Bachelor of Mechanical Engineering Examination, 2017
(4th Year 2nd Semester OLD)
Subject: **Elective III – Fluid Control and Systems**

Time : Three hours **Full Marks: 100**

Answer any **FIVE** *questions. Different parts of the same question should be answered together.*
Assume any relevant data if necessary.

[1] A control system with 2 inputs and 2 outputs are shown in Fig.P1 below where the controls are shown as r_1 and r_2,; while y_1 and y_2 are outputs of the system representing flow rate and temperature of liquid. The states are shown as x_1, x_2, x_3 and x_4. Construct a state spaee model for the system. [20]

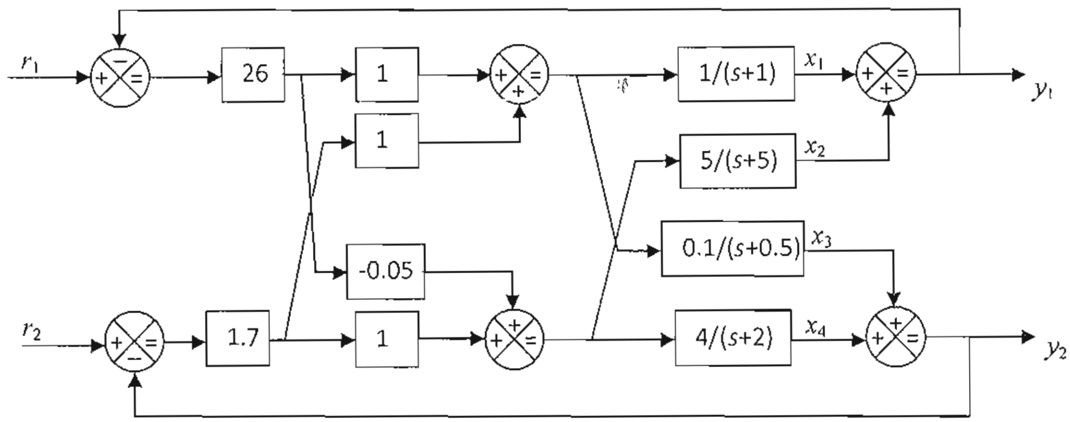

Fig.P1

[2] (a) Determine the output response of the system to the initial conditions and a unit step input.

$$\dot{\mathbf{x}} = \begin{bmatrix} -1 & 1 \\ 0 & -2 \end{bmatrix}\mathbf{x} + \begin{bmatrix} 0 \\ 1 \end{bmatrix}u \qquad \mathbf{y} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}\mathbf{x} \qquad \mathbf{x}_0 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

(b) State the *Modal Control theorem* for designing state feedback to move the poles λ_i, λ_j to $\hat{\lambda}_i, \hat{\lambda}_j$. [14+6]

[3] (a) Explain what is meant by *Optimal Control* for a state space system $\dot{\mathbf{x}} = \mathbf{Ax} + \mathbf{Bu}$; $\mathbf{y} = \mathbf{Cx}$ with state feedbaek $\mathbf{u} = -\mathbf{k}'\mathbf{x}$. Explain the solution of the problem using the matrix *Liapunov equation*.
(b) State the *Optimal Regulator Theorem* using the matrix *Riccati equation*. [15+5]

[4] (a) For the plant $\dot{\mathbf{x}} = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}\mathbf{x} + \begin{bmatrix} 0 \\ 2 \end{bmatrix}u$, design a state feedback eontrol $u = -\mathbf{k}'\mathbf{x}$ to place the closed-loop eigenvalues at $-2 \pm 2j$.
(b) What is meant by state feedbaek and pole assignment? [12+8]

[5] (a) For the plant $\dot{\mathbf{x}} = \begin{bmatrix} -3 & 1 \\ 3 & -5 \end{bmatrix}\mathbf{x} + \begin{bmatrix} 0 \\ 1 \end{bmatrix}u$, use modal control to design state feedback control $u = -\mathbf{k}'\mathbf{x}$ that will place the <u>*closed loop poles*</u> at -8 and -6.
(b) For the system $\dot{\mathbf{x}} = \begin{bmatrix} -3 & 2 \\ 4 & -5 \end{bmatrix}\mathbf{x} + \begin{bmatrix} 0 \\ 1 \end{bmatrix}u$; $\mathbf{x}_0 = \begin{bmatrix} 5 \\ 3 \end{bmatrix}$, express the response to $\mathbf{x}_0$ by *modal decomposition*. [12+8]

[6] (a) Design the observer matrix **L** to estimate the states of the system $\dot{\mathbf{x}} = \begin{bmatrix} -1 & 1 \\ 0 & -4 \end{bmatrix}\mathbf{x} + \begin{bmatrix} 0 \\ 4 \end{bmatrix}u$; $y = \begin{bmatrix} 1 & 0 \end{bmatrix}\mathbf{x}$, from the output y.
Place the observer eigenvalues at $-10 \pm 10j$.
(b) Explain how a *Multi-variable Integral Control* can be designed for a state space system using state feedback and zero integrated steady state error? [10+10]

[7] Write short notes on any <u>four (4)</u> of the following:
(i)Transition Matrix
(ii)Controllability and Stabilizability
(iii)Companion Matrix
(iv)Dynamic Observers
(vi)Transfer function matrix and stability of state space models [4×5]