CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
EET385	CONTROL SYSTEMS	VAC	3	1	0	4

Preamble: This course deals with the fundamental concepts of control systems theory. Modelling, time domain analysis, frequency domain analysis and stability analysis of linear systems based on transfer function approach are discussed. The state space concept is also introduced.

Prerequisite: Basics of Dynamic Circuits and Systems

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

CO 1	Describe the role of various control blocks and components in feedback systems
CO 2	Analyse the time domain responses of the linear systems
CO 3	Apply Root locus technique to assess the performance of linear systems
CO 4	Analyse the stability of the given LTI systems.
CO 5	Apply state variable concepts to assess the performance of linear systems

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	3	-	-	-	-	-	-	-	-	-	3
CO 2	3	3	3	-	-	-	-	-	-	-	-	3
CO 3	3	3	3	-	2	-	-	-	-	-	-	3
CO 4	3	3	3	-	-	-	-	-	-	-	-	3
CO 5	3	3	3	3	-	-	-	-	-	-	-	3

Assessment Pattern:

Total Marks	CIE marks	ESE marks	ESE Duration
150	50	100	03 Hrs

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember (K1)	10	10	20
Understand (K2)	10	10	20
Apply (K3)	30	30	60
Analyse (K4)			
Evaluate (K5)			
Create (K6)			

End Semester Examination Pattern : There will be two parts; Part A and Part B. **Part A** contains 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 carries 14 marks and can have maximum 2 sub-divisions.

Course Level Assessment Questions:

Course Outcome 1 (CO1)

1. Derive and explain the transfer function of field controlled dc servo motor.
2. With the help of suitable example explain the need for analogous systems.
3. Explain how does the feedback element affect the performance of the closed loop system?

Course Outcome 2 (CO2):

1. Obtain the different time domain specification for a given second order system with impulse input and assess the system dynamics.
2. Determine the value of the natural frequency of oscillation ω_n for the unity feedback system with forward transfer function $G_p(s) = \frac{K}{s(s+10)}$, which results in a critically damped response.
3. Problems related to static error constant and steady state error for a given input.

Course Outcome 3 (CO3):

1. Determine the value of K such that the closed loop system with $G(s)H(s) = \frac{K}{s\,(s+1)\,(s+4)}$ is oscillatory, using Root locus.
2. Construct the Root locus for the closed loop system with $G(s)H(s) = \frac{K}{s\,(s^2+3s+2)}$.

   Determine the value of K to achieve a damping factor of 0.5?
3. Problem on root locus for systems with positive feedback.

Course Outcome 4 (CO4):

1. Problems related to application of Routh's stability criterion for analysing the stability of given system.
2. Determine the value of K such that the gain margin for the system with $G(s)H(s) = \frac{K}{s\,(s+2)\,(s+5)}$ equals to 10 dB.
3. Problem related to the analysis of given system using Polar plot.

Course Outcome 5 (CO5):

1. Determine the transfer function of the system given by:

   system with state model:

   $$\dot{X} = \begin{bmatrix} -2 & 1 \\ -1 & -2 \end{bmatrix} x + \begin{bmatrix} 1 \\ 1 \end{bmatrix} u; \quad y = \begin{bmatrix} 0 & 1 \end{bmatrix} x \cdot$$

2. Obtain the time response y(t) of the homogeneous system represented by:

   $$\begin{bmatrix} \dot{X} \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -3 & -4 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \quad [y] = [1 \quad 0][X] \text{ with } x(0) = \begin{bmatrix} 1 \\ -2 \end{bmatrix}$$

3. Derive and analyse the state model for a field controlled dc servo motor.

Model Question Paper PAGES: 3

QP CODE:

