ADVANCED COMPUTATIONAL AERODYNAMICS

I Semester: AE								
Course Code	**Category**	**Hours /Week**			**Credits**	**Maximum Marks**		
		L	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
BAEC05	**Elective**	3	-	-	3	30	70	100
ContactClasses:45	**Tutorial Classes: Nil**	**Practical Classes: Nil**				**Total Classes:45**		

I. COURSE OVERVIEW:

This course deals with the theory behind the commercially available computational fluid dynamic softwares and numerical methods for theory of the fluid flows. The primary focus of this course is on most used, progressive numerical techniques and time dependent methods used to solve the partial differential equations. The students will learn about the boundary layer equations and its transformations. Generation of the grids and its types, various boundary conditions in a fluid flow at different conditions discussed. Philosophy of methods of characteristics for solving the supersonic flow is appreciated. Quintessential method for solving flow around an airfoil that is Panel Methods is addressed.

II. COURSE OBJECTIVES:

The students will try to learn:

I. Advanced techniques in the numerical solution of aerodynamic problems, issues that arise in the solution of such equations in CFD.
II. The formation of boundary layer equations and the boundary conditions to solve the aerodynamics problems.
III. Different methods evolved in analyzing numerical stability of solutions and evaluate the parameters over which the stability depends and their range of values.
IV. Basic formulation of panel methods and consideration to establish the numerical solutions.

III. COURSE OUTCOMES:

After successful completion of the course, students will be able to:

CO 1	**Apply** the flux approach, flux vector splitting, upwind reconstruction- evolution methods for solving the compressible flow problems using Euler's equations.	**Apply**
CO 2	**Make use of** the explicit, implicit, time split methods and approximate factorization schemes for obtaining the stabilized numerical solution of subsonic and supersonic nozzle flows.	**Understand**
CO 3	**Develop** the boundary layer transformation equations for steady external flows on airfoil, wings and aircraft using finite difference method.	**Apply**
CO 4	**Analyze** the structured, unstructured grids and dummy cells using physical boundary conditions for attaining the accurate results of fluid flow problems.	**Apply**
CO 5	**Identify** the characteristic lines and compatibility equations for designing the supersonic nozzle having shock free and isentropic flow.	**Apply**
CO 6	**Utilize** the effects of compressibility and viscosity on thin airfoil for establishing the numerical solution in aerodynamic problems.	**Analyze**

IV. SYLLABUS:

MODULE-I: NUMERICAL SOLUTIONS (10)

Euler equations: Flux approach, Lax-Wendroff method, basic principles of upwind schemes, flux vector splitting, Steger Warming flux vector splitting,VanLeer flux vector splitting, Upwind reconstruction, evolution, Godunov"s first order upwind method, Roe's first order upwind method.

MODULE-II: TIME DEPENDENT METHODS (10)

Stability of solution, explicit methods, FTFS, FTCS, FTBS, Leapfrog method, Lax method. Implicit methods:

Euler‟s FTCS, Crank Nicols on method, description of Lax-Wendroff scheme, McCormack two step predictor corrector method, description of time split methods, approximate factorization schemes.

MODULE-III: BOUNDARY CONDITIONS (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 in viscid flow, viscous flow, farfield concept to 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.

MODULE-IV: METHOD OF CHARACTERISTICS (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.

MODULE-V: PANEL METHODS (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.

IV. TEXT BOOKS:

1. Tannehill John C, Anderson Dale A, Pletcher Richard H, “Computational Fluid Mechanics and Heat Transfer”, Taylor &Francis, 2nd Edition,1997.
2. ChungT 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.

V. 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.

VI. 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

VII. E-TEXT BOOKS:

1. https://books.google.co.in/books/about/Advanced_Computational_Fluid_and_Aerodyn.html?id=dWS4jgEACAAJ&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.