LEAD CITY UNIVERSITY, IBADAN
FACULTY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
SEMESTER/SESSION: 1ST SEMESTER, 2024/2025

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Course Particulars

Course Code: EEE 403
Coarse Title: Control Theory II
Course Units: 3
Course Status: Core

Lecturer's Details

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Areas of Specialization
Digital Signal Processing, Digital Image Processing, Engineering in Medicine and Renewable Energy

Course Synopsis

State-space description of linear systems. Concepts of controllability and observability. Feedback concept, advantages, system classification, structures, control systems components - mechanical, electronic, hydraulic, thermal, position control, transient analysis of servo-mechanism, signal regulators compensation techniques. Series/parallel feedback controllers. System transfer functions, signal flow graphs, stability, Routh-Hurwitz criteria. Modern control observers. Realization of systems having specified transfer function. Optimization methods. Linear discrete dynamic systems. System identification methods. Non-linear control application.

The course objectives are to:

- Facilitate the understanding of the mathematical concepts of state space modeling of systems
- Facilitate the understanding of control system's classification, structures and components
- Discuss the operational principles of feedback control
- Explain the principle of control system design and analysis
- Study the performance of control systems

Course Learning Outcomes (CLOs)

At the end of this course, students would be able to:

1. Understand and explain the principles of mathematical modeling of physical systems
2. Identify the structures and components of feedback control systems
3. Design and modeling linear time invariant (LTI) control systems
4. Understand and explain the concepts of non-linear control
5. Understand the application of methods of control system analysis
6. Design and analyze LTI control systems in MATLAB

Lecture Delivery Method

- Lecture with interactive sessions
- Tutorial exercises

LECTURE PLAN

Course Modules
Module 1: Mathematical modeling of linear time invariant (LTI) control system
Module 2: State space modeling of feedback control system
Module 3: Design of Control systems
Module 4: Analysis of Control systems

Course Outline
Module 1: Mathematical modeling of linear time invariant (LTI) control system
Number of Lecture Hours: 12

Week	Lecture Topic	Contents	Learning Objectives
1	Introduction and Course Overview	Course outlines, delivery methods, assessments, course materials and recommended text books	Discuss the general overview of the course, as well as rules and regulations requisite for successful achievement of the course objectives.
2	Overview of Mathematical Modeling of Control Systems	Review of Transfer Function. Frequency and Time domain descriptions of control system	To review the fundamental concepts of control system modeling.
3	State space representation of control system	Methods of obtaining state space models of dynamic systems. Conversion from state space to transfer function. State transition matrix	Understand the concepts of state space models of dynamic systems
4	Solutions of state space equations	Solution to homogeneous (free) system equation Solution to non-homogeneous (forced) system equation.	Explain the solution procedures for state space equations.

Module 2: State space modeling of feedback control system
Number of Lecture Hours: 9

Week	Lecture Topic	Contents	Learning Objectives

5	Modeling of Electrical system	Modeling of RC, LC and RLC electrical circuits.	Understand the principles of state space modeling of electrical systems
6	Modeling of mechanical system I	Modeling of mechanical spring-mass-damper systems	Understand the principles of state space modeling of mechanical systems
7	Modeling of mechanical system II	Modeling of fluids and thermal systems etc.	Understand the principles of state space modeling of fluid and thermal systems

Module 3: Design of Control systems
Number of Lecture Hours: 9

Week	Lecture Topic	Contents	Learning Objectives
8	Controllers in control system design	Proportional, integral, derivative (PID) Controllers.	Understand the design concepts and principles of Proportional, integral, derivative (PID) Controllers.
9	Methods of Controller parameter tuning	Pole placement method. Ziegler Nichols method. MATLAB exercises.	Apply the design concepts and principles of Proportional, integral, derivative (PID) Controllers.
10	Overview of Frequency response plots	Frequency response design approach: Bode plots, Root locus plot, Nyquist plot, Nichols plots. MATLAB exercises.	Understand the principles of frequency response design approach.

