INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad -500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**AIRCRAFT STABILITY AND CONTROL**				
Course Code	AAE014				
Programme	B.Tech				
Semester	VI	AE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	-	-
Chief Coordinator	Dr. Yagya Dutta Dwivedi, Professor				
Course Faculty	Mr. S. Devaraj, Asst. Professor				

I. COURSE OVERVIEW:

Aircraft Stability and Control is the science that investigates the stability and control of aircraft and other flying vehicles. From first flight by the Wright brothers it was observed that flight without knowledge of stability and control is unfeasible. Since then, several different concepts for controlling aircraft flight have been devised including control surfaces, deformable surfaces, morphing of wings etc. This course introduces some of these concepts and describes their operation, as well as the degree of stability that they can provide. Both fixed wing and rotary wings are addressed in this course. Modern aircraft control is ensured through automatic control systems known as autopilot. Their role is to increase safety, facilitate the pilot's task and improve flight qualities. The course will introduce modern aircraft stability and control and discuss some of its objectives and applications.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AAE011	V	Aircraft Performance	4

III. MARKS DISTRIBUTION

Subject	SEE Examination	CIA Examination	Total Marks
Aircraft Stability and Control	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✗	Chalk & Talk	✓	Quiz	✓	Assignment	✗	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	Assignments
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, Real time applications
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	Seminars

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.	-	-
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.	2	Tutorials
PSO 3	**Practical implementation and testing skills:** Providing different types of in-house 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 and allied systems to become technocrats.	-	-

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES (COs):

The course should enable the students to:

I	Demonstrate concept of stability and application to dynamic systems like Aircraft, and the role of primary controls and secondary controls in longitudinal stability.
II	Understand the concept of slide slip angle, roll angle and yaw angle their concepts related to lateral-directional stability.
III	Learn about the mathematical modeling of an aircraft in longitudinal, lateral and directional cases.

IV	Estimate the longitudinal and directional parameters with the help of the linearized equations of aircraft motion.
V	Analyze the different type of dynamic modes in longitudinal, lateral and directional motion of aircraft, and recovery from those modes.

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Demonstrate concept of stability and application to dynamic systems like Aircraft, and the role of primary controls and secondary controls in longitudinal stability.	CLO 1	Remember concept of stability, controllability and maneuverability in an aircraft.
		CLO 2	Understand the basic mathematics, science and engineering for solving problems of longitudinal, lateral and directional static stability.
		CLO 3	Describe stick fixed and stick free conditions for neutral point.
		CLO 4	Demonstrate different methods for finding static margin, control force and CG limitation.
CO 2	Understand the concept of slide slip angle, roll angle and yaw angle their concepts related to lateral-directional stability.	CLO 5	Remember total stability parameters in order of merit of flight conditions.
		CLO 6	Understand the cause of instability in an aircraft and solve the issue.
		CLO 7	Identify aircraft different types of stability for different categories of aircraft.
		CLO 8	Demonstrate the aircraft component contribution for lateral and directional stability.
CO 3	Learn about the mathematical modeling of an aircraft in longitudinal, lateral and directional cases.	CLO 9	Understand the axes system and forces and moments.
		CLO 10	Remember the Lateral and directional equations of motion of aircraft.
		CLO 11	Understand the Eulers angles and determination of velocity.
		CLO 12	Apply the Equations of motion for all the six degree of freedom applied to aircraft.
CO 4	Estimate the longitudinal and directional parameters with the help of the linearized equations of aircraft motion.	CLO 13	Understand the linearized equations of motion related to airplane.
		CLO 14	Remember the force contribution in linearization of equations of the motion.
		CLO 15	Understanding the different derivatives used for solving stability and control problems in aircrafts.
		CLO 16	Apply the concept of Linearised longitudinal and lateral-directional equations of perturbed motion
CO 5	Analyze the different type of dynamic modes in longitudinal, lateral and directional motion of aircraft, and recovery from those modes	CLO 17	Remember the modes of motion characteristics, mode shapes and its significance.
		CLO 18	Understanding one degree of freedom, two degree of freedom approximations.
		CLO 19	Remember short period, constant angle of attack (long period) approximations- solutions.
		CLO 20	Apply equation for longitudinal dynamic stability and lateral dynamic stability considering coefficients of characteristics and stability criteria,

