INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**HIGH SPEED AERODYNAMICS**				
Course Code	AAE008				
Programme	B.Tech				
Semester	V	AE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	-	-
Chief Coordinator	Mr. G Satya Dileep, Assistant Professor				
Course Faculty	Mr. G Satya Dileep, Assistant Professor Ms. D Anitha, Assistant Professor				

I. COURSE OVERVIEW:

The primary objective of this course is to introduce the concept of high-speed aerodynamics (Compressible aerodynamics). The high-speed aerodynamics is the first course for graduate and undergraduate students in Aerospace Engineering. The precise algorithm, mathematical derivation, numerical solutions is also the primary objective of this subject. The experimental techniques and its applications are taught to meet the requirements of industry need. The course consists of a strong mathematical component in addition to the design of various concepts. 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 learning.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AAE004	IV	Low Speed Aerodynamics	4

III. MARKSDISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
High 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 8^{th} and 16^{th} 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 25multiple 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	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	**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	2	Mini project
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:** 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

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
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.	1	Capability Demonstration

3= High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES:

The course should enable the students to:	
I	Understand the effect of compressibility at high-speeds and the ability to make intelligent design decisions.
II	Explain the dynamics in subsonic, transonic and supersonic flow regimes in both internal and external geometries.
III	Analyze the airfoils at subsonic, transonic and supersonic flight conditions using the perturbed flow theory assumption.
IV	Formulate appropriate aerodynamic models to predict the forces and performance of realistic three dimensional configurations.

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Explain a brief review of thermodynamics and fluid mechanics in relation to compressible flows	CLO 1	Demonstrate the concept of supersonic flow, how it is different from incompressible flow.
		CLO 2	Understand governing equations of supersonic flow in various form and thermodynamics properties.
		CLO 3	Describe the governing equations required for compressible flows.
CO 2	Demonstrate different types of shock waves and expansion waves and its properties across different situations.	CLO 4	Illustrate the impact of supersonic flow in the presence of compression and expansion corner
		CLO 5	Demonstrate supersonic aircraft design and applications to aircrafts, supersonic wind tunnel and shock tubes.
		CLO 6	Understand the concepts of shock wave boundary layer interaction.
CO 3	Understand the importance of quasi one dimensional flow for obtaining supersonic speeds.	CLO 7	Illustrate the concepts of quasi one dimensional flow for compressible flows
		CLO 8	Describe isentropic flow in nozzles, area Mach relations, choked flow, under and over expanded nozzles, slipstream line.

		CLO 9	Understand the impact of heat and Friction in duct flow and fanno flow
CO 4	Illustrate the concepts of method of characteristics and its applications in nozzle designs.	CLO 10	Describe small perturbation equations for subsonic, transonic, supersonic and hypersonic flow
		CLO 11	Understand experimental characteristics of airfoils in compressible flow, supercritical airfoils and area rule.
		CLO 12	Explain supersonic nozzle design using method of characteristics.
CO 5	Understand the experimental methods and their characteristics of various wind tunnels.	CLO 13	Illustrate working principle of subsonic wind tunnels, supersonic wind tunnels, shock tunnels
		CLO 14	Explain free-piston shock tunnel, detonation-driven shock tunnels, and expansion tubes and characteristic features, their operation and performance.
		CLO 15	Demonstrate flow visualization techniques for compressible flows.

