BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ENGINEERING AND PHYSICS

Bachelor of Science Honours Degree in Electronic Engineering

EEE4203/EEE5104: MODERN CONTROL ENGINNERING

Duration: 3 Hours **Total Marks: 100**

Special Requirements: Scientific Calculator, rule, pen, pencil

INSTRUCTIONS TO CANDIDATES

JUN 2025

1. Answer any **five (5)** questions
2. The question paper contains **SEVEN (7)** questions
3. Each question carries 20 marks

1(a) Find inverse of the following matrix

$$A = \begin{bmatrix} 1 & 2 & 0 \\ -1 & 1 & 1 \\ 1 & 2 & 3 \end{bmatrix}$$ [15]

(b) The dynamic equations that describe the system, that is, the state equations, are

$$\dot{x}(t) = Ax(t) + Bu(t)$$

$$y(t) = Cx(t) + Du(t)$$

$$x(t_o) = x(0)$$

Using the state equation, define the following parameters stating their dimensions.

(i) x(t) [1]
(ii) u(t) [1]
(iii) y(t) [1]
(iv) D [1]
(v) C [1]

2(a) Outline the advantages of State Variable Analysis of control systems. [5]
(b) Draw the block diagram of state equations in time domain and frequency domain. [10]
(c) Compare and contrast transfer function model and state variable model. [5]

3(a) A system is characterized by the following differential equation.

$$\frac{d^2y}{dt^2} + 10\frac{dy}{dt} + 7y - u = 0$$

Determine its transfer function. [4]

(b) The transfer function of a system is given by

$$\frac{Y(s)}{U(s)} = \frac{10}{4s^2 + 2s + 1}.$$

Determine the differential equation governing the system [5]

(c) Consider a linear system described by the transfer function

$$\frac{Y(s)}{U(s)} = \frac{10}{s(s+1)(s+2)}$$

Prove system controllability [11]

4(a) Explain the Controllability and observability of a system [2+2]

(b) Draw the state block diagram for the transfer function given below and obtain state equations. **[3+2]**

$$(a)\ \frac{C(s)}{R(s)} = \frac{1}{(s+1)(s+3)}$$

(c) The dynamic equation of a system is represented by

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} -2 & 1 \\ 0 & -3 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 4 \\ 1 \end{bmatrix} u, \quad y = \begin{bmatrix} 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

Prove the system observability? **[5]**

(d) Draw the signal flow graph of the system described the system below **[6]**

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} a_1 & a_2 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} u \text{ and } y = x_3$$

5(a) The state model of a linear time invariant system is given by

$\dot{X}(t) = AX(t) + BU(t)$

$Y(t) = CX(t) + DU(t)$

Show that the transfer function of the system is given by $\frac{Y(s)}{U(s)} = \frac{CAdj[sI-A]B}{|[sI-A]|} + D$. **[10]**

(b) The transfer model is also known as the conventional approach. What are its limitations?
when analyzing control systems. **[5]**

(c)(i) State the three basic units of a block diagram **[3]**

(ii) Draw the diagrams of any two above units in s-domain **[2]**

6(a) With the aid of well-labelled diagrams, explain the following characteristics of nonlinear systems.

(i) Saturation **[3]**

(ii) Dead-zone **[3]**

(b) State the condition necessary for closed loop poles to be placed anywhere in the complex plane. **[3]**

(c) A SISO system is represented by the equations below.

$$\dot{X}_1(t) = a_1X_1(t) + b_1U(t), \qquad \dot{X}_2(t) = a_2X_1(t) + a_3X_2 + b_2U(t) \ and$$
$$Y(t) = c_1X_1(t)c_2X_1(t)$$

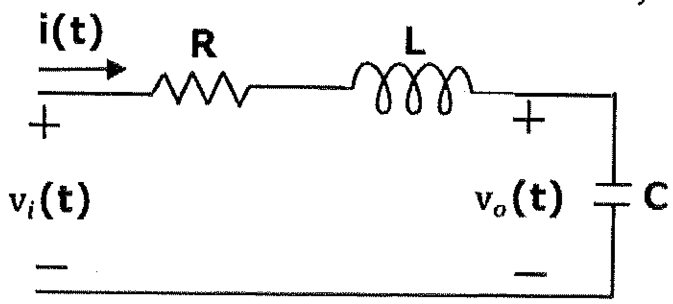
(i) How many state variables are there in the system. **[1]**

(ii) How many integrators are required **[1]**

(iii) Obtain the state diagram represented by the equations **[8]**

(d) Give an example of a state model in modern control engineering. **[1]**

7(a) Obtain the state model of the electric system below [15]



(b) Find Z-transform of a unit impulse signal. [5]

The End of Examination