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
AAE014.01	CLO 1	Remember concept of stability, controllability and maneuverability in an aircraft.	PO1	3
AAE014.02	CLO 2	Understand the basic mathematics, science and engineering for solving problems of longitudinal, lateral and directional static stability.	PO1	3
AAE014.03	CLO 3	Describe stick fixed and stick free conditions for neutral point.	PO2	3
AAE014.04	CLO 4	Demonstrate different methods for finding static margin, control force and CG limitation.	PO1	3
AAE014.05	CLO 5	Remember total stability parameters in order of merit of flight conditions.	PO1	3
AAE014.06	CLO 6	Understand the cause of instability in an aircraft and solve the issue.	PO2	3
AAE014.07	CLO 7	Identify aircraft different types of stability for different categories of aircraft.	PO1	3
AAE014.08	CLO 8	Demonstrate the aircraft component contribution for lateral and directional stability.	PO1	3
AAE014.09	CLO 9	Understand the axes system and forces and moments.	PO3	2
AAE014.10	CLO 10	Remember the Lateral and directional equations of motion of aircraft.	PO1	3
AAE014.11	CLO 11	Understand the Eulers angles and determination of velocity.	PO2	3
AAE014.12	CLO 12	Apply the Equations of motion for all the six degree of freedom applied to aircraft.	PO2	3
AAE014.13	CLO 13	Understand the linearized equations of motion related to airplane.	PO1	3
AAE014.14	CLO 14	Remember the force contribution in linearization of equations of the motion.	PO1	3
AAE014.15	CLO 15	Understanding the different derivatives used for solving stability and control problems in aircrafts.	PO3	2
AAE014.16	CLO 16	Apply the concept of Linearised longitudinal and lateral-directional equations of perturbed motion	PO1	3
AAE014.17	CLO 17	Remember the modes of motion characteristics, mode shapes and its significance.	PO2	3
AAE014.18	CLO 18	Understanding one degree of freedom, two degree of freedom approximations.	PO1	3
AAE014.19	CLO 19	Remember short period, constant angle of attack (long period) approximations- solutions.	PO2	3
AAE014.20	CLO 20	Apply equation for longitudinal dynamic stability and lateral dynamic stability considering coefficients of characteristics and stability criteria,	PO1	3

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

Course Outcomes (COs)	Program Outcomes (POs)			Program Specific Outcomes (PSOs)
	PO 1	PO 2	PO 3	PSO 2
CO 1	3	3		2
CO 2	3	3		2
CO 3	3	3	2	2
CO 4	3		2	2
CO 5	3	3		2

3 = High; 2 = Medium; 1 = Low

XII. MAPPING COURSE LEARNING OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC 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															
CLO 3		3												2		
CLO 4	3															
CLO 5	3															
CLO 6		3														
CLO 7	3													2		
CLO 8	3															
CLO 9			2													
CLO 10	3															
CLO 11		3												2		
CLO 12		3														
CLO 13	3															
CLO 14	3													2		
CLO 15			2													
CLO 16	3															

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 17		3														
CLO 18	3															
CLO 19		3												2		
CLO 20	3															

XIII. ASSESSMENT METHODOLOGIES–DIRECT

CIE Exams	PO 1, PO 2, PO 3,PSO2	SEE Exams	PO 1, PO 2, PO 3,PSO2	Assignments	PO 1, PO 2	Seminars	PO 3
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	PO 1, PO 2, PO 3,PSO2						