Reg. No:___________

Name:_____________

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

FIFTH SEMESTER B.TECH DEGREE EXAMINATION

MONTH & YEAR

Course Code**: EET385**

Course Name: **CONTROL SYSTEMS**

Max. Marks: 100 **Duration: 3 Hours**

PART A

Answer all Questions. Each question carries 3 Marks

1 Give a comparison between open loop and closed loop control systems with suitable examples.

2 With relevant characteristics explain the operation of a tacho generator as a control device.

3 For a closed loop system with $G(s) = \frac{3}{s\,(s+2)}$; and H(s) = 0.1, calculate the steady state error constants.

4 Check the stability of the system given by the characteristic equation, $G(s) = s^5 + 2s^4 + 4s^3 + 8s^2 + 16s + 32$; using Routh criterion.

5 With suitable sketches explain how addition of zeroes to the open-loop transfer function affects the root locus plots.

6 Explain Ziegler – Nichol's PID tuning rules.

7 Explain the features of Non-minimum phase systems with a suitable example.

8 How do you determine the gain margin of a system, with the help of Bode plot?

9 A system is represented by $\frac{Y(s)}{U(s)} = \frac{3}{(s+1)(s+2)}$. Derive the Canonical diagonal form of representation in state space.

10 Discuss the advantages of state space analysis.

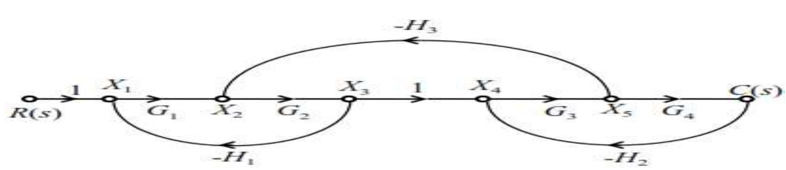
PART B

Answer any one full question from each module. Each question carries 14 Marks

Module 1

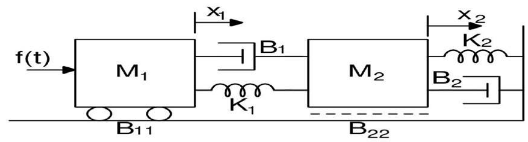
11 a) Derive the transfer function of an Armature controlled dc servo motor. Assess the effect of time constants on the system performance. **(8)**

b) Determine the transfer function of the system represented by the signal flow graph using Mason's gain formula.



(6)

12 a) Derive the transfer function $X_2(s)/\ F(s)$ for the mechanical system.



(9)

b) Compare the effect of H(s) on the pole-zero plot of the closed loop system with $G(s) = \dfrac{s+1}{(s^2+5s+6)}$ with: i) derivative feed back H(s)= s; ii) integral feedback H(s)=1/s. **(5)**

Module 2

13 a) Derive an expression for the step response of a critically damped second order system? Explain the dependency of maximum overshoot on damping factor. **(9)**

b) Determine the value of gain K and the natural frequency of oscillation ω_n for the unity feedback system with forward transfer function $G(s) = \dfrac{K}{s(s+6)}$, which results in a critically damped response when subjected to a unit impulse input.

Also determine the steady state error for unit velocity input. **(5)**

14 a) A unity feedback system is characterized by an open loop transfer function $G(s) = \dfrac{4}{(s^2+ s+5)}$. Determine the transient response when subjected to a unit step input and sketch the response. Evaluate the rise time and peak time of the system. . **(9)**

b) Using Routh criterion determine the value of K for which the unity feedback closed loop system with $G(s) = \dfrac{K}{s(s^2+3s+1)}$ is stable. . **(5)**

Module 3

15 a) Determine the value of K such that the closed loop system with $G(s)H(s) = \dfrac{K}{s\,(s+2)\,(s+5)}$ is oscillatory, using Root locus.

