ECT307	CONTROL SYSTEMS	CATEGORY	L	T	P	CREDIT
		PCC	3	1	0	4

Preamble: This course aims to develop the skills for mathematical modelling of various control systems and stability analysis using time domain and frequency domain approaches.

Prerequisite: EC202 Signals & Systems

Course Outcomes: After the completion of the course the student will be able to

CO 1	Analyse electromechanical systems by mathematical modelling and derive their transfer functions
CO 2	Determine Transient and Steady State behaviour of systems using standard test signals
CO 3	Determine absolute stability and relative stability of a system
CO 4	Apply frequency domain techniques to assess the system performance and to design a control system with suitable compensation techniques
CO 5	Analyse system Controllability and Observability using state space representation

Mapping of course outcomes with program outcomes

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12
CO 1	3	3	2		1							2
CO 2	3	3	2		1							2
CO 3	3	3	3		1							2
CO 4	3	3	3		1							2
CO 5	3	3	3		1							2

Assessment Pattern

Bloom's Category		**Continuous Assessment Tests**		**End Semester Examination**
		1	**2**	
Remember	K1	10	10	10
Understand	K2	20	20	20
Apply	K3	20	20	70
Analyse	K4			
Evaluate				
Create				

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance : 10 marks
Continuous Assessment Test (2 numbers) : 25 marks
Assignment/Quiz/Course project : 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1): Analyse electromechanical systems by mathematical modelling and derive their transfer functions

1. For the given electrical/ mechanical systems determine transfer function.
2. Using block diagram reduction techniques find the transfer function of the given system.
3. Find the overall gain for the given signal flow graph using Mason's gain equation.

Course Outcome 2 (CO2): Determine Transient and Steady State behaviour of systems using standard test signals

1. Derive an expression for time response of a given first/ second order system to step/ ramp input.
2. Determine step, ramp and parabolic error constants for the given unity feedback control system.
3. Obtain the steady state error of a given system when subjected to an input.

Course Outcome 3 (CO3): Determine absolute stability and relative stability of a system

1. Using Ruth Hurwitz criterion, for the given control system determine the location of roots on S- plane and comment on the stability of the system.
2. Sketch the Root Locus for the given control system.

3. Compare P, PI and PID controllers.

Course Outcome 4 (CO4): Apply frequency domain techniques to assess the system performance and to design a control system with suitable compensation techniques

1. Explain frequency domain specifications.
2. Draw the Nyquist plot for the given control system and determine the range of K for which the system is stable.
3. Plot the bode plot for the given transfer function and find the gain margin and phase margin.
4. Describe the design procedure of a lag/ lead compensator.

Course Outcome 5 (CO5): Analyse system Controllability and Observability using state space representation

1. Obtain the state space representation of the given electrical/ mechanical system.
2. For the given control system, obtain the state equations and output equations:-
3. Plot the bode plot for the given transfer function and find the gain margin and phase margin.
4. Determine the controllability and observability of the given system.

SYLLABUS

Module 1:

Introduction: Basic Components of a Control System, Open-Loop Control Systems and Closed-Loop Control Systems, Examples of control system

Feedback and its effects: Types of Feedback Control Systems, Linear versus Nonlinear Control Systems, Time-Invariant versus Time-Varying Systems.

Mathematical modelling of control systems: Electrical Systems and Mechanical systems.

Transfer Function from Block Diagrams and Signal Flow Graphs: impulse response and its relation with transfer function of linear systems. Block diagram representation and reduction methods, Signal flow graph and Mason's gain formula.

Module 2:

Time Domain Analysis of Control Systems: Introduction- Standard Test signals, Time response specifications.

Time response of first and second order systems to unit step input and ramp inputs, time domain specifications.

Steady state error and static error coefficients.

Frequency domain analysis: Frequency domain specifications, correlation between time and frequency responses.

Module 3:

Stability of linear control systems: Concept of BIBO stability, absolute stability, Routh Hurwitz Criterion, Effect of P, PI & PID controllers.

Root Locus Techniques: Introduction, properties and its construction, Application to system stability studies. Illustration of the effect of addition of a zero and a pole.

Module 4:

Nyquist stability criterion: Fundamentals and analysis

Relative stability: gain margin and phase margin. Stability analysis with Bode plot.

Design of Compensators: Need of compensators, design of lag and lead compensators using Bode plots.