XIV. ASSESSMENT METHODOLOGIES-INDIRECT

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

XV. SYLLABUS:

UNIT I	INTRODUCTION AND LONGITUDINAL STABILITY-I
Aircraft axes system, Definition: Equilibrium, stability, controllability, & maneuverability. Examples from simple mechanical systems for stability. Longitudinal static stability and dynamic stability for un accelerated flight. Criteria for longitudinal static stability and trim condition. Contribution of Principle components. Equations of equilibrium- stick fixed neutral point, elevator angle required to trim. Definition-static margin. Equations of motion in steady, symmetric pull-up maneuver, elevator effectiveness, elevator hinge moment, neutral point, maneuver point, static margin for stick fixed and stick free conditions, control force and control gradient. Trim tabs and types of trim tabs, Aerodynamic and mass balancing of control surfaces, forward and aft most limits of CG.	
UNIT II	**LATERAL-DIRECTIONAL STATIC STABILITY**
Introduction to lateral-direction stability- aerodynamic forces and moments, aircraft side force due to side slip, aircraft rolling moment due to side slip, and aircraft yawing moment due to side slip. Aircraft component contribution, directional static stability, Aircraft component contribution for lateral-directional stability, rudder requirements.	
UNIT III	**AIRCRAFT EQUATION OF MOTION**
Description of motion of Flight vehicle - systems of reference frames - earth, body, wind, stability axes - relative merits. Euler angles, angles of attack and sideslip– definitions- earth to body axis transformation, stability axis to body axis transformation. Rotating axis system- expressions for linear and angular moment of rigid body, time derivatives-inertia tensor, components of linear and angular velocities, accelerations. Components of aerodynamic, gravity forces, moments applied on flight vehicle. Equations of motion- longitudinal and lateral-directional. Relation between angular velocity components and Euler angle rates. Determination of velocities of airplane in earth axis system.	

UNIT IV	**LINEARIZATION OF EQUATIONS OF MOTION AND AERODYNAMIC FORCES AND MOMENTS DERIVATIVES**
Description of state of motion of vehicle, forces and moments as perturbations over prescribed reference flight condition. Equation of motion in perturbation variables. Assumption of small perturbations, first order approximations-linearization equations of motion. Linearised of force and moment equation of motion Linearised longitudinal and lateral-directional equations of perturbed motion. Significance of aerodynamic derivatives. Derivatives of axial, normal force components and pitching moment with respect to the velocity, angle of attack, angle of attack rate, pitch rate, elevator angle.	
UNIT V	**AIRCRAFT DYNAMIC STABILITY**
Principle modes of motion characteristics, mode shapes and significance, time constant, undamped natural frequency and damping ratio- mode shapes- significance. One degree of freedom, two degree of freedom approximations- constant speed (short period), constant angle of attack (long period) approximations- solutions. Determination of longitudinal and lateral stability from coefficients of characteristic equation- stability and lateral stability from coefficients of characteristics equation- stability criteria, Aircraft spin- entry, balance of forces in steady spin, recovery, pilot techniques.	
TEXT BOOKS:	
1. 1. Yechout, T.R.et al., "Introduction to Aircraft Flight Mechanics", AIAA education Series, 2003, ISBN 1-56347-577-4.	
2. 2. Nelson, R.C., "Flight Stability and Automatic Control", 2nd Edn., Tata McGraw Hill, 2007, ISBN 0-07-066110-3.	
3. 3. Etkin, B and Reid, L.D., "Dynamics of Flight", 3rd Edn., John Wiley, 1998, ISBN0-47103418-5.	
REFERENCES:	
1. Schmidt, L.V., "Introduction to Aircraft Flight Dynamics", AIAA Education Series, 1st Edition, 1998, ISBN A-56347-226-0.	
2. McCormick, B.W., "Aerodynamics, Aeronautics, and Flight Mechanics", Wiley India, 2nd Edition, 1995, ISBN 97.	

XVI. COURSE PLAN:

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

Lecture No	Topic/s to be covered	Course Learning Outcomes (CLOs)	Reference
1-2	**UNIT I:** **INTRODUCTION AND LONGITUDINAL STABILITY-I** Introduction to basic aerodynamics**,** Atmosphere, Characteristics of airfoils, forces and moments, Aircraft Axis system, Equilibrium	CLO1	T2:1.1-1.5 T1: 4.1
3-4	Stability, controllability and maneuverability. Practical example of stability, longitudinal static stability and dynamic static stability	CLO1	T2: 2.1-2.2
5-7	Accelerated flight, Criteria for longitudinal static stability and trim condition. Contribution of the components of static stability, Equations of equilibrium	CLO2	T2: 2.3-2.4
8-9	Stick fixed neutral point, Elevator angle required to trim, Static margin, Equation of motion in steady pull	CLO2	T2: 2.5-2.6

