INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**FLIGHT CONTROL THEORY**				
Course Code	AAE018				
Programme	B.Tech				
Semester	VIII	AE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	-	3	-	-
Chief Coordinator	Mr. P Anudeep , Assistant Professor				
Course Faculty	Mr. P Anudeep, Assistant Professor				

I. COURSE OVERVIEW:

The primary objective of this course introduces the basic concepts of circuit analysis which is the foundation for all subjects of the control engineering discipline. The emphasis of this course if laid on the basic analysis of circuits which includes single phase circuits, open loop system, closed loop system, system time response, autopilot control feedback block diagrams.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AHS002	I	Linear Algebra and Differential Equations	4
UG	AHS003	II	Computational Mathematics and Integral Calculus	4
UG	AEE018	III	Basic Electrical and Electronics Engineering	4
UG	AAE010	V	Aircraft Systems and Control	3

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Flight Control Theory	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✘	Chalk & Talk	✔	Quiz	✔	Assignments	✘	MOOCs
✔	LCD / PPT	✔	Seminars	✘	Mini Project	✔	Videos
✘	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into five units and each unit carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each unit. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept.
50 %	To test the analytical skill of the concept OR to test the application skill of the concept.

Continuous Internal Assessment (CIA):
CIA is conducted for a total of 30 marks (Table 1), with 25 marks for Continuous Internal Examination (CIE), 05 marks for Quiz/ Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	**Theory**		**Total Marks**
Type of Assessment	CIE Exam	Quiz / AAT	
CIA Marks	25	05	30

Continuous Internal Examination (CIE):
Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 25 marks of 2 hours duration consisting of two parts. Part–A shall have five compulsory questions of one mark each. In part–B, four out of five questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Quiz / Alternative Assessment Tool (AAT):
Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are be answered by choosing the correct answer from a given set of choices (commonly four). Marks shall be awarded considering the average of two quizzes for every course. The AAT may include seminars, assignments, term paper, open ended experiments, five minutes video and MOOCs.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Seminars
PO 2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences	3	Assignments
PO 3	**Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	2	Videos

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	**Professional skills:** Able to utilize the knowledge of aeronautical/aerospace engineering in innovative, dynamic and challenging environment for design and development of new products	2	Assignments
PSO2	**Problem-solving Skills:** Imparted through simulation language skills and general-purpose CAE packages to solve practical, design and analysis problems of components to complete the challenge of airworthiness for flight vehicles.	**-**	**-**
PSO 3	**Practical implementation and testing skills:** Providing different types of in house and training and industry practice to fabricate and test and develop the products with more innovative technologies	-	-
PSO 4	**Successful career and entrepreneurship:** To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aeronautical/aerospace allied systems to become technocrats.	-	-

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES :

The course should enable the students to:	
I	Apply stability criteria to determine the stability of an aircraft, and specify the aircraft time-domain and frequency-domain response specifications.
II	Understand Classical control theory in the frequency domain and modern control theory in the state-space are effectively mixed to provide the student with a modern view of systems theory.
III	Design control techniques for aircraft control systems, and study some feedback control applications.
IV	Study the controllability and observability of aerospace systems, and apply the modern control techniques to design enhanced flight control systems.

