INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

AEROSPACE ENGINEERING

COURSE DESCRIPTOR

<table>
<tr><td>Course Title</td><td colspan="5">ADVANCED COMPUTATIONAL AERODYNAMICS</td></tr>
<tr><td>Course Code</td><td colspan="5">BAEB05</td></tr>
<tr><td>Programme</td><td colspan="5">M.Tech</td></tr>
<tr><td>Semester</td><td>I</td><td colspan="4">AE</td></tr>
<tr><td>Course Type</td><td colspan="5">Elective</td></tr>
<tr><td>Regulation</td><td colspan="5">IARE - R18</td></tr>
<tr><td rowspan="3">Course Structure</td><td colspan="3">Theory</td><td colspan="2">Practical</td></tr>
<tr><td>Lectures</td><td>Tutorials</td><td>Credits</td><td>Laboratory</td><td>Credits</td></tr>
<tr><td>3</td><td>-</td><td>3</td><td>-</td><td>-</td></tr>
<tr><td>Chief Coordinator</td><td colspan="5">Ms. D. Anitha, Assistant Professor</td></tr>
<tr><td>Course Faculty</td><td colspan="5">Ms. D. Anitha, Assistant Professor</td></tr>
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I. COURSE OVERVIEW:

This course introduces the basic concepts of formulation, boundary conditions, and steps toward constructing a numerical solution which is the foundation for core Aerodynamics of the Aeronautical Engineering discipline. The emphasis of this course is laid on the basic analysis of boundary condition, formulation and physical considerations, steps to constructing a numerical solution which will also develop the ability to use experimental and advanced computational methods. This is designed to enhance students' knowledge of flow physics and their ability to use state-of-the-art computational tools to improve industrial designs

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
-	-	-	-	-

III. MARKSDISTRIBUTION

Subject	SEE Examination	CIA Examination	Total Marks
Advanced Computational Aerodynamics	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✔	LCD / PPT	✔	Seminars	✔	Videos	✘	MOOCs
✘	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 weight age 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.
30 %	To test the analytical skill of the concept.
20 %	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 Technical Seminar and Term Paper.

Table 1: Assessment pattern for CIA

Component	Theory		Total Marks
Type of Assessment	CIE Exam	Technical Seminar and Term Paper	
CIA Marks	25	05	30

Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 9th and 17th week of the semester respectively. The CIE exam is conducted for 25 marks of 2 hours duration, consisting of 5 one mark compulsory questions in part-A and 4 questions in part-B. The student has to answer any 4 questions out of five questions, each carrying 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Technical Seminar and Term Paper:

Two seminar presentations are conducted during I year I semester and II semester. For seminar, a student under the supervision of a concerned faculty member, shall identify a topic in each course and prepare the term paper with overview of topic. The evaluation of Technical seminar and term paper is for maximum of 5 marks. Marks are awarded by taking average of marks scored in two Seminar Evaluations.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO 1	Identify, formulate and solve complex aerospace engineering problems by applying advanced principles of engineering.	3	Presentation on real-world problems
PO 2	Apply aerospace engineering design to produce solutions that meet specified needs with frontier technologies	2	Seminar
PO 3	Formulate and solve complex engineering problems related to aerospace materials, propulsion, aerodynamics, structures, avionics, stability and control.	1	Term Paper
PO 5	Independently carry out research / investigation and development work to solve practical problems	2	Seminar

3 = High; 2 = Medium; 1 = Low

VII. COURSE OBJECTIVES:

The course should enable the students to:

I	Explain the concept of panel methods, analyze various boundary conditions applied and demonstrate several searching and sorting algorithms.
II	Describe the initial methods applied in the process of CFD tools development their advantages and disadvantages over modern developed methods.
III	Demonstrate different methods evolved in analyzing numerical stability of solutions and evaluate the parameters over which the stability depends and their range of values.
IV	Understand advanced techniques and methods in time marching steps and identify different boundary conditions for different cases in CFD techniques.

VIII. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Understand the solution methodology and numerical solutions for the boundary layer.	CLO 1	Understand the concept of flux approach and its formulations.
		CLO 2	Explain the Euler equations for the aerodynamic solutions computationally.
		CLO 3	Emphasize on basic schemes to solve the differential equations.
CO 2	Summarize various types of equations, their solution techniques including their stability.	CLO 4	Understand the stability of the solution by time dependent methods.
		CLO 5	Explain the implicit methods for the time dependent methods to solve computationally.
		CLO 6	Develop the approximate factorization schemes for time dependent methods.
CO 3	Demonstrate to write and solve implicit and explicit equations including stability of the solution.	CLO 7	Illustrate to apply concepts of discretization and its application for implicit difference equation.
		CLO 8	Distinguish implicit and explicit discretization and differentiation equations for the stability of solution.

