INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad -500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**AIRCRAFT PERFORMANCE**				
Course Code	AAE011				
Programme	B.Tech				
Semester	V	AE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	-	3	-	-
Chief Coordinator	Dr. Yagya Dutta Dwivedi, Professor				
Course Faculty	Dr. Prasanta Kumar Mohanta, Professor				

I. COURSE OVERVIEW:

Aircraft Performance is the science that investigates the control of aircraft and other flying vehicles. From the time of the Wright brothers it was recognized that flight without control is impossible. Since then, several different concepts for controlling aircraft flight have been devised including control surfaces, deformable surfaces, rockets and others. This course introduces some of these concepts and describes their operation, as well as the degree of stability that they can provide. Both aircraft and helicopters are addressed. Modern aircraft control is ensured through automatic control systems. Their role is to increase safety, facilitate the pilot's task and improve flight qualities. The course will introduce modern aircraft control and discuss some of its objectives and applications.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AAE001	III	Introduction to Aerospace Engineering	3
UG	AAE004	IV	Low Speed Aerodynamics	4

III. MARKSDISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Aircraft Performance	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.	2	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 :

The course should enable the students to:	
I	Learn the different regimes of aircraft and performance requirements at different atmospheric conditions.
II	Understand the different type of velocities and gives differences between stall velocity and maximum and minimum velocities.
III	Estimate the time to climb and descent and relate between rate of climb and descent and time to climb and descent at different altitudes.
IV	Illustrate the velocity and radius required for different type of maneuvers like pull-up, pull down and steady turn.
V	Evaluate the equations of motion for an airplane in different flight modes like takeoff, cruise and landing.

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Understand the design mission, performance, standard atmosphere, aerodynamic and propulsive forces, different speeds and estimation methods of aircraft.	CLO 1	Remember the atmospheric conditions that are suitable for better performance of an aircraft.
		CLO 2	Understand the basics of mathematics, science and engineering for problem solving.
		CLO 3	Describe different atmospheric models that an aircraft encounters in its real-time flight.
		CLO 4	Demonstrate different methods for the measurement of air data and their respective systems working principle.
CO 2	Remember and describe the cruise performance of an airplane in relation with range and endurance with different types of engines also to understand effects of weight, altitude and temperature on performance.	CLO 5	Describe mission profiles that an aircraft adapts depending upon its category and requirements.
		CLO 6	Understand different phases of design process from performance standpoint.
		CLO 7	Identify definition of aircraft performance for different categories of aircraft.
		CLO 8	Explain the force system of the aircraft and the development of equations of motion.
CO 3	Determine and apply the concept of climb and descent performance and to calculate power for best climb and descent performance.	CLO 9	Evaluate the performance of aircraft in cruising phase and appropriate conclusions are drawn.
		CLO 10	Illustrate the climb and descent performance of the aircraft and its performance parameters are measured.
		CLO 11	Understand the concept behind various methods that are employed during takeoff and landing phases depending upon its mission.
		CLO 12	Evaluate the factors that enhance the performance of aircraft during takeoff and landing.
CO 4	Describe about aircraft maneuver performance in turn, pull-ups by considering limitations of power for military and civil aircrafts.	CLO 13	Understand the maneuver performance of typical transport and military aircrafts.
		CLO 14	Understand the parametric performance data analysis for different phases of aircraft and various methods of measurement.
		CLO 15	Understand the concept of flight planning, fuel planning and how it affects the performance of aircraft.
		CLO 16	Understand the propulsive force characteristics like thrust that affects the aircraft performance.
CO 5	Explore the methods to	CLO 17	Describes the flight measurement of performance, with detailed sections on airworthiness certification

COs	Course Outcome	CLOs	Course Learning Outcome
	calculate take off and landing runway distances and to understand fuel planning, safety and environment effects of aircraft performance.		and the performance manual.
		CLO 18	Evaluate the calibration methods that are used for the aircraft instruments to derive air data.
		CLO 19	Understand the aerodynamic force characteristics like lift and drag that affects the aircraft performance.
		CLO 20	Evaluate the equation of motion, which are used in the expressions for maneuver performance.