IX. COURSE OUTCOMES (CO'S):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Describe the analysis techniques for classical control theory to nonlinear system	CLO 1	Define the basic concepts associated with Control Theory and its application.
		CLO 2	Review Fourier Transform with mathematical operations and its applications.
		CLO 3	Review Laplace Transform and some other important mathematical operations.
CO 2	To describe and analyze the physical system with inherent non-linearity for stability and performance	CLO 4	Understand about the concepts of Transfer function, its merits and applications.
		CLO 5	Understand the control system performance with the time domain description.
		CLO 6	Analyze the steady state response and application of feedback in augmentation controls.
CO 3	Provide knowledge on various adaptive schemes, with a basic understanding on closed loop system stability and implementation issues	CLO 7	Understand the control system performance with the frequency domain description.
		CLO 8	Analyze an aircraft's performance to controls and related aspects.
		CLO 9	Evaluate an aircraft's performance from the control point of view as a system.
CO 4	Describe the principle of approximations to aircraft transfer functions, control surface actuators-review. response of aircraft to elevator input, response of aircraft to rudder input and response of aircraft to aileron input to atmosphere	CLO 10	Determine the Approximations to aircraft transfer functions.
		CLO 11	Understand about stability augmentation systems for an aircraftt with autopilot system.
		CLO 12	Determine the Flying qualities of aircraft and requirements.
CO 5	Define reversible and irreversible flight control systems. flying qualities of aircraft-relation to airframe transfer function. pilot's opinion ratings. flying quality requirements- pole-zero, frequency response and time- response specifications	CLO 13	Understand about the concepts of feedback control its merits and applications.
		CLO 14	Understand the concept of control surface actuators and its usage in aircraft applications.
		CLO 15	Determine the Displacement and rate feedback determination of gains conflict with pilot inputs resolution

X. COURSE LEARNING OUTCOMES (CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AAE018.01	CLO 1	Define the basic concepts associated with Control Theory and its application.	PO 1	3
AAE018.02	CLO 2	Review Fourier Transform with mathematical operations and its applications.	PO 1 PO 2	3
AAE018.03	CLO 3	Review Laplace Transform and some other important mathematical operations.	PO 2 PO 3	3

AAE018.04	CLO 4	Understand about the concepts of Transfer function, its merits and applications.	PO 1	3
AAE018.05	CLO 5	Understand the control system performance with the time domain description.	PO 1	3
AAE018.06	CLO 6	Analyze the steady state response and application of feedback in augmentation controls.	PO 1 PO 2	2
AAE018.07	CLO 7	Understand the control system performance with the frequency domain description.	PO 1	3
AAE018.08	CLO 8	Analyze an aircraft's performance to controls and related aspects.	PO 3	2
AAE018.09	CLO 9	Evaluate an aircraft's performance from the control point of view as a system.	PO 1 PO 3	2
AAE018.10	CLO 10	Determine the Approximations to aircraft transfer functions.	PO 2 PSO1	3
AAE018.11	CLO 11	Understand about stability augmentation systems for an aircraftt with autopilot system.	PO 1 PSO1	3
AAE018.12	CLO 12	Determine the Flying qualities of aircraft and requirements.	PO 1	3
AAE018.13	CLO 13	Understand about the concepts of feedback control its merits and applications.	PO 1 PO 3	3
AAE018.14	CLO 14	Understand the concept of control surface actuators and its usage in aircraft applications.	PO 1 PO 3	2
AAE018.15	CLO 15	Determine the Displacement and rate feedback determination of gains conflict with pilot inputs resolution	PO 3	2

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XI. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES:

Course Outcomes (COs)	Program Outcomes			Program Specific Outcomes
	PO1	PO2	PO3	PSO1
CO1	3	3	1	
CO2	3	2		
CO3	3		1	
CO4	3	2		2
CO5	3		3	

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XII. MAPPING COURSE LEARNING OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CLO 1	3															
CLO 2	3	3														

CLO 3		3	2													
CLO 4	3															
CLO 5	3															
CLO 6	2	2														
CLO 7	3															
CLO 8			2													
CLO 9	3	2	2													
CLO 10		3											2			
CLO 11	3												2			
CLO 12	3												2			
CLO 13	3		3													
CLO 14	2		2										2			
CLO 15			2													

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XIII. ASSESSMENT METHODOLOGIES–DIRECT

CIE Exams	PO 1, PO 2, PO 3	SEE Exams	PO 1, PO 2, PO 3	Assignments	PO 2	Seminars	PO 1
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	PO 2						

XIV. ASSESSMENT METHODOLOGIES-INDIRECT

✔	Early Semester Feedback	✔	End Semester OBE Feedback
✘	Assessment of Mini Projects by Experts		

XV. SYLLABUS

UNIT-I	**INTRODUCTION TO CONTROL SYSTEMS:**
Dynamical systems-principal constituents-input, output-process (plant)-block diagram representation. Inputs-control input, noise. Function of controls regulation (hold), tracking (command)-examples. Measure of effectiveness. Sensitivity of output to control input, noise and system parameters- robustness. Deterministic and stochastic control. Control in everyday life. The pervasiveness of control in nature, engineering and societal systems. The importance of study of control system. Need for stable, effective (responsive), robust control system. Modeling of dynamical systems by differential equations-system parameters. Examples from diverse fields. First and second order systems, higher order systems, single input single output systems, and multiple-input multiple-output.	