Module 5:

State Variable Analysis of Linear Dynamic Systems: State variables, state equations, state variable representation of electrical and mechanical systems, dynamic equations, merits for higher order differential equations and solution.

Transfer function from State Variable Representation, Solutions of the state equations, state transition matrix

Concept of controllability and observability and techniques to test them - Kalman's Test.

Text Books

1. Farid Golnaraghi, Benjamin C. Kuo, Automatic Control Systems, 9/e, Wiley India.
2. I.J. Nagarath, M.Gopal: Control Systems Engineering (5th-Edition) —New Age International Pub. Co., 2007.
3. Ogata K., Discrete-time Control Systems, 2/e, Pearson Education.

Reference Books

1. I.J. Nagarath, M.Gopal: Scilab Text Companion for Control Systems Engineering (3rd-Edition) —New Age International Pub. Co., 2007.
2. Norman S. Nise, Control System Engineering, 5/e, Wiley India.
3. M. Gopal, Digital Control and State Variable Method, 4/e, McGraw Hill Education India, 2012.
4. Ogata K., Modern Control Engineering, Prentice Hall of India, 4/e, Pearson Education,2002.

5. Richard C Dorf and Robert H. Bishop, Modern Control Systems, 9/e, Pearson Education,2001.

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**Introduction**	
1.1	Basic Components of a Control System, Open-Loop Control Systems and Closed-Loop Control Systems, Examples of control system	1
1.2	**Feedback and its effects:** Types of Feedback Control Systems, Linear versus Nonlinear Control Systems, Time-Invariant versus Time-Varying Systems	2
1.3	**Mathematical modelling of control systems:** Electrical Systems and Mechanical systems	3
	Transfer Function from Block Diagrams and Signal Flow Graphs	
1.4	Impulse response and its relation with transfer function of linear systems. Block diagram representation and reduction methods	2
	Signal flow graph and Mason's gain formula	2
2	**Time Domain Analysis of Control Systems**	
2.1	Introduction- Standard Test signals, Time response specifications	2
2.2	Time response of first and second order systems to unit step input and ramp inputs, time domain specifications	3
2.3	Steady state error and static error coefficients	2
2.4	**Frequency domain analysis:** Frequency domain specifications, correlation between time and frequency responses.	2
3	**Stability of linear control systems**	
3.1	Stability of linear control systems: concept of BIBO stability, absolute stability, Routh's Hurwitz Criterion	3
3.2	Effect of P, PI & PID controllers	3
	Root Locus Techniques	
3.3	Introduction, properties and its construction, Application to system stability studies. Illustration of the effect of addition of a zero and a pole	3
4	**Nyquist stability criterion**	
4.1	Fundamentals and analysis	2
4.2	**Relative stability:** gain margin and phase margin. Stability analysis with Bode plot	3
4.3	**Design of Compensators:** Need of compensators, design of lag and lead compensators using Bode plots	4

5	**State Variable Analysis of Linear Dynamic Systems**	
5.1	State variables, state equations	3
5.2	State variable representation of electrical and mechanical systems	2
5.3	Dynamic equations, merits for higher order differential equations and solution	2
5.4	Transfer function from State Variable Representation, Solutions of the state equations, state transition matrix	2
5.5	Concept of controllability and observability and techniques to test them - Kalman's Test	4

Simulation Assignments

The following simulations can be done in Python/ Scilab/ Matlab/ LabView:

1. Plot the pole-zero configuration in s-plane for the given transfer function.
2. Determine the transfer function for given closed loop system in block diagram representation.
3. Plot unit step response of given transfer function and find delay time, rise time, peak time and peak overshoot.
4. Determine the time response of the given system subjected to any arbitrary input.
5. Plot root locus of given transfer function, locate closed loop poles for different values of k.
6. Plot bode plot of given transfer function and determine the relative stability by measuring gain and phase margins.
7. Determine the steady state errors of a given transfer function.
8. Plot Nyquist plot for given transfer function and determine the relative stability.
9. Create the state space model of a linear continuous system.
10. Determine the state space representation of the given transfer function.

