Government of Karnataka
Department of Technical Education
Board of Technical Examinations, Bengaluru

Course Title: Control Engineering		Course Code:15MC54B
Mode (L:T:P) : 4:0:0	Credits:4	Core/ Elective: Elective
Type of Course: Lectures & Student Activities		Total Contact Hours: 52
CIE= 25 Marks		SEE= 100 Marks

Pre-requisites: Knowledge of Mathematics,

Course Objectives: Understand the importance and application of control systems with respect to stability, response of the system to various types of inputs/signals

Co**urse Outcome**: At the end of the course, the student will be able to

1. Explain the importance of control systems
2. Explain the modelling of physical systems
3. Explain transfer functions, draw block diagrams and signal flow graphs
4. Explain time response of feedback control systems
5. Examine the stability of a given transfer function
6. Explain the importance of frequency response analysis

Course Outcome		Cognitive Level	Linked with PO	Teaching Hours
CO1	Explain the importance of control systems	***U***	2	4
CO2	Explain the modelling of physical systems	***U***	1,2	8
CO3	Explain transfer functions, and draw block diagrams and signal flow graphs	***U***	1,2	10
CO4	Explain time response of feedback control systems	***U***	1,2	8
C05	Examine the stability of a given transfer function	***A***	1,2	12
C06	Explain the importance of frequency response analysis	***U***	1,2	10
		Total sessions		**52**

Legend: R; Remember, U: Understand A: Analyzing

Mapping of Course Outcomes with Program Outcomes

Course	Programme Outcomes									
	1	2	3	4	5	6	7	8	9	10
Control Engineering	**3**	**3**	-	-	-	-	-	-	-	-

Course Content and Weightage For SEE

Unit No	Unit Name	CO	Hour	Marks allocated for different Cognitive level Questions			Marks weightage (%)
				R	U	A	
1	Introduction to Control Systems	1	4	-	10	-	6.90
2	Modeling of Physical Systems	2	8	-	20	-	13.80
3	Transfer functions, Block diagrams and Signal flow graphs	3	10	-	30	-	20.68
4	Time response of feedback control systems	4	8	-	20	-	13.80
5	Stability – concepts and analysis and Root Locus Techniques	5	12	-	-	35	24.14
6	Frequency response and analysis	6	10	-	30	-	20.68
	Total		52	145 Marks			100

Contents

Unit-I

Introduction to Control Systems

Introduction, Open loop control system,, Closed loop control system, Development of control systems, Multivariable control system, Advantages of control systems

4 Hours

Unit-II

Modeling of Physical Systems

Physical system, Physical model and Mathematical model, Differential equations: Mechanical translational system, Mechanical rotational system, Thermal system, Liquid level system, Analogous systems (Force-Voltage and Force-Current)

8 Hours

Unit-III

Transfer functions, Block diagrams and Signal flow graphs

Introduction to Laplace transform, Definition of Laplace transform, Inverse of Laplace transform, Laplace transform theorems, Laplace transform pairs, Transfer function, Procedure for deriving transfer functions, Block diagram algebra, Block diagram of a Single-input closed-loop system, Signal flow graphs: Signal flow graph of a closed-loop system, Construction of signal flow graph, Mason's Gain formula (only definition and equation)

10 Hours

Unit-IV

Time response of feedback control systems

Transient response and Time response of control system, Standard test signals: Step signal, Ramp signal, Parabolic signal, Impulse signal, Time response of first-order systems for step-signal, Time response specifications, Performance indices for step response, Compensations in second and higher order systems (PD, PI and PID controller), Lag-Lead Compensation

8 Hours

Unit-V

Stability – concepts and analysis and Root Locus Techniques

Concept of stability, Relative stability, Conditions for stability, methods determination of stability of linear continuous data system (without involving root solving) of Routh-Hurwitz stability criterion, Introduction to Root locus concept, Construction of Root loci, Construction rules, Breakaway points on real axis – analytical approach, Breakaway points on real axis – graphical approach, Breakaway directions of Root locus branches, Determination of roots from Root locus, Root contours