UNIT-II	MATHEMATICAL MODELLING OF DYNAMIC SYSTEMS
Control system performance- time domain description- output response to control inputs-- impulse and indicial response- characteristic parameters- significance- relation to system parameters- examples- first and second order linear systems, higher order systems. Synthesis of response to arbitrary input functions from impulse and indicial response. Review of Fourier transforms and Laplace transforms- inverse transforms- significance, applications to differential equations. 's' (Laplace) domain description of input- output relations- transfer function representation- system parameters- gain, poles and zeroes. Characteristic equation- significance- examples. Frequency and damping ratio of dominant poles. Relation of transfer functions to impulse response. Partial fraction decomposition of transfer functions-significance	
UNIT-III	**STEADY STATE RESPONSE ANALYSIS**
System type, steady state error, error constants- overall system stability. Application of feedback in stability augmentation, control augmentation, automatic control-examples. Composition, reduction of block diagrams of complex systems-rules and conventions. Control system components - sensors, transducers, servomotors, actuators, filters-modeling, transfer functions. Single-input single-output systems. Multiple input-multiple output systems, matrix transfer functions-examples. Types of control problems- the problem of analysis, control synthesis, system synthesis- examples- static control of aircraft. Extension to dynamic control. System identification from input output measurements importance. Experimental determination of system transfer functions by frequency response measurements. Example. Frequency domain description- frequency response- gain and phase shift- significance- representation asymptotic (Bode) plots, polar (Nyquist) plots, frequency transfer functions. Characteristic parameters corner frequencies, resonant frequencies, peak gain, and bandwidth- significance. First and second order systems- extension to higher order systems.	
UNIT-IV	**AIRCRAFT RESPONSE TO CONTROLS**
Approximations to aircraft transfer functions, control surface actuators-review. Response of aircraft to elevator input, Response of aircraft to rudder input and Response of aircraft to aileron input to atmosphere. Need for automatic control. Auto pilots Stability augmentation systems-pitch damper and yaw damper.	
UNIT-V	**FLYING QUALITIES OF AIRCRAFT**
Reversible and irreversible flight control systems. Flying qualities of aircraft-relation to airframe transfer function. Pilot's opinion ratings. Flying quality requirements- pole-zero, frequency response and time-response specifications. Displacement and rate feedback determination of gains conflict with pilot input s resolution-control augmentation systems- Full authority fly-by-wire. Auto Pilot-Normal acceleration, Turn rate, Pitch rate Commands-Applications.	
Text Books:	
1. Kuo, B.C., ―Automatic Control Systems, Prentice Hall India, 1992. 2. Stevens, B.L. and Lewis, F.L., ―Aircraft Control and Simulation, John Wiley, 1992.	
Reference Books:	
1. Mc Lean, D., ―Automatic Flight Control Systems, Prentice Hall, 1990 J. 2. Bryson, A.E., ―Control of Aircraft and Spacecraft, Princeton University Press, 1994. 3. E H J Pallett, Shawn Coyle ―Automatic Flight Control, 4th Edition, 2002.	

