

Course-Plan

School : ENGINEERING
Department : Mechanical Engineering
Course Code : ME 441
Course Name : Elements of Computational Fluid Dynamics

Instructor: Dr. Paragmoni Kalita

1. Abstract:

ME 441 is an ME elective course offered in the fifth semester of the B.Tech. programme. The course starts with a review of the governing equations of fluid dynamics followed by the physical and mathematical classification of these equations. It then covers different techniques to discretize the governing equations for their numerical solutions, the issues of accuracy, consistency, stability and convergence and some special numerical methods to solve the elliptic, parabolic and hyperbolic equations governing fluid mechanics and heat transfer.

2. Objectives:

The course shall be taught with the following objectives:

- i. To revise the governing equations of fluid dynamics
- ii. To train the students on the discretization techniques for the numerical solution of the governing equations
- iii. To familiarize with the critical issues of consistency, stability, convergence and discretization errors
- iv. To teach the finite difference and finite volume techniques for numerical solutions of the fluid flow problems
- v. To train the students to numerically solve the fluid flow problems with the help of computer programming using Fortran/C/C++.
- vi. To acquaint the students with the research scopes in the field of computational fluid dynamics

3. Prerequisites of the course:

There is no prerequisite of the course. However, basic knowledge of fluid mechanics, ordinary and partial differential equations and computer programming using Fortran/C/C++ is desirable.

Course outline:

General form of a conservation law; The Navier-Stokes (NS) equation; Mathematical nature of PDE's and flow equations. Basic Discretization techniques-Finite Difference Method (FDM), Integration methods for systems of ODE's, Linear Solver, Accuracy, Consistency; Stability; Convergence; Fourier or von Neumann stability analysis; Modified equation; Application of FDM to wave, Heat, Laplace and Burgers equations, Introduction to Finite Volume Method on structured grids, Numerical solution of the Euler equations, Mathematical formulation of the system of Euler equations; Numerical solution of the incompressible Navier-Stokes equations,

5. (a) Time-Plan

Topic	Content	Book	Class Hours
The governing equations of fluid dynamics and their classification	General form of a conservation law; Equation of mass conservation	[AJ]	1
	Conservation law of momentum; Conservation equation of energy		1
	Physical and Mathematical nature of PDE's and flow equations		2
Basic Discretization techniques-Finite Difference Method (FDM)	Taylor series expansion, Introduction to Finite Difference Method	[TAP]	1
	Central and Upwind Schemes		1
	Order of accuracy of finite difference schemes		1
Integration methods for systems of ODE's:	Explicit and Implicit Methods	[TAP]	1
	Multi-step methods		1
	Predictor-corrector schemes		1
	ADI methods		1
	Thomas Algorithm		1
	The Runge-Kutta schemes		1
Linear Solver	Error and convergence properties of methods for solving system of algebraic equations	[TAP]	1
	Point Jacobi method,		1
	Gauss-Seidel method		1
	Point and Line Successive Over-relaxation methods		1
Analysis and Application of Numerical Schemes	Consistency; Stability; Convergence	[TAP]	2
	Modified equation		1
	Fourier or von Neumann stability analysis		1
	Application of von Neumann stability analysis to wave, Heat, Laplace and Burgers equations		3
Introduction to Finite Volume Methods	Finite Volume Discretization of Time Derivative	[TAP]	1
	Finite Volume Discretization of the Convective Term		1
	Finite Volume Discretization of the Dissipative Term		1
	Treatment of Boundary Conditions		1
Numerical solution of the incompressible Navier-Stokes equations	Stream function-vorticity formulation	[TAP]	2
	Primitive variable formulation		1
	staggered and collocated grids		2
	MAC, SMAC, SIMPLE, SIMPLER and SIMPLEC algorithms		5
	Lid-driven cavity flow.		1
Total Classes			39

Texts:

1. Computational Fluid Mechanics and Heat Transfer 2e- Tannehill, Anderson and Pletcher, Taylor and Francis, 1997.
2. Computational Methods for Fluid Dynamics- J. H. Ferziger, M. Peric, Springer, 2002

References:

1. An introduction to computational fluid dynamics: The finite volume method - H.K. Versteeg and W. Malalasekera, Longman, 1995
2. Numerical Heat Transfer and Fluid Flow - S.V. Patankar, Hemisphere, 1980.

Examination plan

Test No.	Marks	To be completed within
Sessional Test I	10	04.09.2025
Mid-semester examination	30	18.10.2025
Sessional Test II	10	07.11.2025
End-semester evaluation	40	13.12.2025
Total Marks	100	

6. Pedagogy:**Teaching-learning methods to be used:**

Lecture and Discussion
 Presentations
 Assignment problems,
 Class Tests/Quiz

7. Course outcomes:

- CO1: Classify a given Partial Differential Equation (PDE) as per its physical and mathematical behavior.
- CO2: Discretize the governing equations of fluid mechanics and heat transfer on FDM and FVM framework using various time-integration techniques.
- CO3: Write mathematical formulations to generate structured grids.
- CO4: Numerically solve a system of linear algebraic equations using various iterative linear solvers.
- CO5: Apply proper boundary conditions for the numerical computation of any basic flow problem involving fluid flow and heat transfer
- CO6: Carry out linear stability analysis of basic discretization methods for various types of PDEs.