the algebraic (or Matrix) Riccati equation for the design of optimal state feedback controller. ***(03)***

2B. Consider a system given by the following state space model where w is the input disturbance & v is the measurement noise.

$$\dot{\boldsymbol{x}} = \begin{bmatrix} \mathbf{0} & \mathbf{1} \\ \mathbf{0} & \mathbf{0} \end{bmatrix} \boldsymbol{x} + \begin{bmatrix} \mathbf{0} \\ \mathbf{10} \end{bmatrix} \boldsymbol{u} + \begin{bmatrix} \mathbf{0} \\ \mathbf{1} \end{bmatrix} \boldsymbol{w};\ \boldsymbol{y} = [\mathbf{1} \quad \mathbf{0}]\boldsymbol{x} + \boldsymbol{v};$$

Design a Kalman Filter for the above system, when the noise co-variance Q_N=0.6 and R_N=1. ***(07)***

3A. A unity feedback system has an open loop transfer function of $G(s)H(s) = \frac{k}{s(s+5)}$. Design a lead compensator so as to reduce the settling time by a factor of 4 while continuing to operate the system with 20% overshoot. Write the transfer function of the compensated system with overall gain. ***(07)***

3B. Consider a unity feedback system with

$$G(S)= \frac{1}{(S+1)(S+3)}$$

Design a proportional controller so that the response of the system with the controller has an overshoot of 15%. ***(03)***

4A. A unity feedback system with G(S)= $\frac{k}{S(S+7)}$ is desired to have a damping ratio of 0.6.

(i)Evaluate the finite steady state error of the uncompensated system.

(ii)Design a suitable compensator in order to improve the finite steady-state error by a factor of 10 considering the gain calculated in (i) for the compensated system. ***(05)***

4B. Differentiate between a linear system and a nonlinear system. (at least four points) ***(02)***

4C. 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 θ is the angular position of bead on the hoop, g is the acceleration due to gravity, ω the angular velocity of the hoop. Linearize the system about the origin when $\omega^2 < \frac{g}{R}$ & comment on the stability of the origin. ***(03)***

5A. Prove that the origin of $\dot{x}_1 = x_2;\ \dot{x}_2 = -x_1^3 - x_2^3$ is globally asymptotically stable using Liapunov's method. ***(04)***

5B. Consider a system with saturating amplifier s=1 and having slope K in its linear region with describing function

N=$(\frac{2K}{\pi})(sin^{-1}\left(\frac{S}{X}\right) - \left(\frac{S}{X}\right)\sqrt{1-\left(\frac{S}{X}\right)^2})$ for $X \geq S$.

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. Predict the frequency, amplitude and nature of the limit cycle for K=3. ***(06)***