INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad -500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**LOWSPEED AERODYNAMICS**				
Course Code	AAE004				
Programme	B.Tech				
Semester	IV	AE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	3	2
Chief Coordinator	Dr. Maruthupandiyan K, Associate Professor				
Course Faculty	Dr. Maruthupandiyan K, Associate Professor Dr. P K Mohanata, Associate Professor				

I. COURSE OVERVIEW:

Aerodynamics extends fluid mechanic concepts to the aerodynamic performance of wings and bodies in sub/supersonic regimes. The course has four components: (i) subsonic potential flows, including source/vortex panel methods; (ii) viscous flows, including laminar and turbulent boundary layers; (iii) aerodynamics of airfoils and wings, including thin airfoil theory, lifting line theory, and panel method/interacting boundary layer methods; (iv) introduction to propeller. Aerodynamics is the study of the flow of air about a body. In this case, the body will be an airplane, but much of the aerodynamics in this course is relevant to a wide variety of applications from sail boats to automobiles to birds. The course should help students to: formulate and apply appropriate aerodynamic models to predict the forces on and performance of realistic three-dimensional configurations; assess the applicability of aerodynamic models to predict the forces on and performance of realistic three-dimensional configurations and estimate the errors resulting from their application; perform a computational and experimental aerodynamic analysis and design.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AHS007	I	Applied physics	4
UG	AAE102	III	Fluid Mechanics and Hydraulics	4

III. MARKSDISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Low Speed Aerodynamics	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 fiveunits 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	Presentation on real-world problems
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	2	Seminar
PO3	**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.	3	Designing
PO 4	**Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	1	Assignments

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	1	Seminar
PSO 2	**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 and training and industry practice to fabricate and test and develop the products with more innovative technologies	3	Mini project
PSO 4	**Successful career and entrepreneurship:** To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aerospace and allied systems and become technocrats	-	-

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES (COs):

The course should enable the students to:	
I	Understand the basics of aerodynamics, aerofoil and wing characteristics
II	Calculate forces and moments acting on aero foils and wings under ideal flow conditions.
III	Design a propeller and determine aerodynamic interaction effects between different components of aircraft.

IX. 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
CAAE004.01	CLO 1	Apply knowledge and understand the essential facts, concepts and principles of aerodynamics.	PO 1	3
CAAE004.02	CLO 2	Adapt the basic knowledge of mathematics, science and engineering for problem solving.	PO 1	3
CAAE004.03	CLO 3	Describe principles of physics and aerodynamics to study the wing-body interference junction.	PO 1	3
CAAE004.04	CLO 4	Explain the concept of boundary layer flows to increase the performance of the body.	PO 2	2
CAAE004.05	CLO 5	Understand the concept of source, sink, doublet and vortex.	PO 3	3
CAAE004.06	CLO 6	Demonstrate importance of aerodynamics to develop effective aircraft design and operations.	PO 2	2
CAAE004.07	CLO 7	Apply the concept of lifting line theory to study potential flows over different aerofoils.	PO 4	1
CAAE004.08	CLO 8	Identify the elliptic load distribution for obtaining high lift performance on finite wings.	PO 2, PO 4	2
CAAE004.09	CLO 9	Evaluate the source and vortex panel method for non-lifting and lifting aerofoils.	PO 3	3
CAAE004.10	CLO 10	Illustrate the propeller aerodynamics and the effects of propeller on the wing.	PO 2	2
CAAE004.11	CLO 11	Understand the concept of Prandtl's lifting line theory and eliptical lift distribution.	PO 1, PO 2	2
CAAE004.12	CLO 12	Understand the lift augmentation techniques for high-lift devices and slats.	PO 1	3
CAAE004.13	CLO 13	Understand aerodynamic effect of taper and twist applied to wings.	PO 2	2
CAAE004.14	CLO 14	Apply temperature effects on boundary layer, transition and turbulent flow regimes.	PO 1, PO 3	2
CAAE004.15	CLO 15	Understand the aerodynamic effect of vortex formation around wings.	PO 2	2
CAAE004.16	CLO 16	Evaluate flow past non lifting bodies and method of singularities	PO 2	2
CAAE004.17	CLO 17	Understand the effect of sweep in the context of delta wings.	PO 1, PO 2	2
CAAE004.18	CLO 18	Understand the relation between circulation and lift.	PO 1, PO 3	3
CAAE004.19	CLO 19	Understand the various sources of drag including induced drag and skin friction drag.	PO 1, PO 2	2
CAAE004.20	CLO 20	Evaluate displacement thickness, momentum thickness, energy thickness.	PO 2, PO 4	2

3 = High; 2 = Medium; 1 = Low

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

3 = High; 2 = Medium; 1 = Low

XI. ASSESSMENT METHODOLOGIES–DIRECT

CIE Exams	PO 1, PO 2PO 3, PO 4	SEE Exams	PO 1, PO 2PO 3, PO 4	Assignments	PO 1, PO 2	Seminars	PO 2
Laboratory Practices	PO2, PO 3PO 4	Student Viva	-	Mini Project	PO 3	Certification	-
Term Paper	-						

