Computational Fluid Dynamics

1.1 Course Number: MA 324

1.2 Contact Hours: 41 (L) Credits: 9 [LTP: 3-0-0]

1.3 Semester-offered: Even

1.4 Prerequisite: Fluid Dynamics; Numerical Methods; Differential Equations; and Matlab

1.5 Syllabus Committee Member: Dr. C. Kundu, Dr. M.K. Rajpoot (convener), Dr. A. Kumar, Dr. G. Rakshit.

2. **Objective:**

To foster an in-depth understanding of basic concepts from fluid dynamics, implementation of numerical methods and to introduce the concepts of stability, accuracy, and convergence. The main aim is to inculcate the ability to use the computers for the simulations to real-world fluid-flow problems.

3. **Course Content:**

Unit-wise distribution of content and number of lectures

Unit	Topics	Sub-topic	Lectures
1	**Introduction to partial differential equations (PDEs) and Numerical methods**	Classification, well-posedness and system of PDEs. Numerical methods: Different kinds of errors in computations, finite differences, consistency, and stability constraints. Convergence for time marching PDEs, conservative form, Fourier stability analysis.	6
2	**Numerical methods for hyperbolic/parabolic and elliptic PDEs**	Numerical methods for hyperbolic PDEs: Explicit/implicit Euler methods, upwind/downwind methods, leap-frog method, Lax-Wendroff method, McCormack method and Rusanov method. Numerical methods for parabolic PDEs: Explicit/implicit method, Richardson’s method, Crank-Nicolson, and alternating direction implicit (ADI) methods. Numerical methods for elliptic PDEs: Finite differences for Laplace’s equation, direct/iterative methods for linear algebraic equations.	12
3	**Governing equations for**	Continuity equation, momentum equation, energy equation, derived and primitive variables formulations, equation of	7

	fluid flows	state, boundary layer approximation for steady incompressible flow, Euler equations, shock dynamics.	
4	**Numerical methods for inviscid flows**	Method of characteristics for linear and nonlinear (quasilinear) systems, shock-capturing methods.	8
5	**Numerical methods for boundary layer approximations**	Explicit/implicit methods, Crank-Nicolson and Du Fort-Frankel Methods.	8
		Total	41

4. Readings

4.1 Textbook:

I. D. A. Anderson, John C. Tannehill and Richard H. Platcher, *Computational Fluid Mechanics and Heat Transfer*, CRC Press, 4th Ed. (2020).

II. C. A. J. Fletcher, *Computational Techniques for Fluid Dynamics*: Vol. I and II, Springer, 2nd Ed. (1998).

4.2 Reference books:

I. W. F. Ames, *Numerical Method for Partial Differential Equation*s, Academic Press, 3rd Ed. (1992).

5 Outcome of the Course:

Students will be:

- ✓ Capable of applying computational tools to solve the continuous physical/engineering fluid-flow problems.
- ✓ Able to analyse and interpret the data obtained from the numerical solution of fluid flow problems.