Also determine the value of K to achieve a damping factor of 0.866. **(10)**

b) Compare between PI and PD controllers. **(4)**

16 a) Sketch the root locus for a system with $G(s)H(s) = \dfrac{K(s-1)}{s(s+4)}$. Hence determine the range of K for the system stability. **(9)**

b) With help of suitable sketches, explain how does Angle and Magnitude criteria of Root locus method help in control system design. **(5)**

Module 4

17 a) The open-loop transfer function of a unity feedback system is G(s)=$\dfrac{K}{s(0.5s+1)(0.04s+1)}$.Use asymptotic approach to plot the Bode diagram and determine the value of K for a gain margin of 10 dB. **(10)**

b) Derive and explain the dependence of resonant peak on damping factor**.** **(4)**

18 a) Draw the polar plot for the system with $G(s)H(s) = \dfrac{K}{s(s+0.5)(s+2)}$ and determine the value of K such that phase margin equals to 40^{o}. **(9)**

b) Explain the detrimental effects of transportation lag using Bode plot. **(5)**

Module 5

19 a) Obtain the time response y(t) of the homogeneous system represented by:

$$\begin{bmatrix}\dot{X}\end{bmatrix}=\begin{bmatrix}-1 & 1\\ -2 & -3\end{bmatrix}\begin{bmatrix}x_1\\ x_2\end{bmatrix} \quad [y]=[1 \quad 0][X] \text{ with } x(0)=\begin{bmatrix}1\\ 0\end{bmatrix}$$ **(6)**

b) Derive and analyse the state model for a field controlled dc servo motor **(8)**

20 a) A system is represented by $\frac{Y(s)}{U(s)}=\frac{4(s+0.5)}{(s+1)(s+2)}$. Derive the phase variable representation in state space. **(5)**

b) Derive the transfer function for the system with

$$\begin{bmatrix}\dot{X}\end{bmatrix}=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 2\\ -12 & -7 & -4\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}+\begin{bmatrix}0\\ 1\\ 1\end{bmatrix}u; \quad [y]=[1 \quad 0 \quad 0][X]$$

(9)

Syllabus

Module 1

System Modeling (8 hours)

Open loop and closed loop control systems

Transfer function of LTI systems- Electrical, translational and rotational systems – Force voltage and force current analogy

Block diagram representation - block diagram reduction

Signal flow graph - Mason's gain formula

Control system components: Transfer functions of DC and AC servo motors– Control applications of Tacho generator and Stepper motor.

Module 2

Performance Analysis of Control Systems (12 hours)

Characteristic equation of Closed loop systems- Effect of feedback-.

Time domain analysis of control systems: Time domain specifications of transient and steady state responses- Impulse and Step responses of first order and second order systems.

Error analysis: Steady state error analysis - static error coefficients of type 0,1,2 systems.

Stability Analysis: Concept of stability- BIBO stability and Asymptotic stability- Time response for various pole locations- stability of feedback systems - Routh's stability criterion- analysis - relative stability

Module 3

Root Locus Analysis and Compensators (8 hours)

Root locus technique: General rules for constructing Root loci – stability from root loci - Effect of addition of poles and zeros on Root Locus- Effect of positive feedback systems on Root Locus

Need for controllers: Types- Feedback, cascade and feed forward controllers

PID controllers (basic functions only)- Zieglar Nichols PID tuning methods

Introduction to MATLAB functions and Toolbox for Root locus based analysis (Demo/Assignment only))

Module 4

Frequency Domain Analysis (9 hours)

Frequency domain specifications- correlation between time domain and frequency domain responses

Polar plot: Concepts of gain margin and phase margin- stability analysis

Bode Plot: Construction of Bode plots- Analysis based on Bode plot

Effect of Transportation lag and Non-minimum phase systems

Introduction to MATLAB functions and Toolbox for various frequency domain plots and analysis (Demo/Assignment only).

Module 5

State Space Analysis of Systems (10 hours)

Introduction to state space and state model concepts- state equation of linear continuous time systems, matrix representation- features -Examples of simple electrical circuits, and dc servomotor.