Module 4: Analysis of Control systems
Number of Lecture Hours: 15

Week	Lecture Topic	Contents	Learning Objectives
11	Analysis of control system I	Controllability of control system	Understand and apply the concepts of controllability for the analysis of control system
12	Analysis of control system II	Observability of control system	Understand and apply the concepts of observability for the analysis of control system

13	Stability of control system	Poles and Zeros. Eigen values, stability of linear systems. Routh Hurwitz stability criterion.	Explain the concepts of poles and zeros; eigen-values and Routh criterion for control system stability analysis
14	Methods of frequency response analysis.	Stability analysis: Bode plots, Root locus plot, Nyquist plot, Nichols plots	Apply frequency response methods for control system stability analysis
15	Revision	Tutorial exercises	

Grading System

This course will be graded as follows:
Attendance: 10%
CA/Assignments: 30%
Examination: 60%
Total: 100%

References

1. Katsuhiko Ogata: Modern Control Engineering (5th Edition). Prentice Hall, 2010.
2. Norman S. Nise: Control Systems Engineering (6th Edition). John Wiley and Sons, 2011.

EEE 403 Tutorial Questions

Question 1
Given a feedback control system with R as reference input, U as control input, Y as measured output and D as external disturbance as shown in Fig Q1.

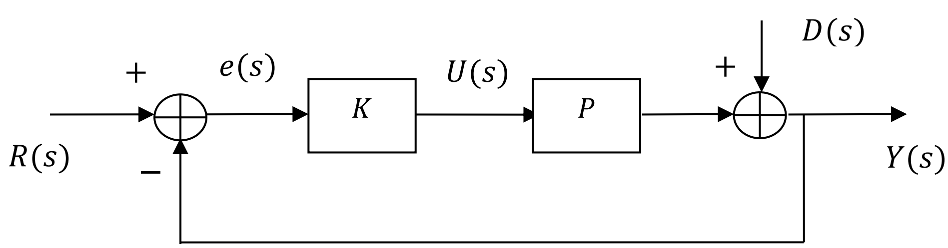


Fig Q1.

i) Show that the measure output, Y(s) is given by:

$$Y(s) = \frac{PK}{1+PK}R(s) + \frac{1}{1+PK}D(s)$$

ii) Explain the effects of the parameter K on the reference input R(s) and disturbance D(s)

Question 2

The state space equation of a mechanical system is given below. Find the transfer function for the system.

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -k/m & -b/m \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1/m \end{bmatrix} u$$

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

Question 3

Derive the transfer function of a single input single output (SISO) system from the state space equations given as:

$$\dot{x} = Ax + Bu$$

$$y = Cx + Du$$

Question 4

Obtain the state space representation of the RCL circuit shown.

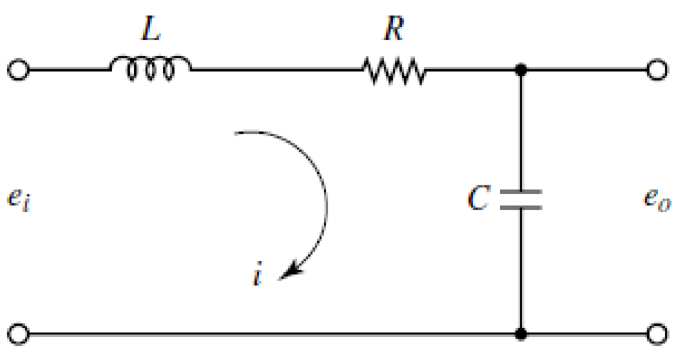


Fig Q4

Question 5

A system is characterized by the transfer function given by:

$$\frac{Y(s)}{U(s)} = \frac{2}{s^3 + 6s^2 + 11s + 6}$$

Test the controllability and observability of the system?

Question 6

Obtain the state space representation of the RC circuit shown in Fig Q6.

