

Branch Name:	Mechanical Engineering
Semester/Year:	Semester VIII / Fourth Year
Subject Title:	Computational Fluid Dynamics
Subject Code:	1ET1010803
Pre-requisite:	Fluid Mechanics, Heat Transfer, Transport Phenomena, Elementary Numerical Analysis, ODE, PDE

Course Objectives:

1. To introduce and develop the main approaches and techniques which constitute the basis of numerical fluid mechanics for engineers and applied scientists.
2. To familiarize students with the numerical implementation of these techniques and numerical schemes, so as to provide them with the means to write their own codes and software, and so acquire the knowledge necessary for the skillful utilization of computational fluid dynamics (CFD) packages or other more complex software.
3. To cover a range of modern approaches for numerical and computational fluid dynamics, without entering all these topics in detail, but aiming to provide students with a general knowledge and understanding of the subject, including recommendations for further studies.

Teaching Scheme (Hours per week)				Evaluation Scheme (Marks)				
Lecture (L)	Tutorial (T)	Practical (P)	Credit	Theory (Marks)		Practical (Marks)		Total (Marks)
				University Assessment	Continuous Assessment	University Assessment	Continuous Assessment	
03	00	02	04	70	30	30	20	150

Subject Contents			
Sr. No	Topic	Total Hours	Weightage (%)
1	Introduction to Computational Fluid Dynamics and Principles of Conservation: Computational Fluid Dynamics: What, When, and Why?, CFD Applications, Numerical vs. Analytical vs. Experimental, Modeling vs. Experimentation, Fundamental principles of conservation, Reynolds transport theorem, Conservation of mass, Conservation of linear momentum: Navier-Stokes equation, Conservation of Energy, General scalar transport equation	04	10
2	Classification of Partial Differential Equations and Physical Behaviour: Mathematical classification of Partial Differential Equation, Illustrative examples of elliptic, parabolic and hyperbolic equations, Physical examples of elliptic, parabolic and hyperbolic partial differential equations	02	06
3	Approximate Solutions of Differential Equations: Error Minimization Principles, Functional involving higher order derivatives, Approximate solution of differential equations through variational formulation, Boundary conditions in the variational form: Primary and secondary variables, Essential and natural boundary conditions, Approximate solutions of differential equations, Properties of variational form, Weighted residual approach: trial function and weighting function, Requirement of trial function and weighting function, Least square method, Point Collocation method, Galerkin's method, Rayleigh-Ritz method	03	10
4	Fundamentals of Discretization: Discretization principles: Pre-processing, Solution, Post-processing, Finite Element Method, Finite difference method, Well posed boundary value problem, Possible types of boundary conditions,	03	08

	Conservativeness, Boundedness, Transportiveness, Finite volume method (FVM), Illustrative examples: 1-D steady state heat conduction without and with constant source term		
5	Finite Volume Method: Some Conceptual Basics and Illustrations through 1-D Steady State Diffusion Problems: Physical consistency, Overall balance, FV Discretization of a 1-D steady state diffusion type problem, Composite material with position dependent thermal conductivity, Four basic rules for FV Discretization of 1-D steady state diffusion type problem, Source term linearization, Implementation of boundary conditions	02	06
6	Discretization of Unsteady State Problems: 1-D unsteady state diffusion problems: implicit, fully explicit and Crank-Nicholson scheme	01	02
7	Important Consequences of Discretization of Time Dependent Diffusion Type Problems: Consequences of time-discretization in finite discretization, Consistency, Stability, Convergence, LAX Equivalence theorem, Grid independent and time independent study, Stability analysis of parabolic equations (1-D unsteady state diffusion problems): FTCS scheme, Stability analysis of parabolic equations (1-D unsteady state diffusion problems): CTCS scheme, Stability analysis of hyperbolic equations: FTCS, FTFS, FTBS and CTCS Schemes	04	10
8	Finite Volume Discretization of 2-D unsteady State Diffusion type Problems: FVM for 2-D unsteady state diffusion problems	01	02
9	Solution of Systems of Linear Algebraic Equations: Criteria for unique solution, infinite number of solutions and no solution, Solution techniques for systems of linear algebraic equations	09	20
10	Discretization of Convection-Diffusion Equations: A Finite Volume Approach: Finite volume discretization of convection-diffusion problem: Central difference scheme, Upwind scheme, Exponential scheme and Hybrid scheme, Power law scheme, Generalized convection-diffusion formulation, Finite volume discretization of two-dimensional convection-diffusion problem, The concept of false diffusion, QUICK scheme.	05	10
11	Discretization of Navier Stokes Equations: Discretization of the Momentum Equation: Stream Function-Vorticity approach and Primitive variable approach, Staggered grid and Collocated grid, SIMPLE Algorithm, SIMPLER Algorithm	04	10
12	• Unstructured Grid Formulation • What is there in implementing a CFD code? • Introduction to Turbulence Modeling-Important features of turbulent flow, Vorticity transport equation, Statistical representation of turbulent flows: Homogeneous turbulence and isotropic turbulence, General Properties of turbulent quantities, Reynolds average Navier stokes (RANS) equation, Closure problem in turbulence: Necessity of turbulence modeling, Different types of turbulence model	04	06

Course Outcomes:

The student will be able to...

1. Understand the fundamentals of the numerical fluid mechanics.
2. Implement the numerical techniques to solve the complex fluid dynamics problems.
3. Utilize knowledge in solving CFD problems using complex software packages.
4. Develop their own code/software in order to address real life industrial issues related to fluid flow.

List of Reference Books:

1. S. V. Patankar, Numerical Heat Transfer and Fluid Flow, McGraw-Hill.
2. John D. Anderson Jr, Computational Fluid Dynamics, McGraw Hill Book Company.
3. John C. Tannehill, Dale A. Anderson and Richard H. Pletcher, Computational Fluid Mechanics and Heat Transfer, Taylor & Francis.
4. J. Blazek, Computational Fluid Dynamics: Principles and Applications, Elsevier.
5. T. J. Chung, Computational Fluid Dynamics, Cambridge University Press.
6. H. K. Versteeg & W. Malalasekera, An Introduction to Computational Fluid Dynamics, Longman

Scientific & Technical.

7. J. H. Ferziger and M. Peric, Computational Methods for Fluid Dynamics, Springer.

List of Practical:

1. Introduction to CFD Tool
2. To simulate flow through forward facing step
3. To simulate flow through backward facing step
4. To simulate flow through nozzles and diffusers
5. To simulate flow through convergent divergent nozzle
6. To simulate flow through T-shape duct
7. To simulate flow over the flat plate
8. To simulate flow over the cylinder
9. To simulate flow over an airfoil
10. To simulate flow over double wedge airfoil

E-Resources:

- <https://nptel.ac.in/courses/112105045/>
- <http://vlab.co.in/>