Model Question paper

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIFTH SEMESTER B. TECH DEGREE EXAMINATION, (**Model Question Paper)**

Course Code: ECT307

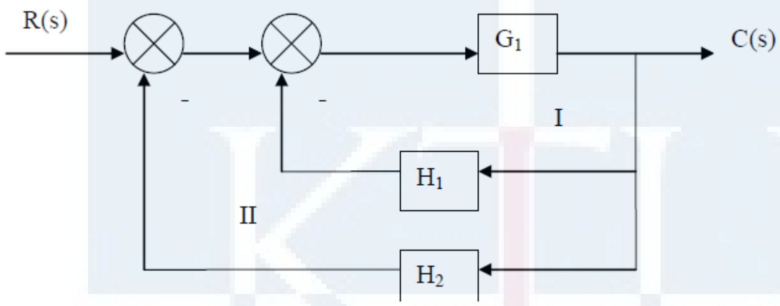
Course Name: CONTROL SYSTEMS

Max. Marks: 100 Duration: 3 Hours

PART A

Answer ALL Questions. Each Carries 3 mark.

1	Draw the signal flow graph for the following set of algebraic equations: $x_1=ax_0+bx_1+cx_2$, $x_2=dx_1+ex_3$	K2
2	Using block diagram reduction techniques find C(s) / R(s) for the given system:	K2

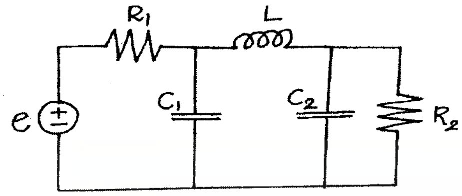


3	Derive the expression for peak time of a second order system	K2
4	Determine the parabolic error constant for the unity feedback control system $G(s) = 10\,(S+2)/\,(s+1)\,s^2$	K3
5	Using Routh Hurvitz criterion, determine the number of roots in the right half of S-plane for the system $S^4+2S^3+10S^2+20S+5=0$.	K3
6	Compare PI, PD and PID controllers.	K1
7	State and explain Nyquist Stability criteria.	K1
8	Briefly describe the design procedure of a lead compensator.	K1
9	A dynamic system is represented by the state equation:	K3

$$X= \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & -2 & -3 \end{bmatrix} X + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} r$$

Check whether the system is completely controllable.

10 Obtain the state space representation of the given electrical system: K3

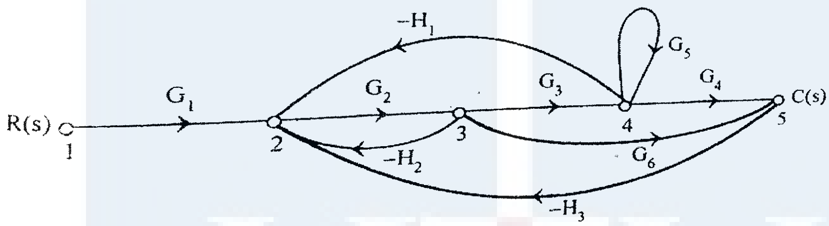


PART – B

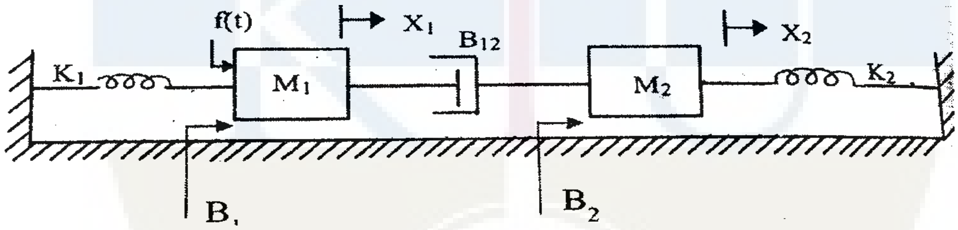
Answer one question from each module; each question carries 14 marks.

Module - I

11a. Find the overall gain C(s)/ R(s) for the signal flow graph shown using Mason's gain equation 7 CO1 K3

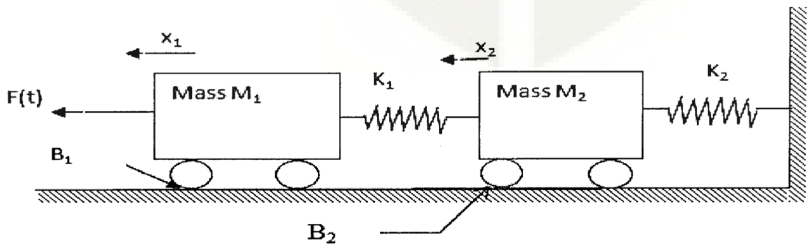


11b. Determine the transfer function $X_1(s)/ F(s)$ for the system shown below: 7 CO1 K3



