INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad -500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**EXPERIMENTAL AERODYNAMICS**				
Course Code	AAE509				
Programme	B.Tech				
Semester	VI	AE			
Course Type	Elective				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	-	3	-	-
Chief Coordinator	Dr. Prasanta Kumar Mohanta, Associate Professor				
Course Faculty	Dr. Prasanta Kumar Mohanta, Associate Professor				

I. COURSE OVERVIEW:

The experimental aerodynamics is the first course for graduate and undergraduate students in Aerospace Engineering. The testing methodology employed in low and high-speed aerodynamics is a new techniques through which the students will learn various type of wind tunnels, tools and techniques. The experimental aerodynamics will be helpful to industrial aerodynamics study in various engineering branches like, environmental engineering, civil engineering, Automobile engineering etc., so that students get exposure to the various aspects of the subject related issues to measuring techniques, wind tunnel design, method and practical applications used. This subject will help the students to develop the tool by using multidisciplinary techniques. A number of problems/examples will be cited to enhance the understanding of the subject matter and besides, many unsolved problems will be provided with answers to further test the student's learning.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AAE004	IV	Low Speed Aerodynamics	3
UG	AAE008	V	High Speed Aerodynamics	3

III. MARKSDISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Experimental 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 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, engineeringfundamentals, 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 complexengineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences	2	Seminar
PO3	**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
PO 4	**Conduct investigations of complex problems**: Use research-based knowledge and researchmethods 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:** The ability to understand, analyze and develop computer programs in the areas related to algorithms, system software, multimedia, web design, big data analytics, and networking for efficient design of computer-based systems of varying complexity.	1	Seminar
PSO 2	**Problem-Solving Skills:** The ability to apply standard practices and strategies in software project development using open-ended programming environments to deliver a quality product for business success.	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:** The ability to employ modern computer languages, environments, and platforms in creating innovative career paths to be an entrepreneur, and a zest for higher studies.	2	Capability Demonstration

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES:

The course should enable the students to:	
I	Fundamentals of Aerodynamics experiments, their need in comparison with numerical computation and theoretical studies.
II	Develop concepts of flow similarity and evaluate the loss coefficients of wind tunnel components.
III	Analyze the concept of force and moment measurements using wind tunnel balance and extrapolate it to new balance development.
III	Summarize various techniques for pressure, velocity, temperature measurement and flow visualization

IX. COURSE LEARNING OUTCOMES (CLOs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Understand the Fundamental need of Experimental Aerodynamics and various types of wind tunnels and their applications.	CLO 1	Types of wind tunnels and their usages
		CLO 2	Wind tunnel Scale models
		CLO 3	Over all idea of various parts of wind tunnels
		CLO 4	Special types of wind tunnels and applications
CO 2	Understand various wind tunnel design criteria of each parts, losses and corrections.	CLO 5	Various parts design criteria of wind tunnels
		CLO 6	Advantages and disadvantages over various types of wind tunnels
		CLO 7	Various sources of losses in wind tunnels
		CLO 8	Corrections requirements and general practice.
CO 3	Interpret the various model mounting techniques and load computation	CLO 9	Understand various types of model mounting techniques
		CLO 10	Understand various tools to mount the models
		CLO 11	Computation of load measurements techniques
		CLO 12	Benefits of various mounting techniques
CO 4	Understand the basic construction structures of sensors and measuring techniques.	CLO 13	Manual measurements basic tool usage and the design criteria
		CLO 14	Various transducers, sensors and their working principles
		CLO 15	Equipment setting and their usages in wind tunnels
		CLO 16	Complexity involved in of various techniques and their measuring limitations
CO 5	Evaluate the Flow visualization techniques for low speed and high speed aerodynamics	CLO 17	Basic definition and terminology used in wind tunnel and experimental aerodynamics
		CLO 18	Low wind tunnel visualization techniques and result analysis
		CLO 19	High speed wind tunnel flow visualization setup setting and data analysis
		CLO 20	Data interpretation, the merits and demerits of each flow visualization technique.