XII. ASSESSMENT METHODOLOGIES-INDIRECT

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

XIII. SYLLABUS

UNIT-I	**INTRODUCTORY TOPICS FOR AERODYNAMICS**
Potential flow, velocity potential, stream function, Laplace equation, flow singularities-Uniform flow, source, sink, doublet, Vortex, Non lifting and lifting flow over a cylinder Kutta-Joukowski theorem.	
UNIT -II	**THIN AEROFOIL THEORY**
Aerofoil nomenclature, aerodynamic characteristics, centre of pressure and aerodynamic centre; Wing of infinite aspect ratio, CL-α- diagram for a wing of infinite aspect ratio, generation of lift, starting Vortex, Kutta's trailing edge condition; Thin aerofoil theory; Elements of panel method; High lift airfoils, High lift devices.	
UNIT-III	**FINITE WING THEORY**
Vortex motions, vortex line, vortex tube, vortex sheet; Circulation; Kelvin and Helmhotz theorem; BiotSavart's law, applications, Rankine's vortex; Flow past finite wings, vortex model of the wing and bound vortices; Induced drag; Prandtl's lifting line theory; Elliptic wing. Influence of taper and twist applied to wings, effect of sweep back wings; Delta wings, primary and secondary vortex; Elements of lifting surface theory. Source Panel Vortex panel and Vortex lattice methods.	
UNIT-IV	**FLOW PAST NON-LIFTING BODIES AND INTERFERENCE EFFECTS**
Flow past non lifting bodies, method of singularities; Wing-body interference; Effect of propeller on wings and bodies and tail unit; Flow over airplane as awhole.	
UNIT-V	**BOUNDARY LAYER THEORY**
Introduction to boundary layer, laminar and turbulent boundary layer, transition, boundary layer on flat plate, displacement thickness, momentum thickness, energy thickness, effect of curvature, temperature boundary layer.	
Text Books:	
1. J.D.Anderson, "Fundamentals of Aerodynamics", McGraw-Hill publications, 5th Edition, 2011. 2. E. L. Houghton and P.W. Carpenter, "Aerodynamics for Engineering Students", Edward Arnold Publishers Ltd., London, 5th Edition, 1982. 3. John J. Bertin and Russell M. Cummings, "Aerodynamics for Engineering Students", Pearson,5th Edition, 2009.	
Reference Books:	
1. L. J. Clancy, "Aerodynamics", Pitman, 1st Edition, 1986. 2. Louis M. Milne, "Thomson, Theoretical Aerodynamics", 2nd Edition, Dover Publications, 1985. 3. K. Karamcheti, "Principles of Ideal-fluid Aerodynamics", 2nd Edition, Krieger Publication &Co; 2nd Edition, 1980.	

XIV. 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	Discuss Importance of Aerodynamics	CLO 1	T1:1.1
2	Define potential flow, velocity potential and stream function	CLO 2	T1:2.4-2.15
3	Derive Laplace equation	CLO 2	T1:2.15
4	Discuss flow singularities	CLO 3	T1:3.9-3.15
5	Discuss uniform flow, source, sink	CLO 5	T1:3.11
6	Discuss doublet, Vortex	CLO 5	T1:3.12-3.14
7	Discuss non-lifting flow over a cylinder	CLO 6	T1:3.13
8	Discuss lifting flow over a cylinder	CLO 6	T1:3.15
9	Derive Kutta-Joukowski theorem	CLO 7	T1:3.16
10	Discuss aerofoil nomenclature	CLO 8	T1:4.2
11	Discuss aerodynamic characteristics	CLO 9	T1:4.3
12	Explain centre of pressure, aerodynamic centre and wing of infinite aspect ratio	CLO 11	T1:1.6-4.9
13	Discuss CL-α- diagram for a wing of infinite aspect ratio, generation of lift	CLO 11	T1:4.7
14	Discuss starting Vortex, Kutta‘s trailing edge condition	CLO 11	T1:4.5-4.6
15	Discuss thin aerofoil theory	CLO 12	T1:4.7- 4.10
16-17	Discuss elements of panel method	CLO 9	T1:4.10
18	Discuss high lift airfoils, High lift devices	CLO 12	T1:4.12
19	Discuss vortex motions, vortex line, vortex tube, vortex sheet	CLO 15	T1:5.2
20	Discuss Circulation; Kelvin and Helmhotz theorem vortices; induced drag	CLO 15	T1:4.6
21	Discuss Biot-Savart‘s law, applications, Rankine‘s vortex	CLO 15	T1:5.2
22	Discuss flow past finite wings, vortex model of the wing and bound vortices; induced drag	CLO 15	T1:5.3
23-24	Discuss Prandtl‘s lifting line theory; Elliptic wing	CLO 11	T1:5.3
25	Discuss influence of taper and twist applied to wings, effect of sweep back wings	CLO 13	T1:5.4
26	Discuss delta wings, primary and secondary vortex	CLO 13	T1:5.6
27	Discuss elements of lifting surface theory	CLO 11	T1:5.5

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
28	Discuss Source Panel method	CLO 09	T1:5.4
29	Discuss Vortex Panel method	CLO 09	T1:5.4
30	Discuss Vortex Lattice method	CLO 09	T1:5.5
31	Describe flow past non lifting bodies	CLO 16	T1:5.4
32-33	Discuss method of singularities	CLO 16	T1:5.3
34	Discuss Wing-body interference	CLO 03	T3:5.2
35-37	Discuss effect of propeller on wings and bodies and tail unit	CLO 10	T2:7.1
38	Discuss flow over airplane as a whole	CLO 03	T3:6.2
39-41	Discuss boundary layer	CLO 04	T1:17.1
42-43	Explain laminar and turbulent boundary layer, transition	CLO 04	T1:18.1- 19.1
44-47	Discuss boundary layer on flat plate	CLO 04	T1:18.2
48-52	Discuss displacement thickness, momentum thickness, energy thickness	CLO 20	T1:17.3
53-56	Discuss effect of curvature	CLO 20	T1:17.5
57-60	Explain temperature boundary layer	CLO 20	T1:19.2

XV. 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 aerodynamic design of a new aircraft	Seminars / Guest Lectures / NPTEL	PO 4,	PSO 3
2	Broad knowledge of aerodynamic studies for various aerofoils and wings currently in use	Seminars / Guest Lectures / NPTEL	PO 4,	PSO 3

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