		CLO 9	Explain the flow gradients at boundaries of unstructured grids.
CO 4	Illustrate the concepts of method of characteristics and its applications in nozzle designs.	CLO 10	Understand the concept of philosophy of method of characteristics
		CLO 11	Explain supersonic nozzle design using method of characteristics.
		CLO 12	Differentiate the domain of dependence and range of influence.
CO 5	Describe basic formulation techniques and boundary condition for panel methods.	CLO 13	Understand the basic formulation and boundary conditions.
		CLO 14	Explain the reduction of a problem to a set of linear algebraic equations.
		CLO 15	Discuss the preliminary considerations prior to establishing numerical solution.

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
BAEB05.01	CLO 1	Understand the concept of flux approach and its formulations.	PO 3	3
BAEB05.02	CLO 2	Explain the Euler equations for the aerodynamic solutions computationally.	PO 1,PO 3, PO 5	3
BAEB05.03	CLO 3	Emphasize on basic schemes to solve the differential equations.	PO 1, PO 2	3
BAEB05.04	CLO 4	Understand the stability of the solution by time dependent methods.	PO 1,PO 2, PO 3	3
BAEB05.05	CLO 5	Explain the implicit methods for the time dependent methods to solve computationally.	PO 1, PO 5	2
BAEB05.06	CLO 6	Develop the approximate factorization schemes for time dependent methods.	PO 3 , PO 5	2
BAEB05.07	CLO 7	Illustrate to apply concepts of discretization and its application for implicit difference equation.	PO 2	2
BAEB05.08	CLO 8	Distinguish implicit and explicit discretization and differentiation equations for the stability of solution.	PO 2	3
BAEB05.09	CLO 9	Explain the flow gradients at boundaries of unstructured grids.	PO 1, PO 2	2
BAEB05.10	CLO 10	Understand the concept of philosophy of method of characteristics	PO 1	2
BAEB05.11	CLO 11	Explain supersonic nozzle design using method of characteristics.	PO 2	2
BAEB05.12	CLO 12	Differentiate the domain of dependence and range of influence.	PO 2	3
BAEB05.13	CLO 13	Understand the basic formulation and boundary conditions.	PO 1, PO 3	3
BAEB05.14	CLO 14	Explain the reduction of a problem to a set of linear algebraic equations.	PO 3, PO 5	2
BAEB05.15	CLO 15	Discuss the preliminary considerations prior to establishing numerical solution.	PO 1	2

3 = High; 2 = Medium; 1 = Low

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

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

3 = High; 2 = Medium; 1 = Low

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

Course Learning Outcomes (CLOs)	Program Outcome (PO)						
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CLO 1			2				
CLO 2	2		1		2		
CLO 3	3	2					
CLO 4	3	2	1				
CLO 5	2				2		
CLO 6			1		2		
CLO 7		2					
CLO 8		2					
CLO 9	3	2					
CLO 10	3						
CLO 11		2					
CLO 12		2					
CLO 13	3		2				
CLO 14			1		1		
CLO 15	3						

3 = High; 2 = Medium; 1 = Low

XII. ASSESSMENT METHODOLOGIES –DIRECT

CIE Exams	PO1, PO2, PO3	SEE Exams	PO1, PO2, PO3	Seminar and Term Paper	PO1, PO2, PO3
Viva	-	Mini Project	-	Laboratory Practices	-

XIII. ASSESSMENT METHODOLOGIES -INDIRECT

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

XIV. SYLLABUS:

Unit-I	**NUMERICAL SOLUTIONS**
Euler equations: Flux approach, Lax-Wendroff method, basic principles of upwind schemes, flux vector splitting, Steger Warming flux vector splitting, Van Leer flux vector splitting, Upwind reconstruction, evolution, Godunov's first order upwind method, Roe's first order upwind method.	
Unit-II	**TIME DEPENDENT METHODS**
Stability of solution, explicit methods, FTFS, FTCS, FTBS, Leapfrog method, Lax method. Implicit methods: Euler's FTCS, Crank Nicolson method, description of Lax- Wendroff scheme, McCormack two step predictor corrector methods, description of time split methods, approximate factorization schemes.	
Unit-III	**BOUNDARY CONDITIONS**
Boundary Layer Equations: Setting up the boundary layer equations, flat plate boundary layer solution, boundary layer transformations, explicit and implicit discretization, solution of the implicit difference equations, integration of the continuity equation, boundary layer edge and wall shear stress, Keller-box scheme. Concept of dummy cells, solid wall inviscid flow, viscous flow, farfield concept of characteristic variables, modifications for lifting bodies inlet outlet boundary, injection boundary, symmetry plane, coordinate cut, periodic boundaries, interface between grid blocks, flow gradients at boundaries of unstructured grids.	
Unit-IV	**METHOD OF CHARACTERISTICS**
Philosophy of method of characteristics, determination of characteristic lines, two dimensional irrotational flow, determination of compatibility equations, unit processes, supersonic nozzle design by the method of characteristics, supersonic wind tunnel nozzle, minimum length nozzles, domain of dependence and range of influence.	
Unit-V	**PANELMETHODS**
Basic formulation, boundary conditions, physical considerations, reduction of a problem to a set of linear algebraic equations, aerodynamic loads, preliminary considerations prior to establishing numerical solution, steps toward constructing a numerical solution, solution of thin airfoil with lumped vortex filament, accounting for effects of compressibility and viscosity.	
Text Books:	
1. Tannehill John C, Anderson Dale A, Pletcher Richard H, "Computational Fluid Mechanics and Heat Transfer", Taylor & Francis, 2nd Edition, 1997. 2. Chung T G, "Computational Fluid Dynamics", Cambridge University Press, 2nd Edition, 2010. 3. Katz Joseph and Plotkin Allen, "Low-Speed Aerodynamics", Cambridge University Press, 2nd Edition, 2006.	