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
AAE509.01	CLO 1	Wind tunnel experimental test and measuring techniques	PO 1	3
AAE509.02	CLO 2	Development of wind tunnel experimental test	PO 1	3
AAE509.03	CLO 3	Types of Wind tunnels and their requirements will help the students to design and application	PO 1	3
AAE509.04	CLO 4	Wind tunnels for industrial and various applications apart from aerospace requirements	PO 4	1
AAE509.05	CLO 5	Requirements for quality assurance in testing methodology	PO 3	3
AAE509.06	CLO 6	Experimental requirements and design constraints	PO 4	1
AAE509.07	CLO 7	Wind tunnel quality and performance	PO 3	3
AAE509.08	CLO 8	Source of errors and correction methodology	PO 3	3
AAE509.09	CLO 9	Usage and need of wind tunnel balance	PO 1	3
AAE509.10	CLO 10	Models mounting techniques	PO 4	1
AAE509.11	CLO 11	Various techniques used in wind tunnels for flow visualization	PO 4	1
AAE509.12	CLO 12	Schlieren system and set up	PO 2	2
AAE509.13	CLO 13	Merits and demerits of various flow visualization techniques	PO 4	1
AAE509.14	CLO 14	Right tools and techniques for required flow speed	PO 3	3
AAE509.15	CLO 15	Flow measurements techniques for steady	PO 1	3
AAE509.16	CLO 16	Flow measurements techniques for unsteady flow	PO 1	3
AAE509.17	CLO 17	Usage of electronic device and transducer	PO 3	3
AAE509.18	CLO 18	Usage of hot wire Anemometry	PO 4	1
AAE509.19	CLO 19	Usage of electronic device and transducer	PO 3	3
AAE509.20	CLO 20	Flow visualization techniques foe subsonic and supersonic flow	PO 4	3

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XI. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Course Outcomes (COs)	Program Outcomes (POs)				Program Specific Outcomes (PSOs)			
	PO 1	PO 2	PO 3	PO 4	PSO1	PSO2	PSO3	PSO4
CO 1	3			1	3			
CO 2			3	1	3	3		
CO 3	3	2	3	1	3		3	
CO 4	3		3	1		3	2	
CO 5			3	2	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												1			
CLO 2	3												1			
CLO 3	3												1			
CLO 4				1									1			
CLO 5			3											2		
CLO 6				1											3	
CLO 7			3												3	
CLO 8			3												3	
CLO 9	3														3	
CLO 10				1											3	
CLO 11				1											3	
CLO 12		2												2		
CLO 13				1									1			
CLO 14			3												3	
CLO 15	3														3	
CLO 16	3												1			

CLO 17			3											2		2
CLO 18				1											3	
CLO 19			3											2		2
CLO 20				2												

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XIII. ASSESSMENT METHODOLOGIES–DIRECT

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

XIV. ASSESSMENT METHODOLOGIES-INDIRECT

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

XV. SYLLABUS

Unit-I	FUNDAMENTALS OF EXPERIMENTS IN AERODYNAMICS
Forms of aerodynamic experiments, observations, measurement objectives. History: Wright Brother‘s wind tunnel, model testing, wind tunnel principles, scaling laws, scale parameters, geometric similarity, kinematic similarity& dynamic similarity. Wind tunnels: low speed tunnel, high speed tunnels, transonic, supersonic and hypersonic tunnels, shock tubes. Special tunnels: low turbulence tunnels, high Reynolds number tunnels, environmental tunnels, automobile tunnels, distinctive features, application.	
Unit-II	**WIND TUNNEL EXPERIMENTATION CONSIDERATIONS**
Low speed wind tunnels, principal components. Function, description, design requirements, constraints and loss coefficients. Wind tunnel performance flow quality, power losses, wind tunnel corrections, sources of inaccuracies: buoyancy, solid blockage, wake blockage, streamline curvature causes, estimation and correction.	
Unit-III	**WIND TUNNEL BALANCE**
Load measurement: low speed wind tunnel balances, mechanical & Strain gauge types, null displacement methods & strain method, sensitivity, weigh beams, steel yard type and current balance type, balance linkages, levers and pivots. Model support three point wire support, three point strut support, platform balance, yoke balance, strain gauge, 3-component strain gauge balance, description, application.	
Unit-IV	**PRESSURE, VELOCITY & TEMPERATURE MEASUREMETNS**
Pressure: static pressure, surface pressure orifice, static probes, pitot probe for total pressure, static pressure and flow angularity, pressure sensitive paints, steady and unsteady pressure measurement and various types of pressure probes and transducers, errors in pressure measurement. Temperature: measurement of temperature using thermocouples, resistance thermometers, temperature sensitive paints and liquid crystals. Velocity: measurement of airspeed, Mach number from pressure measurements, flow direction, boundary layer profile using pitot static probe, 5 hole probe yaw meter, total head rake, hot wire anemometry, laser doppler anemometry, particle image velocimetry, working principle description of	

