COMPUTATIONAL AERODYNAMICS

VI Semester: AE								
Course Code	Category	Hours / Week			Credits	Maximum Marks		
AAEC25	Core	L	T	P	C	CIA	SEE	Total
		3	1	-	4	30	70	100
Contact Classes: 45	Tutorial Classes: 15	Practical Classes: Nil				Total Classes: 60		
Prerequisite: Knowledge of Fluid Dynamics and Aerodynamics								

I. COURSE OVERVIEW:

Computational aerodynamics is the study of computational analysis on aerodynamic flow bodies. This course deals with the basic aspects of Computational Fluid Dynamics, emphasizing on the governing equations of fluid dynamics and their numerical discretization techniques using finite volume and finite difference methods. The course also discusses the methods of grid generation techniques for both structured and unstructured grid in 2D as well as 3D. It describes the mathematical behavior of the different classes of partial differential equations, this deal with pressure based solvers for incompressible viscous flow.

II. COURSE OBJECTIVES:

The student will try to learn:

I	The concepts of grid generation techniques for simple and complex domains to model fluid flow problems.
II	The aspects of numerical discretization techniques such as finite volume and finite difference methods.
III	The mathematical modeling of different classes of partial differential equations toshow their impact on computational fluid dynamics.
IV	The characteristics of different turbulence models and numerical schemes for estimating the criteria of stability, convergence, and error of fluid flow problem.

III. COURSE OUTCOMES:

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

CO 1	**Summarize** the concepts of computational fluid dynamics and itsapplications in industries as a tool for fluid analysis.	Understand
CO 2	**Choose** the type of flow from the finite control volume and infinitesimal small fluid element for the fluid flow analysis.	Apply
CO 3	**Select** the quasi linear partial differential equation for estimating the behavior in computational fluid dynamics.	Apply
CO 4	**Identify** CFD techniques for relevant partial differential equations for getting analytical solutions for fluid flow problems.	Apply
CO 5	**Make use of** finite difference approach for numerical formulations based on fluid mechanics and heat transfer concepts for getting the solutions of fluid flow problems.	Apply
CO 6	**Utilize** the grid generation and transformation techniques in implementation of finite difference and finite volume methods in solving complex fluid and aerodynamic problems.	Apply

IV. COURSE SYLLABUS:

MODULE-I: INTRODUCTION (09)

Need of computational fluid dynamics, philosophy of CFD, CFD as a research tool as a design tool, applications in various branches of engineering, models of fluid flow finite control volume, infinitesimal fluid element, substantial derivative physical meaning of divergence of velocity, derivation of continuity, momentum and energy equations, physical boundary conditions significance of conservation and non-conservation forms and their implication on CFD applications strong and weak conservation forms shock capturing and shock fitting approaches

MODULE –II: MATHEMATICAL BEHAVIOR OF PARTIAL DIFFERENTIAL EQUATIONS AND THEIR IMPACT ON COMPUTATIONAL AERODYNAMICS (08)

Classification of quasi-linear partial differential equations by Cramer‘s rule and Eigen value method, general behavior of different classes of partial differential equations and their importance in understanding physical and CFD aspects of aerodynamic problems at different Mach numbers involving hyperbolic, parabolic and elliptic equations: domain of dependence and range of influence for hyperbolic equations, well-posed problems.

MODULE –III: BASIC ASPECTS OF DISCRETIZATION (10)

Introduction to finite difference: finite difference approximation for first order, second order and mixed derivatives, explicit and implicit approaches, truncation and round-off errors, consistency, stability, accuracy, convergence, efficiency of numerical solutions. Von Neumann stability analysis, physical significance of CFL stability condition.

Need for grid generation, structured grids artesian grids, stretched (compressed) grids, body fitted structured grids, H-mesh, C-mesh, O-mesh, I-mesh, multi-block grids, C-H mesh, H-O-H mesh, overset grids, adaptive grids, unstructured grids: triangular, tetrahedral cells, hybrid grids, quadrilateral, hexahedral cells.

MODULE –IV: CFD TECHNIQUES (09)

Lax-Wendroff technique, MacCormack‘s technique, Crank Nicholson technique, Relaxation technique, aspects of numerical dissipation and dispersion. Alternating-Direction-Implicit (ADI) Technique, pressure correction technique: application to incompressible viscous flow, need for staggered grid. Philosophy of pressure correction method, pressure correction formula. Numerical procedures: SIMPLE, SIMPLER, SIMPLEC and PISO algorithms, boundary conditions for the pressure correction method.

MODULE –V:FINITE VOLUME METHODS (09)

Linear Impulse and Momentum, Connected Bodies, Conservation of Momentum, Coefficient of restitution, Types of Impact. Vibrations - Basic terminology, free and forced vibrations, types of pendulum, Derivation for frequency and time period of simple, compound and torsion pendulums.

V. TEXT BOOKS:

1. J. D. Anderson, Jr., “Computational Fluid Dynamics- The Basics with Applications”, McGraw Hill, 2012.
2. D A Anderson, J C Tannehill, R H Pletcher, “Computational Fluid Mechanics and Heat Transfer”, 1st Edition, 1997.

VI. REFERENCE BOOKS:

1. Hirsch, C., “Numerical Computation of Internal and External Flows: The Fundamentals of Computational Fluid Dynamics”, Vol. I, Butter worth-Heinemann, 2nd Edition, 2007.
2. H K Varsteeg, W Malalasekera, “An Introduction to Computational Fluid Dynamics – The Finite Volume Method”, Longman Scientific and Technical, 1st Edition, 1995.
3. Patankar, S.V., “Numerical Heat Transfer and Fluid Flow”, Hemisphere Pub. Corporation, 1st Edition, 1980.

VII. WEB REFERENCES:

1. https://www.mathematik.uni-dortmund.de/~kuzmin/cfdintro/lecture1.pdf
2. https://bookboon.com/en/computational-fluid-dynamics-ebook
3. https://www.sciencedirect.com/science/book/9780080445069
4. https://cg.informatik.uni-freiburg.de/course_notes/cfd.pdf

VIII. E-TEXT BOOKS:

1. https://www.leka.lt/sites/default/files/dokumentai/computational-fluid-dynamics.pdf
2. https://www.topajka-shaw.co.nz/UCFD.htm
3. https://www.grc.nasa.gov/WWW/wind/valid/tutorial/tutorial.html
4. https://www.scribd.com/doc/311680146/eBook-PDF-Cfd-Fluent