12 Hours

Unit-VI

Frequency response and analysis

Introduction to Frequency response specifications, Polar plots, Bode plots, General procedure for constructing Bode plots, All-pass and Minimum-phase systems, Log-magnitude versus phase plots

10 Hours

REFERENCE BOOKS:

1. I.J. Nagarath and M. Gopal, "*Control Systems Engineering*", 5th edition, New Age International, New Delhi,
2. Benjamin C. Kuo and Farid Golnaraghi, "*Automatic Control Systems*", 8th edition, Wiley India, New Delhi,
3. Katsuhiko Ogatta, "*Modern Control Engineering*", 4th edition, Pearson Education, Bangalore,
4. *Schaum's Outline of Feedback and Control Systems*
5. S N Verma, "*Automatic Control System*", Khanna Publishers

e-Reference

1. http://www.site.uottawa.ca/~rhabash/ELG4152LN01.pdf
2. **https://www.ent.mrt.ac.lk/~rohan/teaching/EN2142/Reading/DORFCH1.pdf**
3. **http://www.electrical4u.com/signal-flow-graph-of-control-system/**
4. **http://ocw.nctu.edu.tw/upload/classbfs1209114844102343.pdf**
5. **https://www.maplesoft.com/content/EngineeringFundamentals/11/MapleDocument_11/Block%20Diagrams,%20Feedback%20and%20Transient%20Response%20Specifications.pdf**
6. **http://lpsa.swarthmore.edu/Root_Locus/RLocusExamples.html**
7. **https://www.youtube.com/watch?v=CRvVDoQJjYI**
8. **http://www.me.ust.hk/~mech261/index/Lecture/Chapter_7.pdf**
9. **https://www.facstaff.bucknell.edu/mastascu/eControlHTML/Freq/Freq5.html**
10. **https://www.facstaff.bucknell.edu/mastascu/eControlHTML/Freq/Freq5.html**

Student Activity

Activity No	Description of the Student Activity
1	Prepare root locus for given problems
2	Prepare bode plot for given problems

Note:

1. Group of max four students should do any one of the above activity or any other similar activity related to the course COs and get it approved from concerned Teacher and HOD.
2. No group should have activity repeated or similar
4. Teacher should asses every student by using suitable **Rubrics** approved by HOD

Sample Rubrics

Dimension	Exemplary	Accomplished	Developing	Beginning	Roll No. of the Student				
	5/4	3	2	1	1	2	3	4	5
Organization	Information presented in logical, interesting sequence	Information in logical sequence	Difficult to follow presentation--student jumps around	Cannot understand presentation--no sequence of information	Ex: 2				
Subject Knowledge	Demonstrates full knowledge by answering all class questions with explanations and elaborations	At ease with expected answers to questions but does not elaborate	Uncomfortable with information and is able to answer only rudimentary questions	Does not have a grasp of the information. Cannot answer questions about subject	4				
Graphics	Explain and reinforce screen text and presentation	Relate to text and presentation	Occasionally uses graphics that rarely support text and presentation	Uses superfluous graphics or no graphics	5				
Oral Presentation	Maintains eye contact and pronounces all terms precisely. All audience members can hear	Maintains eye contact most of the time and pronounces most words correctly. Most audience members can hear presentation	Occasionally uses eye contact, mostly reading presentation, and incorrectly pronounces terms. Audience members have difficulty hearing	Reads with no eye contact and incorrectly pronounces terms. Speaks too quietly	3				
Total Score=2+3+4+5=14/4=3.5=4									

Course Assessment Pattern

Particulars			Max Marks	Evidence	Course outcomes
Direct Assessment	**CIE**	Three tests (Average of three tests)	20	Blue books	1,2,3,4,5,6
		Student Activity	05	Student Activity Sheets	1,2,3,4,5,6
	SEE	End of the course	100	Answer scripts at BTE	1,2,3,4,5,6
Indirect Assessment	**Student Feedback on course**	Middle of the course		Feedback forms	1, 2&3
		End of the course		Feedback forms	1,2,3, 4, 5&6

Note: I.A. test shall be conducted for 20 marks. Average marks of three tests shall be rounded off to the next higher digit.