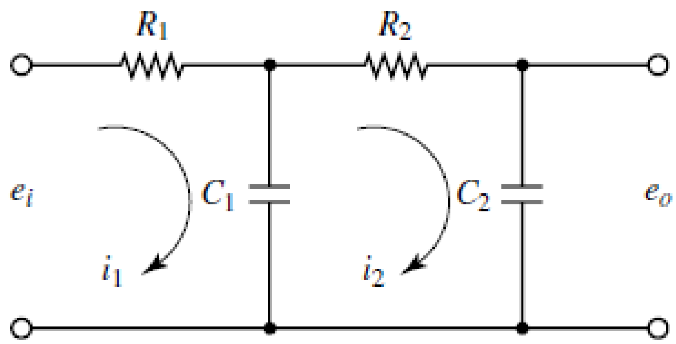


Fig Q6

Question 7

Obtain a state space model of the system shown in Fig Q7.

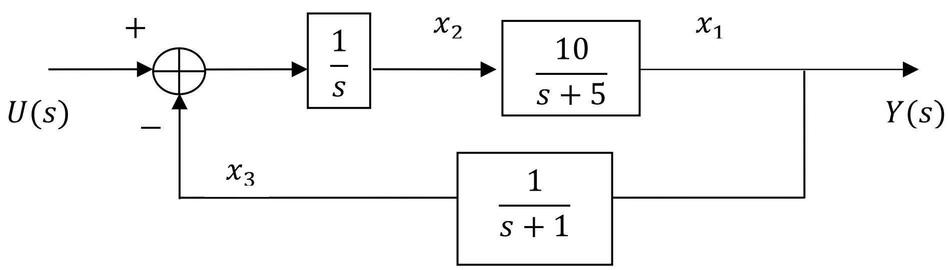


Fig Q7

Question 8

Consider the spring-mass-dashpot system mounted on a massless cart as shown in Fig. Obtain a state space model of the system.

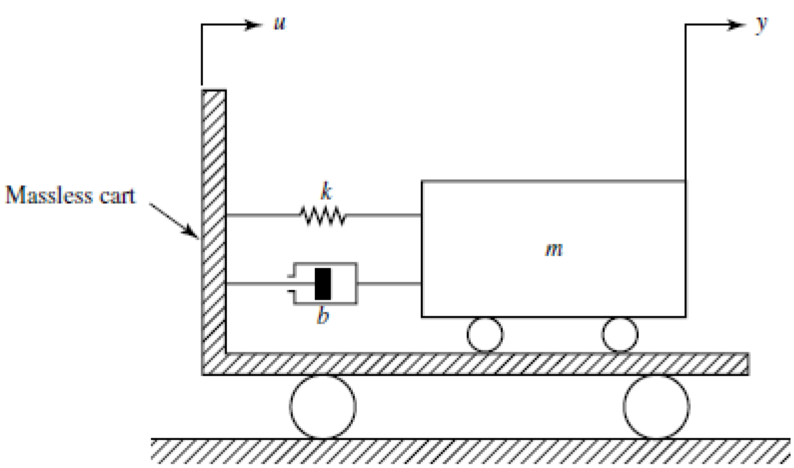


Fig Q8

Question 9

Using the final value theorem, find the steady state error of the system depicted by the block diagram in Fig Q9 for the inputs (i) $r(t) = 4u(t)$ (ii) $r(t) = t^2u(t)$ (iii) $r(t) = 12tu(t)$

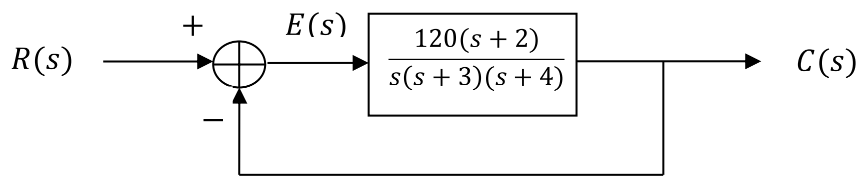


Fig Q9

Question 10
Using block diagram reduction method, find the transfer function of the system in Fig Q10?