equipment, settings, calibration, measurement, data processing, applications.	
Unit-V	**FLOW VISUALIZATION TECHNIQUES**
Flow visualization: necessity, streamlines, streak lines, path lines, time lines, tufts, china clay, oil film, smoke, hydrogen bubble. Optical methods: density and refractive index, schlieren system, convex lenses, concave mirrors, shadowgraph, interferometry, working principle, description, setting up, operation, observation, recording, interpretation of imagery, relative merits and applications.	
Text Books:	
1. Jewel B Barlow, William H Rae Jr. & Alan Pope, "Low Speed Wind Tunnel Testing", John Wiley& Sons Inc, Re-Print, 1999. 2. Alan Pope, Kennith L Goin, "High Speed Wind Tunnel Testing", John Wiley & Sons, Reprint, 1965.	
Reference Books:	
1. Gorlin S M &Slezinger I I, "Wind tunnels & Their Instrumentations", NASA publications, Translated version, 1966. 2. Jorge C Lerner &UlfilasBoldes, "Wind Tunnels and Experimental Fluid Dynamics Research", InTech, 1st Edition, 2011. 3. Liepmann H W and Roshko A, "Elements of Gas Dynamics", John Wiley & Sons, 4th Edition, 2003.	

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	Introduction and need of experimental test	CLO 1	T1:2.1
2	Experimental Test requirements and history	CLO 2	T1:2.2
3-5	Types of Wind tunnels and their requirements	CLO 3	T1: 2.3
6-8	Wind tunnels for industrial and various applications apart from aerospace requirements	CLO 4	T1:2.5-2.10
9	Introduction wind tunnel experimentation considerations	CLO 5	T1:2.9
10-11	Experimental requirements and design constraints	CLO 6	T1:2.9
12	Wind tunnel quality and performance	CLO 7	T1: 3.1
13-14	Source of errors and correction methodology	CLO 8	T1: 3.9-3.10
15	Introduction to wind tunnel balance	CLO 9	T1: 7.1
16-18	Mounting techniques of models	CLO 10	T1: 7.5
19-21	Various techniques used in wind tunnels	CLO 11	T1: 4.1-4.5
22	Useful applications	CLO 12	T1: 4.1-4.5
23-26	Introduction to tools and techniques used in wind tunnels	CLO 13	T1: 4.1-4.5, T1:6.1-6.4
27-29	Flow measurements techniques for steady and unsteady flow	CLO 14	T1:5.1-5.5, T1:6.1, 6.4
30-32	Flow measurements techniques for steady and unsteady flow	CLO 15	T1:6.4
33-35	Usage of electronic device and transducer	CLO 16	T1:4.1, 4.4
36-38	Hot wire anemometry	CLO 17	T1:4.1, 4.4
39-42	Laser Doppler anemometry and working principle	CLO 18	T1:4.1, 4.4

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
43-45	Data processing tools and techniques	CLO 19	T1:6.1, 6.4
46-48	Various flow visualization techniques	CLO 18	T1:6.1, 6.4
49-52	Schlieren system and set up, Merits and demerits of various flow visualization techniques	CLO 19	T1:6.1, 6.4

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 scientific programming	Seminars	PO 1	PSO 1
2	Broad knowledge of experimental aerodynamics and industrial applications	Seminars / NPTEL	PO 4	PSO 1
3	Application of knowledge and skills in the scientific programming	NPTEL	PO 2	PSO 1

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