Phase variable forms of state representation- controllable and observable forms- Diagonal Canonical forms - Jordan canonical form

Derivation of transfer function from state equations.

State transition matrix: Properties of state transition matrix- Computation of state transition matrix using Laplace transform- Solution of homogeneous systems

Textbooks

1. Nagarath I. J. and Gopal M., Control System Engineering, 5/e, New Age Publishers
2. Ogata K, Modern Control Engineering, 5/e, Prentice Hall of India.
3. Nise N. S, Control Systems Engineering, 6/e, Wiley Eastern
4. Dorf R. C. and Bishop R. H, Modern Control Systems, 12/e, Pearson Education
5. K R Varmah, Control Systems, Tata McGrawHill, 2010

Reference Books

1. Kuo B. C, Automatic Control Systems, 7/e, Prentice Hall of India
2. Desai M. D., Control System Components, Prentice Hall of India, 2008
3. Gopal M., Control Systems Principles and Design, 4/e, Tata McGraw Hill.
4. Imthias Ahamed T. P, Control Systems, Phasor Books, 2016
5. Gopal M., Modern Control System Theory, 2/e, New Age Publishers

Course Contents and Lecture Schedule:

Module	Topic coverage	No. of Lectures
1	**System Model (8 hours)**	
1.1	Open loop and closed loop control systems	1
1.2	Transfer function of LTI systems- Electrical, translational and rotational systems – Force voltage and force current analogy	2
1.3	Block diagram representation - block diagram reduction	2
1.4	Signal flow graph - Mason's gain formula	1
1.5	Control system components: Transfer functions of DC and AC servo motors –Control applications of Tacho generator and Stepper motor.	2
2	**Performance Analysis of control systems (10 hours)**	
2.1	Characteristic equation of CL systems- Effect of feedback	1

2.2	Time domain analysis of control systems: Time domain specifications of transient and steady state responses, Impulse and Step responses of first order systems, Impulse and Step responses of second order systems.	3
2.3	Error analysis: Steady state error analysis - static error coefficients of type 0, 1, 2 systems.	2
2.4	Stability Analysis: Concept of stability- BIBO stability and Asymptotic stability- Time response for various pole locations- stability of feedback systems	2
2.5	Routh criterion: Routh's stability criterion- analysis - relative stability	2
3	**Root locus Analysis and Compensators (8 hours)**	
3.1	Root locus technique: General rules for constructing Root loci - stability from root loci -	3
3.2	Effect of addition of poles and zeros on Root Locus.	1
3.3	Effect of positive feedback on Root Locus	1
3.4	Need for controllers: Types- Feedback, cascade and feed forward controllers	1
3.5	PID controllers: PID controllers (basic functions only)- Zieglar Nichols tuning methods	2
3.6	*Introduction to MATLAB functions and Toolbox for Root locus based analysis (Demo/Assignment only)*	
4	**Frequency domain analysis (9 hours)**	
4.1	Frequency domain specifications- correlation between time domain and frequency domain responses	2
4.2	Polar plot: Concepts of gain margin and phase margin- stability analysis	2
4.3	Bode Plot: Construction of Bode plots- Analysis based on Bode plot	4
4.4	Effect of Transportation lag and Non-minimum phase systems	1
4.5	*Introduction to MATLAB functions and Toolbox for various frequency domain plots and analysis (Demo/Assignment only)*	
5	**State space Analysis of systems (10 hours)**	
5.1	Introduction to state space and state model concepts- state equation of linear continuous time systems, matrix representation- features -Examples of simple electrical circuits, and dc servomotor.	3
5.2	Phase variable forms of state representation-controllable and observable forms	2
5.3	Diagonal Canonical forms of state representation- diagonal & Jordan canonical forms	2
5.4	Derivation of transfer function from state equation.	1
5.5	State transition matrix: Properties of state transition matrix- Computation of state transition matrix using Laplace transform- Solution of homogeneous systems	2