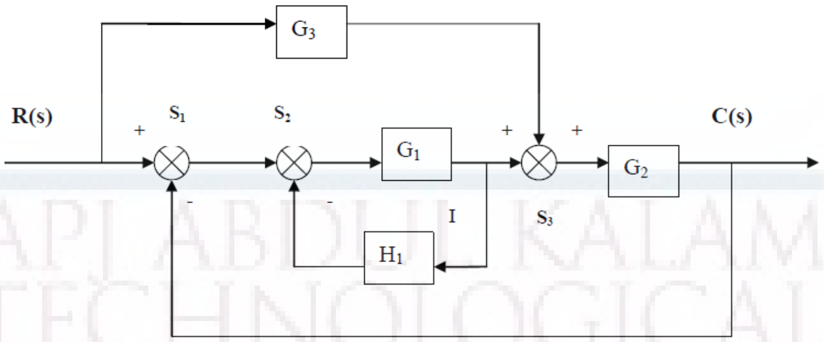
OR

12a. Find the transfer function $X_2(s)/ F(s)$. Also draw the force voltage analogy of the given system: 8 CO1 K3



12b.

Determine the overall transfer function of the block diagram shown in below figure: 6 CO1 K3



Module - II

13a. The open loop transfer function of a servo system with unity feedback is G(s) = 10/s(0.1s+1). Evaluate the static error constants of the system. Obtain the steady state error of the system when subjected to an input given by $r(t)= a_0+a_1t+a_2t^2/2$ 7 CO2 K2

13b. A unity feedback control system is characterized by an open loop transfer function G(s) = K/ s(s+10). Determine the gain K so that the system will have a damping ratio of 0.5 for this value of K. Determine the settling time, peak overshoot, rise time and peak time for a unit step input. 7 CO2 K2

OR

14a. Find kp, kv, ka and steady state error for a system with open loop transfer function G(s)H(s) = 15 (s+4) (s+9)/ s(s+3) (s+6) (s+8) 7 CO2 K2

14b. Derive the expression for time response of a second order under damped system to step input. 7 CO2 K2

Module - III

15a. Sketch the root locus for $G(s)H(s) = K/ s(s+6) (s^2+4s+13)$ 7 CO3 K3

15b. The characteristic equation of a system is $s^7+9s^6+24s^5+24s^4+24s^3+24s^2+23s+15$. Determine the location of roots on S- plane and hence comment on the stability of the system using Ruth Hurwitz criterion. 7 CO3 K3

OR

16a.	Prove that the breakaway points of the root locus are the solutions of dK/ds = 0.	7
16b.	where K is the open loop gain of the system whose open loop transfer function is G(s).	CO3 K2
17a.	For a system with, F(s) = s4 + 22s3 + 10 s2 + s + K = 0. obtain the marginal value of K, and the frequency of oscillations of that value of K.	7 CO3 K3

Module - IV

17b.	Plot the bode diagram for the transfer function G(S) = 10/ S(1+0.4S) (1+0.1S) and find the gain margin and phase margin.	7 CO4 K3
	The open loop transfer function of a feedback system is given by G(s) = K / s (T1s+1) (T2s+1) Draw the Nyquist plot. Derive an expression for gain K in terms of T1, T2 and specific gain margin Gm.	7 CO4 K3

OR

18a.	A servomechanism has an open loop transfer function of G(s) = 10 / s (1+0.5s) (1+0.1s) Draw the Bode plot and determine the phase and gain margin. A network having the transfer function (1+0.23s)/(1+0.023s) is now introduced in tandem. Determine the new gain and phase margins. Comment upon the improvement in system response caused by the network.	8 CO4 K3
18b.	Draw the Nyquist plot for the system whose open loop transfer function is G(s)H(s) = K/ S(S+2) (S+10). Determine the range of K for which the closed loop system is stable.	6 CO4 K3

Module - V

19a.	Obtain the state model for the given transfer function Y(s)/ U(s) = 1/ (S^2+S+1).	7 CO5 K3
19b.	What is transfer matrix of a control system? Derive the equation for transfer matrix.	7 CO5 K2

OR

20a.	A system is described by the transfer function Y(s)/ U(s) = 10 (s+4)/ s (s+2) (s+3). Find state and output equations of the system.	7 CO5 K3
20b.	Determine the state transition matrix of $A=\begin{bmatrix} 2 & 0 \\ -1 & 2 \end{bmatrix}$	7 CO5 K3