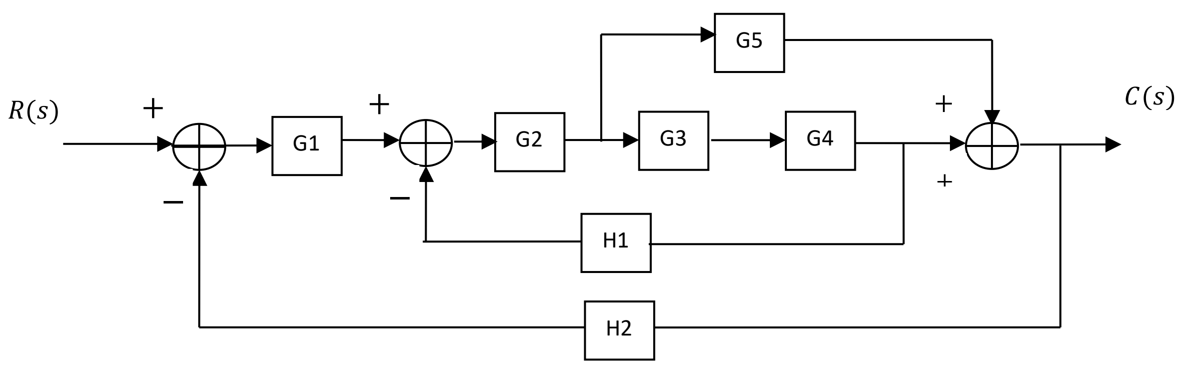


Fig Q10

Question 11
Determine the range of values for control parameter k required for the stability of the system with given characteristic equation:

$$s^3 + 8s^2 + 2s + 4k = 0$$

Question 12
Consider the system shown in Fig. Q12, model the input-output characteristics of the system where q and q2 are the input and output flowrates respectively. Assume variation at steady state is negligible.

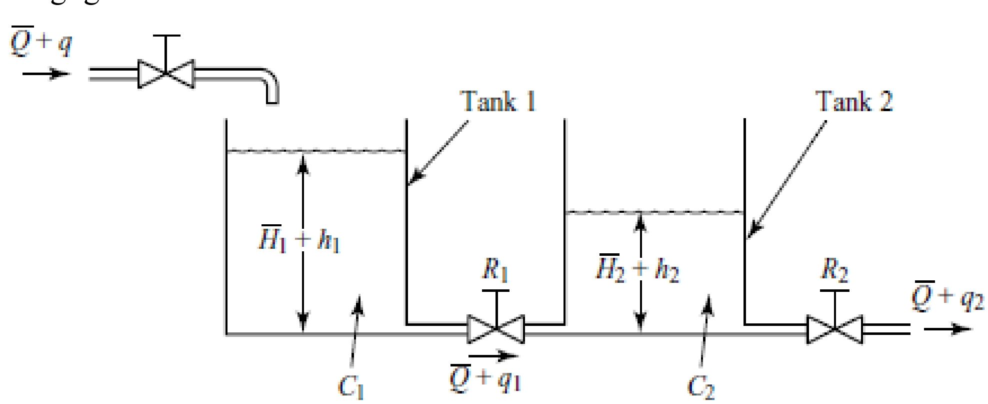


Fig. Q12

Question 13

a) Define Mason's Gain Formula?
b) Obtain the transfer function (C/R) of the system whose signal flow graph is shown in Fig.Q13b.

