# MERU UNIVERSITY OF SCIENCE AND TECHNOLOGY

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**UNIVERSITY EXAMINATIONS 2024/2025**

FOURTH YEAR, FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF TECHNOLOGY IN ELECTRICAL AND ELECTRONIC ENGINEERING

**EET 3407: CONTROL SYSTEMS II**

**DATE: JANUARY 2025** **TIME: 2 HOURS**

**INSTRUCTIONS: Answer Question ONE and any other TWO questions.**

**QUESTION ONE (30 MARKS)**

a) A system is defined as: $A = \begin{bmatrix} -2 & 3 \\ 1 & 0 \end{bmatrix}, B = \begin{bmatrix} 1 \\ 0 \end{bmatrix}, C = [1 \quad 2]$. Design a full state feedback control that keeps the stable pole, while the unstable pole is mirrored to the imaginary axis. (8 Marks)

b) Explain the following terms as applied in control systems.

i. Eigen vector

ii. Linear time invariant systems

iii. State Variable

iv. Observability (8 Marks)

c) Consider the state equation

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

The problem is to determine the state transition matrix $\phi(t)$ and state transition equation x(t) for t≥0 when the input is u(t)=1 for t≥0. The coefficient matrices are identified to be

$$A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} \qquad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$$ (8 Marks)

d) Explain the main difference between lead and lag compensators in terms of their effect on transient and steady-state responses? (6 Marks)

## QUESTION TWO (15 MARKS)

a) A linear time invariant system is characterized by homogenous state equation.

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix} * \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

Compute the solution of the state equation assuming the initial state vector.

$$x_0 = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$$

(8 Marks)

b) Discuss how PID parameters affect system dynamics (3 Marks)

c) Discuss the importance of eigen values. (4 Marks)

## QUESTION THREE (15 MARKS)

a) When is a system state controllable?

i) Give the Kalman controllability criterion. (1 Mark)

ii) Check the given system controllability and observability by using Kalman's method.

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 \\ -2 & -3 & 0 \\ 0 & 2 & -3 \end{bmatrix} * \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 2 \\ 5 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} * \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

(7 Marks)

b) The parameter matrices of a continuous system are:

$$A = \begin{bmatrix} -4 & 0 \\ 0 & -1 \end{bmatrix}, B = \begin{bmatrix} 2 \\ 3 \end{bmatrix}, C = [1 \;\; 1].$$

The system is controlled with state feedback. The state feedback vector is $K = [1 \;\; 2]$. Determine the transfer functions and the poles of the origin and that of the feedback system. (7 Marks)

**QUESTION FOUR (15 MARKS)**

a) Explain how dynamic compensation using operational amplifiers is implemented in real-world analog control systems (3 Marks)

b) Discuss and Provide real-world examples of the application of:

i. a lead compensator

ii. a cascade compensator (3 Marks)

c) Discuss Ziegler- Nicholas method of tuning PID controllers. (6 Marks)

d) The following differential equation represent linear time invariant systems. Write down the dynamic equations (state equations and output equations) in vector matrix form.

$$4\frac{d^4y(t)}{dt^4} + 7\frac{d^3y(t)}{dt^3} + 2.5\frac{d^2y(t)}{dt^2} + 8y(t) = 2r(t)$$

(3 Marks)

**QUESTION FIVE (15 MARKS)**

a) The transfer function of an unstable continuous system is:

$$P(s) = \frac{-9}{(s+6)(s-3)}$$

i. Give the state equation in controllable canonical form.

ii. Determine the stabilizing state feedback vector. (Prescribing the poles of the closed loop system, mirror the unstable pole to the imaginary axis, and leave the stable pole at its location.) (7 Marks)

b) Given the transfer function of an Observable Canonical Form, resolve the signal flow representation and derive the state and output equations.

$$\frac{Y(s)}{U(s)} = \frac{4s^3 + 5s^2 + 9s + 7}{8s^3 + 6s^2 + 7s + 5}$$

(6 Marks)

c) Explain how a lead-lag compensator improves both the transient and steady-state behavior of a system (2 Marks)