Reference Books:
1. Anderson J D, "Modern Compressible Fluid Flow", McGraw Hill 2nd Edition, 1990. 2. Anderson J D, "Fundamentals of Aerodynamics", Tata McGraw Hill, 5th Edition, 2010. 3. Anderson J D, "Computational Fluid Dynamics", McGraw Hill, 1995. 4. Rathakrishnan E, "Gas Dynamics", Prentice-Hall India, 2004.

XV. 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
1-2	Euler equations: Flux approach	CLO 1	T2 : 5.5
3-5	Lax-Wendroff method, basic principles of upwind schemes	CLO 1	T1 : 4.1.6,
6-7	Flux vector splitting, Steger Warming flux vector splitting	CLO 2	T1 :6.4, T2:6.2-6.4
7-8	Van Leer flux vector splitting, Upwind reconstruction, evolution	CLO 3	T1:6.4.2;
9-10	Godunov's first order upwind method, Roe's first order upwind method	CLO 3	T1 : 3.6 R4:4.3
11-13	Stability of solution, explicit methods, FTFS, FTCS, FTBS	CLO 4	T1:3.8 R2:6.4
14-15	Leapfrog method, Lax method	CLO 4	T1: 4.1.5, 4.1.3
16-17	Implicit methods: Euler's FTCS, Crank Nicolson method	CLO 5	T1:4.2, 4.5.1,4.2.4
18-19	Description of Lax- Wendroff scheme, McCormack two step predictor corrector method	CLO 6	T1:4.1.7, 4.1.8
20-21	Description of time split methods, approximate factorization schemes	CLO 5	T1:9.1-9.3 T2:13.3
22-23	Boundary Layer Equations: Setting up the boundary layer equations, flat plate boundary layer solution, boundary layer transformations	CLO 7	T1:5.3 T2:13.4
24-25	Explicit and implicit discretization, solution of the implicit difference equations, integration of the continuity equation, boundary layer edge and wall shear stress, Keller-box scheme.	CLO 8	T1:6.1-6.2
26-27	Concept of dummy cells, solid wall inviscid flow, viscous flow, farfield concept of characteristic variables	CLO 7	T2:8.1-8.3
28-29	Modifications for lifting bodies inlet outlet boundary, injection boundary, symmetry plane, coordinate cut	CLO 9	T2:8.3-8.6
30-31	Periodic boundaries, interface between grid blocks, flow gradients at boundaries of unstructured grids	CLO 8	T2:8.7-8.9
32-33	Philosophy of method of characteristics	CLO 10	R1:11.2
34-35	Determination of characteristic lines, two dimensional irrotational flow, determination of compatibility equations	CLO 10	R1:11.3, 11.4
36-37	Unit processes, supersonic nozzle design by the method of characteristics, supersonic wind tunnel nozzle	CLO 11	R1:11.5,11. 7,11.8
38-40	Minimum length nozzles, domain of dependence and range of influence.	CLO 12	R1:11.7, 11.6
41	Basic formulation, boundary conditions, physical considerations	CLO 13	T3:9.1- 9.3
42	Reduction of a problem to a set of linear algebraic equations, aerodynamic loads, preliminary considerations prior to establishing numerical solution	CLO 14	T3:9.4- 9.6

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
43-44	Steps toward constructing a numerical solution, solution of thin airfoil with lumped vortex filament	CLO 15	T3:9.7-9.8
45	Accounting for effects of compressibility and viscosity	CLO 15	T3:9.9

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

S No	Description	Proposed Actions	Relevance with POs
1	Encourage students to perform analysis on aerodynamic body computationally.	Seminars	PO 1
2	Encourage students to solve real time applications and prepare towards competitive examinations.	Seminars / NPTEL	PO 3

Prepared By:
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