XVI. COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1	Dynamical systems-principal constituents-input, output-process (plant)-block diagram	CLO 1	T1:1.1 R1:2.1
2	Function of controls regulation (hold), tracking (command)-examples. Measure of effectiveness.	CLO 1	T1:1.2-1.4

3	Sensitivity of output to control input, noise and system parameters- robustness.	CLO 1	T1:1.5
4	Deterministic and stochastic control. Control in everyday life.	CLO 1	T1:1.6
5	The pervasiveness of control in nature, engineering and societal systems.	CLO 1	T1:1.1
6	The importance of study of control system. Need for stable, effective (responsive), robust control system.	CLO 1	T1:2.5-2.7
7-8	Modeling of dynamical systems by differential equations-system parameters. Examples from diverse fields.	CLO 3	T1:2.7
9	First and second order systems, higher order systems, single input single output systems, and multiple-input multiple-output.	CLO 2	T1:2.4-2.7
10	Control system performance- time domain description- output response to control inputs	CLO 5	T1:2.7.4
11	Impulse and indicial response- characteristic parameters- significance- relation to system parameters	CLO 6	T1:2.5.1
12	Examples- first and second order linear systems, higher order systems	CLO 2	T1:5.4.1
13-14	Synthesis of response to arbitrary input functions from impulse and indicial response.	CLO 6	T1:3.1
15-16	Review of Fourier transforms and Laplace transforms- inverse transforms- significance, applications to differential equations	CLO 2	T1:2.6
17-19	'S' (Laplace) domain description of input- output relations transfer function representation- system parameters- gain, poles and zeroes.	CLO 2	T1:4.1
20-22	Characteristic equation- significance- examples. Frequency and damping ratio of dominant poles. Relation of transfer functions to impulse response.	CLO 6	T1:2.2
23-24	Partial fraction decomposition of transfer functions- significance.	CLO 4	T1:2.2
24-25	System type, steady state error, error constants- overall system stability. Application of feedback in stability augmentation, control augmentation, automatic control-examples.	CLO 6	T1:5.4.1 T1:2.5
26	Composition, reduction of block diagrams of complex systems-rules and conventions.	CLO 6	T1:3.1
27-28	Control system components - sensors, transducers, servomotors, actuators, filters-modeling, transfer functions. Single-input single-output systems. Multiple input-multiple output systems, matrix transfer functions-examples.	CLO 6	T1:2.6 R1:3.2
29-30	Types of control problems- the problem of analysis, control synthesis, system synthesis- examples- static control of aircraft. Extension to dynamic control. System identification from input output measurements importance.	CLO 9	T1:4.1
31-32	Experimental determination of system transfer functions by frequency response measurements. Example. Frequency domain description- frequency response- gain and phase shift- significance- representation asymptotic (Bode) plots, polar (Nyquist) plots, frequency transfer functions.	CLO 7	T1:2.2
33	Characteristic parameters corner frequencies, resonant frequencies, peak gain, and bandwidth- significance. First and second order systems- extension to higher order systems.	CLO 8	T1:6.1- 6.2
34-35	Approximations to aircraft transfer functions, control surface actuators-review.	CLO 10	T2:4.1
36	Response of aircraft to elevator input, Response of aircraft to rudder input and Response of aircraft to aileron input to atmosphere.	CLO 10	T2:4.2
37-39	Need for automatic control. Auto pilots Stability augmentation systems-pitch damper and yaw damper.	CLO 11	T2:4.3
40-41	Reversible and irreversible flight control systems.	CLO 12	T2:4.4

42	Flying qualities of aircraft-relation to airframe transfer function. Pilot's opinion ratings.	CLO 13	T2:4.5 R1:4.5
43-44	Flying quality requirements- pole-zero, frequency response and time-response specifications.	CLO 14	T1:8.1- 8.4
45-46	Displacement and rate feedback determination of gains conflict with pilot inputs resolution - control augmentation systems- Full authority fly-by-wire.	CLO 15	T1:8.5
47	Auto Pilot-Normal acceleration, Turn rate, Pitch rate Commands-Applications.	CLO 15	T2:4.4 R1:5.3

XVII. GAPS IN THE SYLLABUS - TO MEET INDUSTRY / PROFESSION REQUIREMENTS:

S No	Description	Proposed actions	Relevance with POs	Relevance with PSOs
1	Concept of modern control theory and its applications	Guest Lecture/Seminar	PO1	PSO 1
2	State space modeling of dynamical systems matrix transfer function and Transformations of state equations.	Seminars	PO 2	PSO 1

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