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# MANIPAL INSTITUTE OF TECHNOLOGY
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## VII SEMESTER B.TECH (ELECTRICAL & ELECTRONICS ENGINEERING)
## MAKE-UP EXAMINATIONS, DECEMBER 2022

## CONTROL SYSTEM DESIGN [ELE 4076]
REVISED CREDIT SYSTEM

**Time: 3 Hours** **Date: 30 DEC 2022** **Max. Marks: 50**

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

**1A.** Given A= $\begin{bmatrix} \mathbf{0} & \mathbf{1} \\ \mathbf{-2} & \mathbf{-3} \end{bmatrix}$. Compute the eigenvalues, eigenvectors & state transition matrix. ***(03)***

**1B.** Determine the controllability & observability of the following system

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

***(03)***

**1C.** For the system shown below, design a full order state observer so as to place the observer poles at -5, -5.

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

***(04)***

**2A.** Consider a unity feedback system whose forward path TF $G(s) = \frac{1}{s(s+2\zeta)}$. Determine the value of damping ratio ζ>0 so that when the system is subjected to unit step input, the following performance index is minimized $\mathbf{J} = \int_0^\infty \boldsymbol{e^2 + \dot{e}^2 dt}$. The system is assumed to be initially relaxed. ***(04)***

**2B.** Consider a satellite attitude control system whose state space model is given by

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ 0 & -2 \end{bmatrix} x + \begin{bmatrix} 0 \\ 20 \end{bmatrix} u \qquad \boldsymbol{y} = [\mathbf{1} \quad \mathbf{0}]\boldsymbol{x};$$

Design an optimal control law using Matrix Riccati equation in order to minimize $\mathbf{J}=\int_0^\infty (\boldsymbol{x^2} + \boldsymbol{u^2})\boldsymbol{dt}$ .

***(06)***

**3A.** Consider a unity feedback system whose forward path transfer function is given by G(s)= $\frac{(s+2)}{s(s+6)}$ . Design a lead compensator via root locus method so that the closed loop system will have the following specifications: overshoot =10% and settling time reduced by a factor of 2.

***(07)***

**3B.** Consider a unity feedback system with

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

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

**4A.** Consider a unity feedback system with open loop TF $G(s) = \frac{10}{(s+1)(s+2)}$. Design a lag compensator in order to improve the steady state error by a factor of 20. ***(04)***

**4B.** What are singular points? How are they classified for a second order linear time invariant system? ***(02)***

**4C.** Find the equilibrium point(s) and linearize the system about the equilibrium point(s). Comment on the stability of the equilibrium point(s) for the following system

$\dot{x}_1 = 2x_1 - x_1x_2;\ \ \dot{x}_2 = 2x_1^2 - x_2;$ ***(04)***

**5A.** Determine the stability of an equilibrium point using Liapunov's direct method if

$V(x) = x_1^2 + x_2^2$ & $\dot{V}(x) = -2x_1^2 - 2x_2^2 + x_1x_2;$ ***(03)***

**5B.** A unity feedback system has G(s)=k/s(s+1)(0.5s+1) cascaded with on-off relay nonlinearity with M=1. Determine the range of gain k for which limit cycle is predicted. Also determine the stability, amplitude and frequency of the limit cycle when gain of the linear system is k=10. The describing function of on-off relay is given by $N= \frac{4M}{\pi X}$ .

***(07)***