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
AAE008.01	CLO 1	Demonstrate the concept of supersonic flow, how it is different from incompressible flow.	PO 1	3
AAE008.02	CLO 2	Understand governing equations of supersonic flow in various form and thermodynamics properties.	PO 1	3
AAE008.03	CLO 3	Describe the governing equations required for compressible flows.	PO 1, PO 2	2
AAE008.04	CLO 4	Illustrate the impact of supersonic flow in the presence of compression and expansion corner	PO 1, PO 2	3
AAE008.05	CLO 5	Demonstrate supersonic aircraft design and applications to aircrafts, supersonic wind tunnel, shock tubes.	PO 2	2
AAE008.06	CLO 6	Understand the concepts of shock wave boundary layer interaction.	PO 2	3
AAE008.07	CLO 7	Illustrate the concepts of quasi one dimensional flow for compressible flows	PO 2, PO 3	1
AAE008.08	CLO 8	Describe isentropic flow in nozzles, area Mach relations, choked flow, under and over expanded nozzles, slipstream line.	PO 3	2
AAE008.09	CLO 9	Understand the impact of heat and Friction in duct flow and fanno flow	PO 2	2
AAE008.10	CLO 10	Describe small perturbation equations for subsonic, transonic, supersonic and hypersonic flow	PO 2	3
AAE008.11	CLO 11	Understand experimental characteristics of airfoils in compressible flow, supercritical airfoils and area rule.	PO 1, PO2	1
AAE008.12	CLO 12	Explain supersonic nozzle design using method of characteristics.	PO 2, PO 3	3
AAE008.13	CLO 13	Illustrate working principle of subsonic wind tunnels, supersonic wind tunnels, shock tunnels	PO 1, PO 3	2
AAE008.14	CLO 14	Explain free-piston shock tunnel, detonation-driven shock tunnels, and expansion tubes and characteristic features, their operation and performance.	PO 2, PO 4	2

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AAE008.15	CLO 15	Demonstrate flow visualization techniques for compressible flows.	PO 3, PO4	1

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

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

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	PSO 4
CLO 1	3												1			
CLO 2	3												1			
CLO 3	3	2											1			
CLO 4	3	2											1			
CLO 5		2												2		1
CLO 6		3													3	
CLO 7		2	1											1		
CLO 8			2												3	
CLO 9		2													3	
CLO 10		3													3	
CLO 11	1	2													3	1
CLO 12		2	3												3	
CLO 13	1		3												3	
CLO 14		2		2										2		
CLO 15			1	2									1			1