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
AAE011.01	CLO 1	Remember the atmospheric conditions that are suitable for better performance of an aircraft.	PO 1	2
AAE011.02	CLO 2	Understand the basics of mathematics, science and engineering for problem solving.	PO 1 PO 2	3
AAE011.03	CLO 3	Describe different atmospheric models that an aircraft encounters in its real-time flight.	PO 1	2
AAE011.04	CLO 4	Demonstrate different methods for the measurement of air data and their respective systems working principle.	PO 2	3
AAE011.05	CLO 5	Describe mission profiles that an aircraft adapts depending upon its category and requirements.	PO 1	2
AAE011.06	CLO 6	Understand different phases of design process from performance standpoint.	PO 3	3
AAE011.07	CLO 7	Identify definition of aircraft performance for different categories of aircraft.	PO 1	2
AAE011.08	CLO 8	Explain the force system of the aircraft and the development of equations of motion.	PO 2	1
AAE011.09	CLO 9	Evaluate the performance of aircraft in cruising phase and appropriate conclusions are drawn.	PO 2	3
AAE011.10	CLO 10	Illustrate the climb and descent performance of the aircraft and its performance parameters are measured.	PO 2	2
AAE011.11	CLO 11	Understand the concept behind various methods that are employed during takeoff and landing phases depending upon its mission.	PO 2	3
AAE011.12	CLO 12	Evaluate the factors that enhance the performance of aircraft during takeoff and landing.	PO 1	2
AAE011.013	CLO 13	Understand the maneuver performance of typical transport and military aircrafts.	PO 1	2
AAE011.14	CLO 14	Understand the parametric performance data analysis for different phases of aircraft and various methods of measurement.	PO 2	3
AAE011.15	CLO 15	Understand the concept of flight planning, fuel planning and how it affects the performance of aircraft.	PO 3	3

AAE011.16	CLO 16	Understand the propulsive force characteristics like thrust that affects the aircraft performance.	PO 1	2
AAE011.17	CLO 17	Describes the flight measurement of performance, with detailed sections on airworthiness certification and the performance manual.	PO 2	3
AAE011.18	CLO 18	Evaluate the calibration methods that are used for the aircraft instruments to derive air data.	PO 2	2
AAE011.19	CLO 19	Understand the aerodynamic force characteristics like lift and drag that affects the aircraft performance.	PO 1	3
AAE011.20	CLO 20	Evaluate the full equation of motion, which are developed and used in the expressions for maneuver performance.	PO 2	2

3 = High; 2 = Medium; 1 = Low

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	2	3		2
CO 2	2	1	3	2
CO 3	2	3		2
CO 4	2	3	3	2
CO 5	3	2		2

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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	2															
CLO 2	3	3														
CLO 3	2													2		
CLO 4		3														
CLO 5	2															
CLO 6			3													
CLO 7	1													2		
CLO 8		1														
CLO 9		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 10		2														
CLO 11		3												2		
CLO 12	2															
CLO 13	2															
CLO 14		2												2		
CLO 15			3													
CLO 16	2															
CLO 17		3														
CLO 18		2														
CLO 19	3													2		
CLO 20		2														

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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 TO AIRCRAFT PERFORMANCE
The role and design mission of an aircraft; Performance requirements and mission profile; Aircraft design performance, the standard atmosphere; Off-standard and design atmosphere; Measurement of air data; Air data computers; Equations of motion for performance - the aircraft force system; Total airplane drag-estimation, drag reduction methods; The propulsive forces, the thrust production engines, power producing engines, variation of thrust, propulsive power and specific fuel consumption with altitude and flight speed; The minimum drag speed, minimum power speed; Aerodynamic relationships for a parabolic drag polar.	
UNIT-II	**CRUISE PERFORMANCE**
Maximum and minimum speeds in level flight; Range and endurance with thrust production, and power producing engines; Cruise techniques: constant angle of attack, constant mach number; constant altitude, methods- comparison of performance. The effect of weight, altitude and temperature on cruise performance; Cruise performance with mixed power-Plants.	

UNIT-III	CLIMB AND DESCENT PERFORMANCE
Importance of Climb and descent performance, Climb and descent technique generalized performance analysis for thrust producing, power producing and mixed power plants, maximum climb gradient, and climb rate. Energy height and specific excess power, energy methods for optimal climbs - minimum time, minimum fuel climbs. Measurement of best climb performance. Descent performance in Aircraft operations. Effect of wind on climb and decent performance.	
UNIT-IV	**AIRCRAFT MANEUVER PERFORMANCE**
Lateral maneuvers- turn performance- turn rates, turn radius- limiting factors for turning performance. Instantaneous turn and sustained turns, specific excess power, energy turns. Longitudinal aircraft maneuvers, the pull-up, maneuvers. The maneuver envelope, Significance. Maneuver boundaries, Maneuver performance of military Aircraft, transport Aircraft.	
UNIT-V	**SAFETY REQIREMENTS – TAKEOFF AND LANDING PERFORMANCE AND FLIGHT PLANNING**
Estimation of takeoff distances. The effect on the takeoff distance of weight wind, runway conditions, ground effect. Takeoff performance safety factors. Estimation of landing distances. The discontinued landing, Baulk landing, air safety procedures and requirements on performance. Fuel planning fuel requirement, trip fuel, Environment effects, reserve, and tankering.	
Text Books:	
1. Anderson, J.D. Jr., "Aircraft Performance and Design", International Edition McGraw Hill, 1st Edition, 1999, ISBN: 0 2. Eshelby, M.E., "Aircraft Performance theory and Practice", AIAA Education Series, AIAA, 2nd Edition, 2000, ISBN: 1	
Reference Books:	
1. McCormick, B.W, "Aerodynamics, Aeronautics and Flight Mechanics", John Wiley, 2nd Edition, 1995, ISBN: 0 2. Yechout, T.R. et al., "Introduction to Aircraft Flight Mechanics", AIAA Education Series, AIAA, 1st Edition, 2003, ISBN: 1 3. Shevel, R.S., "Fundamentals of Flight‖, Pearson Education", 2nd Edition, 1989, ISBN: 81	

