ADVANCED COMPUTATIONAL AERODYNAMICS

I Semester: AE

Course Code	Category	Hours / Week			Credits	Maximum Marks		
		L	T	P	C	CIA	SEE	Total
BAEB05	Elective	3	-	-	3	30	70	100
Contact Classes: 45	Tutorial Classes: Nil	Practical Classes: Nil				Total Classes: 45		

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.

COURSE OUTCOMES (COs):

CO 1: Understand the solution methodology and numerical solutions for the boundary layer.

CO 2: Summarize various types of equations, their solution techniques including their stability.

CO 3: Demonstrate to write and solve implicit and explicit equations including stability of the solution.

CO 4: Illustrate the concepts of method of characteristics and its applications in nozzle designs.

CO 5: Describe basic formulation techniques and boundary condition for panel methods.

COURSE LEARNING OUTCOMES (CLOs):

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

UNIT-I	NUMERICAL SOLUTIONS	Classes: 10
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**	**Classes: 10**
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 predictorcorrector method, description of time split methods, approximate factorization schemes.		
UNIT-III	**BOUNDARY CONDITIONS**	**Classes: 09**
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**	**Classes: 08**
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**	**Classes: 08**
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.

Web references:
1. https://s6.aeromech.usyd.edu.au/aerodynamics/index.php/sample-page/subsonic-aerofoil-and-wing-theory/2d-panel-methods/ 2. www.wind.civil.aau.dk/lecture/8sem_CFD/Lecture1/Lecture1.pdf 3. personalpages.manchester.ac.uk/staff/david.d.apsley/lectures/comphydr/timedep.pdf
E-Text Books:
1. https://books.google.co.in/books/about/Advanced_Computational_Fluid_and_Aerodyn.html?id=dWS4jgEAC AAJ&redir_esc=y. 2. https://www.scribd.com/doc/159468983/Low-Speed-Aerodynamics-Joseph-Katz-Alen-Plotkin 3. https://www.crcpress.com/Computational-Fluid-Mechanics-and-Heat-Transfer-Third-edition/Pletcher- Tannehill-Anderson/p/book/9781591690375. 4. https://www.faadooengineers.com/threads/8482-Computational-Fluid-Dynamics-Ebook-Ppt-Pdf-Download.