COMPUTATIONAL AERODYNAMICS

VI Semester: AE								
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
AAE013	**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**		

OBJECTIVES:

The course should enable the students to:

I. Discuss the fundamental aspects of numerical discretization and the major theories, approaches and methodologies used in computational aerodynamics.
II. Analyze to build up the skills in the actual implementation of computational aerodynamics methods boundary conditions, turbulence modeling etc by using commercial CFD codes.
III. Demonstrate the applications of CFD for classic fluid dynamics problems and basic thoughts and philosophy associated with CFD.
IV. Understand the various grids used in practice, including some recommendations related to grid quality and choose appropriate data structure to solve problems in real world.

COURSE OUTCOMES (COs):

CO 1: Understand the applications of CFD in various engineering fields and to generate governing equations in conservative and non-conservative form.
CO 2: Understand the mathematical behavior of partial differential equations and classify into hyperbolic, parabolic and elliptical natures.
CO 3: Acquire the concepts of finite difference method through discretization and grid generation techniques.
CO 4: Identify different CFD techniques available for different partial differential equations.
CO 5: Explore the concepts of finite volume methods, and its difference from finite difference method.

COURSE LEARNING OUTCOMES (CLOs):

1. Understand the necessity of CFD tool as both research and design areas in modern computational world
2. Explain the applications of computational fluid dynamics tool in various engineering branches other than aerospace engineering.
3. Define different types of manometers and explain buoyancy force, stability of floating bodies by determining its meta centre height.
4. Recognize the selection of type of flow from the finite control volume and infinitesimal small fluid element depending upon the requirements.
5. Develop the governing equations required for computational aerodynamics in both conservation and non-conservation forms.
6. Explain the need of classification of quasi linear partial differential equations by Cramer's rule and Eigen Value Method.
7. Understand the concepts of range of influence and domain of dependence for a flow field.
8. Explain the general behaviour of the partial differential equations which falls in hyperbolic, parabolic and elliptic equations.

9. Demonstrate the CFD aspects of the hyperbolic, parabolic and elliptic equations in aerodynamic problems and physical problems.
10. Distinguish between explicit and implicit approaches that are needed for solving different finite differential equations.
11. Explain the Consistency analysis and von Neumann stability analysis of finite difference methods and physical significance of CFL condition.
12. Discuss the different types of grids available for different flow fields available in computational fluid dynamics.
13. Understand the need for generating grids for solving the finite differential equations in analyzing a flow field.
14. Describe the various CFD techniques available for solving the finite differential equations for a flow field.
15. Discuss the aspects of numerical dissipation and numerical dispersion and explain the applications of each in CFD techniques.
16. Explain the technique of pressure correction method with the need of staggered grid and its philosophy.
17. Explain the numerical procedures for analysis like SIMPLE, SIMPLER SIMPLEC and PISO algorithms and differentiate with regular CFD techniques.
18. Discuss the concepts of finite volume method and explain the difference from finite difference method for solving different flow field.
19. Demonstrate the need of finite volume discretization and its general formulation of a numerical scheme in finite volume method.
20. Understand the principle of two dimensional finite volume methods in solving flow fields with finite control volume.

UNIT-I	INTRODUCTION TO COMPUTATIONAL AERODYNAMICS	Classes: 10

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.

UNIT-II	MATHEMATICAL BEHAVIOR OF PARTIAL DIFFERENTIAL EQUATIONS AND THEIR IMPACT ON COMPUTATIONAL AERODYNAMICS	Classes: 09

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.

UNIT-III	BASIC ASPECTS OF DISCRETIZATION	Classes: 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

UNIT-IV	CFD TECHNIQUES	Classes: 08
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.		
UNIT-V	**FINITE VOLUME METHODS**	**Classes: 08**
Basis of finite volume method, conditions on the finite volume selections, cell-centered and cell vertex approaches. Definition of finite volume discretization, general formulation of a numerical scheme, two dimensional finite volume methods with example.		

Text Books:

1. J. D. Anderson, Jr., "Computational Fluid Dynamics- The Basics with Applications", McGrawHill Inc, 2012.
2. D A Anderson, J C Tannehill, R H Pletcher, "Computational Fluid Mechanics and Heat Transfer", 1st edition, 1997.

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. Hoffmann, K. A. and Chiang, S. T., "Computational Fluid Dynamics for Engineers", Engineering Education Systems, 4th edition, 2000.
3. Patankar, S.V., "Numerical Heat Transfer and Fluid Flow", Hemisphere Pub. Corporation, 1st edition, 1980.
4. H K Varsteeg, W Malalasekera, " An Introduction to Computational Fluid Dynamics – The Finite Volume Method", Longman Scientific and Technical, 1st edition, 1995.

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

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