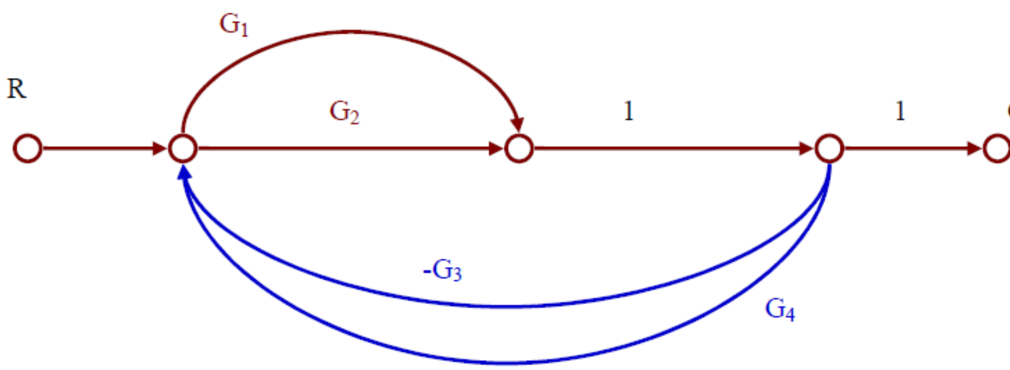
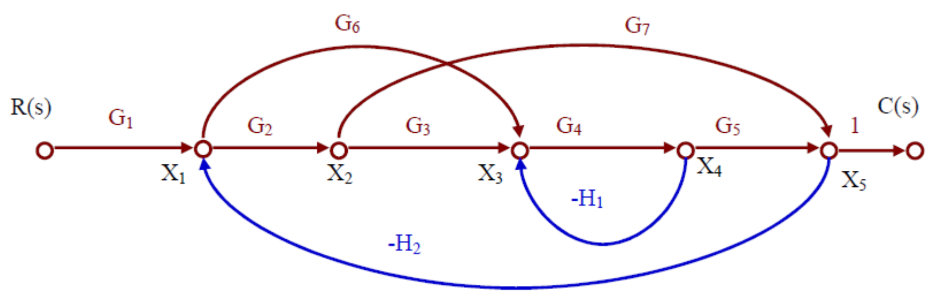


Fig.Q13b.

Question 14

Obtain the transfer function of C(s)/R(s) of the system whose signal flow graph is shown in Fig. Q14.



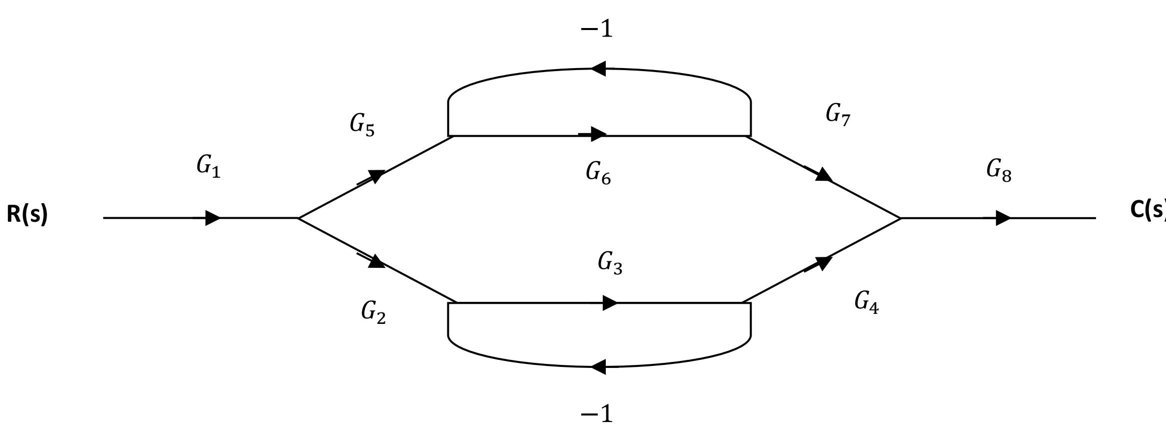


Fig. Q14.

Question 15

Find the transfer function of the system represented by the signal flow graph below?