Note to IA verifier*: *The following documents to be verified by CIE verifier at the end of semester

1. Blue books (20 marks)
2. Student suggested activities report for 5 marks and should be assessed on RUBRICS
3. Student feedback on course regarding Effectiveness of Delivery of instructions & Assessment Methods.

Model Question Paper (CIE)

Date and Time	Semester	Course	Max Marks
1Test(6 th week of sem) 10-11 Am	V SEM	Control Engineering	20
	Year: 2017-18	Course code:15MC54B	

Name of Course coordinator : **Units:1,2 Co: 1,2**

All questions carries equal marks

Q. No	Question	CL	CO	PO
1	Explain open loop control system with examples OR Explain difference between open loop and closed loop control system	U	1	1,2
2	Explain Closed loop control system (automatic) with a block diagram OR Explain basic control system with a block diagram and terminology	U	1	1,2
3	Explain Physical system with an example OR Explain Mathematical model with an example	U	2	1,2
4	Explain thermal system with an example OR Explain force-current analogy	U	2	1,2

Model Question Paper
V Semester Diploma in Mechatronics Engineering
Control engineering

Instructions: Answer any six questions from part A and Seven full questions from part B

PART-A

Answer any six questions. **5X6=30 marks**

1. Explain Open loop control system with a block diagram
2. Explain Physical system with an example
3. Explain transfer function with an example
4. Explain Mason's Gain formula with its related equation
5. Explain the significance of transient response of a control system
6. Explain relative stability of a system
7. Explain root contours with an illustration
8. Explain explain frequency response test on a system
9. Explain a simple illustration, explain Bode plot

PART- B

Answer any seven full questions. **10X7=70M**

1 a) Explain closed loop control system with examples
b) Explain force-voltage analogy

2 a) Explain torque equation for inertia, torsion spring and damper element in mechanical system
b) Explain mechanical rotational system with its related force equation

3 a) Explain assumptions made for deriving transfer functions of physical systems
b) Explain briefly block diagram of a control system with an example

4 Explain the terminology of signal flow graph with an example of a closed-loop System

5 With a sample curve of damped oscillatory nature, explain the time response specifications of control systems to a step-input

6 Solve for the breakaway points of the root locus for the loop transfer function $G(s)\,\mathrm{H(s)} = \dfrac{K(s+4)}{(s^2+2s+4)}$

7 Using Routh-Hurwitz criterion, explain the stability of closed loop system that has the characteristic equation $s^3 + 25s^2 + 10s + 450 = 0$. Solve for the number of roots of each equation that are in the right half of s-plane and on $j\omega$-axis

8 Explain the breakaway points of the root locus for the loop transfer function0

9 a) Explain phase margin and gain margin

b) Explain the general procedure for constructing Bode plots

10 a) Explain between minimum phase transfer and all-pass systems.

b) Explain the significance of a Log-magnitude versus phase plot

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Model Question Bank
V Semester Diploma in Mechatronics Engineering
Control Engineering

Unit -1
Introduction to Control Systems
Cognitive level- Understanding

1. Explain basic control system with a block diagram and terminology
2. Explain Open loop control system with a block diagram.
3. Explain open loop control system with examples
4. Explain Closed loop control system (manually operated) with a block diagram.
5. Explain Closed loop control system (automatic) with a block diagram
6. Explain closed loop control system with examples
7. Explain difference between open loop and closed loop control system
8. Explain with a block diagram describe a multivariable control system.
9. Explain advantages of control systems.