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	The role and design mission of an aircraft; Performance requirements and mission profile	CLO 05, CLO 07	T2:1.1-12 T1:2.1-3
2-3	Aircraft design performance	CLO 06	T2:1.3-1.5 T1:2.3-4
4-5	The standard atmosphere; Off-standard and design atmosphere; Measurement of air data; Air data computers	CLO 01, CLO 03, CLO 04	T2:2.2-2.4
6-7	Equations of motion for performance - the aircraft force system	CLO 02, CLO 08	T2:.3.1-3.2
8	Total airplane drag- estimation, drag reduction methods	CLO 19	T1:3.1-4 R2:3.3
9	The thrust production engines, power producing engines	CLO 16	T1:3.5-7 R2:3.4
10-11	Variation of thrust, propulsive power and specific fuel consumption with altitude and flight speed	CLO 16	T2:3.4
12	The minimum drag speed, minimum power speed; Aerodynamic relationships for a parabolic drag polar	CLO 02, CLO 19	T2:3.3
13-14	Maximum and minimum speeds in level flight	CLO 09	T2:4.2

15	Cruise techniques: constant angle of attack, constant mach number; constant altitude, methods	CLO 09	T2:4.3
16	Comparison of performance	CLO 09	T2:4.3
17	The effect of weight, altitude and temperature on cruise performance	CLO 02, CLO 09	R2:4.3
18-19	Cruise performance with mixed power-Plants	CLO 09	R2:4.5
20-22	Importance of Climb and descent performance	CLO 10	T2:5.1
23	Climb and descent technique generalized performance analysis for thrust producing	CLO 02, CLO 10	T2:5.2,5.5
24	Power producing and mixed power plants	CLO 10	T2:5.2
24-25	maximum climb gradient, and climb rate	CLO 02, CLO 10	T2:5.2
26-28	Energy height and specific excess power	CLO 10	T2:5.2
29-31	Energy methods for optimal climbs - minimum time, minimum fuel climbs	CLO 10	T2:5.3
32-33	Measurement of best climb performance and descent performance in Aircraft operations	CLO 10	T2:5.4
34-36	Lateral maneuvers- turn performance- turn rates, turn radius	CLO 20	T2:7.1
37-39	Limiting factors for turning performance	CLO 20	T2:7.1
40-42	Instantaneous turn and sustained turns, specific excess power, energy turns	CLO 20	T2:7.1
43-44	Longitudinal aircraft maneuvers, the pull-up, maneuvers	CLO 20	T2:7.3
45-46	The maneuver envelope, Significance	CLO 20	T2:7.2
47-48	Maneuver boundaries	CLO 20	T2:7.2.1-7.2.2
49-50	Maneuver performance of military Aircraft, transport Aircraft	CLO 13	T2:7.4-7.5
51-52	Estimation of takeoff distances	CLO 11	T2:6.2
53	The effect on the takeoff distance of weight wind, runway conditions, ground effect	CLO 12	T2:6.2.2
54-55	Takeoff performance safety factors	CLO 12	T2:9.3.3
56-57	Estimation of landing distances	CLO 11	T2:6.3
58-59	The discontinued landing, Baulk landing	CLO 12	T2:9.6.3
60-61	Air safety procedures and requirements on performance	CLO 14	T2:9.3.3
62-63	Fuel planning fuel requirement, trip fuel	CLO 15	T2:9.8
64-65	Environment effects, reserve, and tankering	CLO 15	T2:9.8

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 experimental performance parameters	Guest Lectures / NPTEL	PO 2, PO 4	PSO 2
2	Implementation of aircraft performance measurement in aircraft design.	Seminars / Guest Lectures / NPTEL	PO 2, PO 4	PSO 2

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