COMPUTATIONAL FLUID DYNAMICS
(Elective-II)

Subject Code: 13ME2311 **L P C**
4 0 3

Course Outcomes:

At the end of the course, the student will be able to

CO1: Explain basic approaches and numerical methods to solve fluid dynamics problems

CO2: Explain finite volume method for diffusion and convection-diffusion problems using different interpolation schemes

CO3: Solve linear algebraic equations and transient one and two dimensional heat conduction equations

CO4: Explain stream function-vorticity method, and to solve the pressure equation

CO5: Discuss pressure correction method to solve incompressible and compressible flows, and explain turbulent flow models

UNIT-I

Principles of conservation of mass and momentum – Dimensionless form of equations – Simplified mathematical models for incompressible, inviscid, potential and creeping flows, Boussinesq and boundary layer approximations – Mathematical classification as hyperbolic, parabolic and elliptic flows.

Approaches to fluid dynamical problems – Possibilities and limitations of numerical methods – Components of numerical solution method: Mathematical model, discretization method, coordinate and basis vector systems, numerical grid, finite approximations, solution method, convergence criteria, consistency, stability, convergence – Discretization approaches: finite difference method, finite volume method, finite element method.

UNIT-II

Finite difference methods: Approximation of first, second and mixed derivatives, uniform and non-uniform derivatives, implementation of boundary conditions, discretization errors.

Finite volume methods: Approximation of surface and volume integrals – Interpolation schemes: upwind differencing, central difference scheme, quadratic upwind interpolation (QUICK) scheme – Implementation of boundary conditions – Algebraic equation system.

UNIT-III

Solution of linear algebraic equations: Guass elimination method, Thomas algorithm for tri-diagonal system of equations.

Solution of transient one-dimensional differential equation: explicit method, Crank-Nicolson implicit scheme.

Solution of unsteady two-dimensional differential equation: Alternating Direction Implicit method.

UNIT-IV

Solution of Navier-Stokes equations-I: Discretization of derivative terms: convective and viscous terms, pressure and body force terms – conservation properties.

Variable grid: Collocated arrangement, staggered arrangement

The pressure equation and its solution: A simple explicit time advance scheme, a simple implicit time advance scheme - Stream function-vorticity method.

UNIT-V

Solution of Navier-Stokes equations-II: Implicit pressure correction methods: SIMPLE and SIMPLER algorithms

Turbulent flows: Large eddy simulation (LES) – Reynolds averaged Navier-Stokes equations – Simple turbulence models – Reynolds stress model

Compressible flow: Pressure correction method, pressure-velocity-density coupling, boundary conditions.

TEXT BOOK:

1. J. H, Ferziger and M. Peric, "*Computational Methods for Fluid Dynamics*", 3rd Revised Edition, Springer, 2002.

REFERENCES:

1. C. Hirsch, "*Numerical Computation of Internal and External Flows: Volume 1, Fundamentals of Numerical Discretization*", 2nd Edition, John Wiley & Sons, 2007.
2. Patankar S.V., "*Numerical Heat Transfer and Fluid Flow*", Taylor and Francis, 2004.
3. H. K. Versteeg and W. Malalasekera, "*An Introduction to Computational Fluid Dynamics: the Finite Volume Method*", Longman Scientific & Technical, 1996.
4. Fletcher C.A.J., "*Computational Techniques for Fluid Dynamics*", Vol. 2: Specific Techniques for Different Flow Categories", Springer-Verlag. 1998.