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Fifth Semester B.E. Degree Examination, July/August 2022
Modern Control Theory

Time: 3 hrs. Max. Marks:100

Note: 1. ***Answer any FIVE full questions, selecting atleast TWO questions from each part.***
2. ***Assume Missing data suitably.***

PART – A

1 a. Mention any four advantages of state space analysis over frequency domain analysis. **(04 Marks)**

b. Obtain the state model for a single input single output continuous–time LTI system described by the following differential equation:

$(D^n + a_1D^{n-1} + a_2D^{n-2} + - - - - + a_n)y(t) = u(t)$. **(06 Marks)**

c. For the transfer function : $T(s) = \frac{s(s+2)(s+3)}{(s+1)^2(s+4)}$ obtain the state model in

i) Phase variable form using signal flow graph method
ii) Jordan's canonical form. **(10 Marks)**

2 a. For the electrical shown in Fig. Q2(a) obtain the state model. Choose i_L and v_c as state variables. **(06 Marks)**

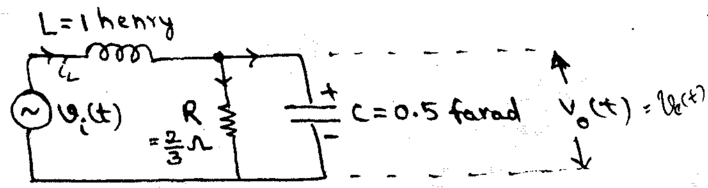

Fig. Q2(a)

b. Obtain the state model of the block diagram shown in Fig Q2(b). **(06 Marks)**

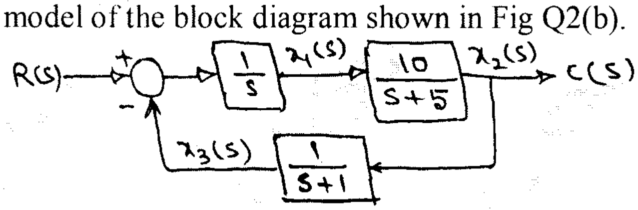

Fig. Q2(b)

c. Derive the state model of an armature controlled d.c motor by selecting $x_1(t) = \theta(t)$ $x_2(t) = \dot{\theta}(t)$ and $x_3(t) = i_a(t)$ as state variables. **(08 Marks)**

3 a. Obtain the state model of the linear system by Direct decomposition method, whose transfer function is **(06 Marks)**

$$\frac{Y(s)}{U(s)} = \frac{5s^2+6s+8}{(s^3+3s^2+7s+9)}.$$

b. Find the transfer function of the system having state model as below : **(06 Marks)**

$$X = \begin{bmatrix} 1 & -2 \\ 4 & -5 \end{bmatrix} x + \begin{bmatrix} 2 \\ 1 \end{bmatrix} u \; ; \quad Y = [\,1 \;\; 1\,]x.$$

c. For the system matrix given by $A = \begin{bmatrix} -4 & 1 & 0 \\ 0 & -3 & 1 \\ 0 & 0 & -2 \end{bmatrix}$.

Determine i) Characteristic equation ii) Eigen value iii) Eigen vector iv) Modal matrix. **(08 Marks)**

4 a. If $A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$ find A^{12} using Cayley-Hamilton theorem. **(06 Marks)**

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

b. A state–space representation of a system in the controllable canonical form is given as
$$\dot{X} = \begin{bmatrix} 0 & 1 \\ -0.4 & -1.3 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix}U \qquad Y = \begin{bmatrix} 0.8 & 1 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}.$$
Check for controllability and observability using Kalman's test. **(08 Marks)**

c. For a system the matrix 'A' is given by $A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}$ compute the state transition matrix using Cayley-Hamilton theorem. **(06 Marks)**

PART – B

5 a. Define Controllability and Observability. A system is describe by
$$\dot{x}(t) = \begin{bmatrix} 0 & 1 \\ 9 & 0 \end{bmatrix}x + \begin{bmatrix} 0 \\ 9 \end{bmatrix}u.$$
Determine the state feedback gain matrix (k), so that control law u = -kx will place the closed loop poles at $-3 \pm j3$ by using Ackerman's formula. **(10 Marks)**

b. Design a full order state observer for the system with
$$\dot{x}(t) = \begin{bmatrix} -1 & 1 \\ 1 & 2 \end{bmatrix}x \quad ; \quad y(t) = [1 \;\; 0]x.$$
The desired eigen values for the observer matrix are $\mu_1 = -5$ and $\mu_2 = -5$. **(10 Marks)**

6 a. State and prove the necessary condition for state feedback design by arbitrary pole placement scheme. **(06 Marks)**

b. Given $\dot{x}(t) = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix}x(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix}u(t)\,; y(t) = [1 \quad 0]x(t)$. design a first order observer for the system with observer pole at $s = -10$. Assume x_1 is measurable. Use direct substitution method. Also give the observer equation of the first order observer. **(06 Marks)**

c. With the help of relevant figures/equations/graphs explain the phenomena of non linearity with respect to the following. Frequency – amplitude dependence, multivariable responses and Jump resonance. **(08 Marks)**

7 a. Draw the phase portraits of the following systems :

i) $\frac{d^2x}{dt^2} + 0.5\frac{dx}{dt} + 2x = 0$ ii) $\frac{d^2x}{dt^2} + \frac{3dx}{dt} + 2x = 0$ iii) $\frac{d^2x}{dt^2} + \frac{3dx}{dt} - 10 = 0$. **(09 Marks)**

b. Obtain all the singularities of the system represented by the equation :
$$\frac{d^2y}{dt^2} - \left\{0.1 - \frac{10}{3}\left(\frac{dy}{dt}\right)^2\right\}\frac{dy}{dt} + y + y^2 = 0.$$ **(04 Marks)**

c. Construct a phase trajectory by Delta method for a non-linear system represented by the differential equation : $\ddot{x} + 4|\dot{x}|\dot{x} + 4x = D$. Choose the initial conditions as $x_1(0) = 1$ and $\dot{x}(0) = 0$. **(07 Marks)**

8 a. Define the following : i) Stability ii) Asymptotic stability iii) Asymptotic stability in the large. **(06 Marks)**

b. Determine whether the following quadratic form is positive definite :
$$Q(x_1\, x_2\, x_3) = 10x_1^2 + 4x_2^2 + x_3^2 + 2x_1x_2 - x_2x_3 - 4x_1x_2.$$ **(06 Marks)**

c. Examine the stability of the system described by the differential equation using Krasovskii's method.
$$\dot{x}_1 = x_1.$$
$$\dot{x}_2 = x_1 - x_2 - x_2^3$$ **(08 Marks)**