	maneuver.		
10	Elevator effectiveness elevator hinge moment,	CLO3	T2: 3.3
11-14	Control force and control gradient, neutral point, maneuver point.	CLO3	T2:3.4
15-17	Trim tabs and types of trim tabs, static margin for stick fixed and stick free conditions.	CLO4	T2: 3.4
18-19	Aerodynamic and mass balancing of control surfaces, forward and aft most limits of CG	CLO4	T2: 3.3
20-21	**UNIT II:** **LATERAL-DIRECTIONAL STATIC STABILITY** Introduction to lateral-direction stability-aerodynamic forces and moments	CLO5	T2: 4.2
22-26	aircraft side force due to side slip, aircraft rolling moment due to side slip	CLO6	T2: 5.1
27	aircraft yawing moment due to side slip	CLO7	T2: 5.2
28-30	Aircraft component contribution, directional static stability,	CLO8	T2: 5.3
31	Aircraft component contribution for lateral-directional stability, rudder requirements.	CLO5	T2: 4.5
32-33	**UNIT-III** **AIRCRAFT EQUATION OF MOTION** Description of motion of Flight vehicle - systems of reference frames - earth, body, wind	CLO9 CLO10	T1: 4.1
34-36	Stability axes - relative merits. Euler angles, angles of attack and sideslip–	CLO11	T1: 4.2
37	Definitions- earth to body axis transformation, stability axis to body axis transformation.	CLO11 CLO10	T1: 4.3
39	Rotating axis system- expressions for linear and angular moment of rigid body, time derivatives-inertia tensor,	CLO10	T2: 5.2
40	Components of linear and angular velocities, accelerations. Components of aerodynamic, gravity forces, moments applied on flight vehicle.	CLO11	T2: 5.2
41-43	Equations of motion- longitudinal and lateral-directional. Relation between angular velocity components and Euler angle rates. Determination of velocities of airplane in earth axis system.	CLO12	T2: 5.3
44-46	**UNIT IV:** **LINEARIZATION OF EQUATIONS OF MOTION AND AERODYNAMIC FORCES AND MOMENTS DERIVATIVES** Description of state of motion of vehicle, forces and moments as perturbations over prescribed reference flight condition	CLO13	T1: 6.1-6.2
47-48	Equation of motion in perturbation variables, Assumption of small perturbations, first order approximations-linearization equations of motion	CLO13	T1: 6.3
49	Linearised of force and moment equation, of motion Linearised longitudinal and lateral-directional equations of perturbed motion. Significance of aerodynamic derivatives.	CLO14	T1: 6.4

50-51	Derivatives of axial, normal force components and pitching moment with respect to the velocity, angle of attack, angle of attack rate, pitch rate, elevator angle.	CLO15	T1: 6.5
52-53	**UNIT V:** **AIRCRAFT DYNAMIC STABILITY** Principle modes of motion characteristics, mode shapes and significance, time constants.	CLO16	T1: 7.1
54	Undamped natural frequency and damping ratio, mode shapes, significance.	CLO17	T1: 7.2
55	One degree of freedom, two degree of freedom approximations- constant speed (short period).	CLO18	T1: 7.3
56-58	Constant angle of attack (long period) approximations- solutions	CLO19	T1: 7.4
59-61	Determination of longitudinal and lateral stability from coefficients of characteristic equation.	CLO19	T1: 7.5
62-64	Stability and lateral stability from coefficients of characteristics equation- stability criteria.	CLO20	T1: 7.6
65	Aircraft spin- entry, balance of forces in steady spin, recovery, pilot techniques.	CLO20	T1: 7.7

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

S NO	Description	Proposed actions	Relevance with pos	Relevance with PSOs
1	Application of knowledge and skills in the estimation of aircraft stability and control system	Seminars / Expert Lectures/NPTEL	PO 2, PO 4	PSO 2
2	Experimental knowledge of aircraft Stability measurement and data handling	Seminars/ NPTEL	PO 2, PO 4	PSO 2

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