Unit –II
Modeling of Physical Systems
Cognitive level- Understanding

1. Explain Physical system with an example
2. Explain Physical model with an example
3. Explain Mathematical model with an example
4. Explain force equation of the mass, spring and damper element in mechanical system
5. Explain torque equation for inertia, torsion spring and damper element in mechanical system
6. Explain mass-spring-dashpot system with its free body diagram with related force equation
7. Explain mechanical translation system
8. Explain mechanical rotational system with its related force equation
9. Explain thermal system with an example
10. Explain liquid level system with an example
11. Explain force-voltage analogy
12. Explain force-current analogy

Unit –III
Transfer functions, Block diagrams and Signal flow graphs
Cognitive level- Understanding

1. Explain transfer function with respect to mass, spring and dashpot system.
2. Explain Laplace transform with an example.
3. Explain inverse Laplace transform with an example.
4. Explain important theorems of Laplace transform without derivation
5. Explain transfer function with an example

6. Explain the procedure for deriving transfer functions of physical systems.
7. Explain assumptions made for deriving transfer functions of physical systems.
8. With a block diagram explain the reduction of a Single-input closed-loop system.
9. Explain briefly block diagram of a control system with an example
10. Explain block diagram elements of typical sensing device
11. Briefly explain the terminology of signal flow graph with an example of a closed-loop system.
12. Explain in brief the construction procedure of signal flow graph.
13. Explain Mason's Gain formula with its related equation

Unit-IV
Time response of feedback control systems
Cognitive level- Understanding

1. Explain the significance of transient response of a control system.
2. Explain the significance of transient time response of a control system.
3. Explain step signal with its graphical and mathematical representation
4. Explain ramp signal with its graphical and mathematical representation
5. Explain parabolic signal with its graphical and mathematical representation
6. Explain impulse (rectangular response) signal with its graphical and mathematical
7. representation.
8. Explain time response of first-order systems (Unit-step Input only).
9. With a sample curve of damped oscillatory nature, explain the time response specifications of control systems to a step-input.
10. Explain the performance indices that characterize the step response of a control system.
11. Explain Compensation
12. Explain Proportional plus Derivative (PD),
13. Explain Proportional plus Integral (PI)
14. Explain Proportional plus Integral and Derivative (PID) Controller.
15. Briefly explain lead-lag compensation in control systems.

Unit-V
Stability – concepts and analysis and Root Locus Techniques
Cognitive level- Analyzing

1. Using Routh-Hurwitz criterion, explain the stability of closed loop system that has the following characteristic equation. Solve for the number of roots of each equation that are in the right half of s-plane and on $j\omega$-axis
   a. $s^3 + 25s^2 + 10s + 450 = 0$
   b. $s^3 + 25s^2 + 10s + 50 = 0$
   c. $s^3 + 25s^2 + 250s + 10 = 0$
   d. $s^4 + 2s^3 + 8s^2 + 4s + 3 = 0$
   e. $s^5 + s^4 + 3s^3 + 9s^2 + 16s + 10 = 0$

2. Determine and solve for the breakaway points of the root locus for the loop transfer function $G(s)\,\mathrm{H(s)} = \dfrac{K}{(s+2)(s+4)}$
3. Determine and solve for the breakaway points of the root locus for the loop transfer function $G(s)\,\mathrm{H(s)} = \dfrac{K(s+4)}{(s^2+2s+4)}$
4. Determine and solve for the breakaway points of the root locus for the loop transfer function $G(s)\,\mathrm{H(s)} = \dfrac{K}{\mathrm{s}(\mathrm{s}+2)(s^2+2s+10)}$
5. The open loop transfer function of a unity feedback control system is $G(s) = \dfrac{K}{(s+2)(s+3)}$. Solve for the values of K and s at the breakaway points of the root locus.
6. Solve for the value of K and the location of breakaway points of the system defined by the loop transfer function $G(s)\,\mathrm{H(s)} = \dfrac{K(s+3)}{s(s+2)}$

Unit-VI
Frequency response and analysis
Cognitive level- Understanding

1. Explain frequency response test on a system
2. Explain the frequency domain specifications
3. Explain procedure to draw Polar plots.
4. Explain procedure to draw Bode plot.
5. Explain phase margin and gain margin
6. Explain the general procedure for constructing Bode plots.
7. Explain minimum phase transfer and all-pass systems.
8. Explain the significance of a Log-magnitude versus phase plot.