COMPUTATIONAL FLUID DYNAMICS

VI Semester: AE

Course Code	Category	Hours / Week			Credits	Maximum Marks		
AAEB20	Core	L	T	P	C	CIA	SEE	Total
		2	1	-	3	30	70	100
Contact Classes: 30	Tutorial Classes: 15	Practical Classes: Nil				Total Classes: 45		

COURSE OBJECTIVES:

The students 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 to show 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.

COURSE OUTCOMES:

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

CO 1 **Demonstrate** the methods of finite control volume and infinitesimal fluid element in both forms such as moving with the fluid and fixed in space solves governing equations.

CO 2 **Develop** the fundamental aspects of numerical discretization of the governing equations and differentiate the integral and differential forms of the governing flow equations suitable for computational fluid dynamics.

CO 3 **Illustrate** the CFD aspects of the hyperbolic, parabolic, and elliptic equations in aerodynamic and other physical problems for understanding mathematical behavior.

CO 4 **Make use of** range of influence and domain of dependence for low-subsonic, subsonic, supersonic, and hypersonic flows.

CO5 **Classify** the quasilinear partial differential equation for the mathematical behavior.

CO 6 **Demonstrate** the finite-difference by replacing the partial derivative with a suitable algebraic difference quotient for coding purpose.

CO 7 **Distinguish** between the structured and unstructured grids for grid generation.

CO 8 **Illustrate** the basics of various numerical discretizations that can be applied for the governing equations.

CO 9 **Make use of** marching steps of time or space obtain the numerical solution of computational fluid dynamics.

CO 10 **Demonstrate** the finite volume discretization and its general formulation of a numerical scheme in the finite volume method.

CO 11 **Explain** the concepts of the finite volume method and identify the difference from finite difference method for solving different flow fields.

MODULE–I	INTRODUCTION	Classes : 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	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.		
MODULE-III	BASIC ASPECTS OF DISCRETIZATION	Classes: 09
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	Classes: 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	SOLUTION METHODS AND APPLICATIONS OF NUMERICS TO SIMPLE PROBLEMS	Classes: 09
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. H K Varsteeg, W Malalasekera, “ An Introduction to Computational Fluid Dynamics – The Finite Volume Method”, Longman Scientific and Technical, 1st edition, 1995.		