3 = High; 2 = Medium; 1 = Low

XIII. ASSESSMENT METHODOLOGIES–DIRECT

CIE Exams	PO 1, PO 2 PO 3, PO 4	SEE Exams	PO 1, PO 2 PO 3, PO 4	Assignments	PO 1, PO 2 PO 3, PO 4	Seminars	PO 1, PO 2 PO 3, PO 4
Laboratory Practices	-	Student Viva	-	Mini Project	PO 4	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	**INTRODUCTION TO COMPRESSIBLE FLOWS**
Basic concepts: Introduction to compressible flow, brief review of thermodynamics and fluid mechanics, integral forms of conservation equations, differential conservation equations, continuum postulates, acoustic speed and Mach number, governing equations for compressible flows.	
Unit-II	**SHOCK AND EXPANSION WAVES**
Shocks and expansion waves: Development of governing equations for normal shock, stationery and moving normal shock waves, applications to aircrafts, supersonic wind tunnel, shock tubes, shock polar, supersonic pitot probes; oblique shocks, governing equations, reflection of shock, Prandtl-Meyer expansion flow, shock expansion method for flow over airfoil, introduction to shock wave boundary layer interaction.	
Unit-III	**DIMENSIONAL AND QUASI ONE DIMENSINAL FLOW**
Quasi one dimensional flow: Isentropic flow in nozzles, area Mach relations, choked flow, under and over expanded nozzles, slip stream line. One dimensional flow: Flow in constant area duct with friction and heat transfer, Fanno flow and Rayleigh flow, flow tables and charts for Fanno flow and Rayleigh flow.	
Unit-IV	**APPLICATIONS OF COMPRESSIBLE FLOWS AND NUMERICAL TECHNIQUES**
Small perturbation equations for subsonic, transonic, supersonic and hypersonic flow; Experimental characteristics of airfoils in compressible flow, supercritical airfoils, area rule; Theory of characteristics, determination of the characteristic lines and compatibility equations, supersonic nozzle design using method of characteristics.	
Unit-V	**EXPERIMENTAL METHODS IN COMPRESSIBLE FLOWS**
Experimental methods: Subsonic wind tunnels, supersonic wind tunnels, shock tunnels, free-piston shock tunnel, detonation-driven shock tunnels, and expansion tubes and characteristic features, their operation and performance, flow visualization techniques for compressible flows	
Text Books:	
1. John D. Anderson, “Modern Compressible flow with historical perspective”, McGraw-Hill Education, 3rd Edition, 2002. 2. John D. Anderson, “Fundamentals of Aerodynamics”, McGraw-Hill Education, 6th Edition, 2016.	
Reference Books:	
1. Ascher H. Shapiro, “The Dynamics and Thermodynamics of Compressible Fluid Flow”, John Wiley & Sons; Volume 1 ed. Edition, 1977. 2. Radhakrishnan Ethirajan, “Gas Dynamics”, John Wiley & Sons, 2nd edition 2010. 3. H W Liepmann and A Roshko, “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 to compressible flow	CLO 1	T1:60, T1:534
2-3	Brief review of thermodynamics and fluid mechanics	CLO 1	T1:488-499
4-5	Integral forms of conservation equations, differential conservation equations	CLO 3	T1:97-132
6	Continuum postulates	CLO 1	T1:58
7-8	Acoustic speed and Mach number	CLO 2	T1:560-564
9-10	Governing equations for compressible flows	CLO 2	T1:499-501
11	Shocks and expansion waves	CLO 4	T1:602-606
12-13	Development of governing equations for normal shock, stationery and moving normal shock waves,	CLO 4	T1:515-557
14	applications to aircrafts	CLO 5	T1:580-581
15-16	Supersonic wind tunnel, shock tubes, shock polars, supersonic pitot probes	CLO 5	T1:570-575
17-18	Oblique shocks, governing equations, reflection of shock	CLO 6	T1:566-570
19-20	Prandtl's-Meyer expansion flow, shock expansion method for flow over airfoil	CLO 6	T1:590-596
21	Introduction to shock wave boundary layer interaction	CLO 6	T1:870 T1:939
22	Quasi one dimensional flow	CLO 7	T1:289
23-24	Isentropic flow in nozzles, area Mach relations, choked flow	CLO 8	T1:626-630
25	Under and over expanded nozzles, slip streamline.	CLO 8	T1:631-638
26	One dimensional flow	CLO 9	R2:61
2728	Flow in constant area duct with friction and heat transfer	CLO 9	R2:314:321
29	Fanno flow and Rayleigh flow	CLO 9	R2:302-314
30-31	Flow tables and charts for Fanno flow and Rayleigh flow.	CLO 9	R2:302-314
32	Small perturbation	CLO 10	R2:232
33-35	Perturbation equations for subsonic, transonic, supersonic and hypersonic flow	CLO 10	R2:232
36-37	Experimental characteristics of airfoils in compressible flow	CLO 11	R2:24
38	Supercritical airfoils	CLO 11	R2:2712
38	Area rule	CLO 11	T1:691-693, T1:704-705,
40-41	Theory of characteristics, determination of the characteristic lines	CLO 12	T1:729-736
42-44	Compatibility equations, supersonic nozzle design using method of characteristics	CLO 12	T1:729-736
45	Experimental methods	CLO 13	T1:200-215
46-47	Subsonic wind tunnels	CLO 13	T1:200-215
48-52	supersonic wind tunnels, shock tunnels, free-piston shock tunnel, detonation-driven shock tunnels, and expansion tubes and characteristic features, their operation and performance	CLO 14	T1:486.701

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
53-55	Flow visualization techniques for compressible flows.	CLO 15	T1:486.701

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 high speed aerodynamics and industrial applications	Seminars / NPTEL	PO 3	PSO 1

Prepared By:

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