COMPUTATIONAL FLUID DYNAMICS

Course Code: 13ME2311 **L P C**
Pre requisites: Fluid mechanics, heat transfer and basic numerical methods **4 0 3**

Course Educational Objectives: To make the student understand

1. mathematical modeling of physical problems
2. basic features of finite difference and finite volume methods
3. numerical methods to solve transient one and two dimensional partial differential equations
4. SIMPLE algorithm to solve Navier-Stokes equations
5. mathematical models for turbulent flows

Course Outcomes:

The student will be able to

1. explain finite difference and finite volume methods
2. solve problems involving Navier-Stokes equations
3. solve problems involving turbulent flows

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: Gauss 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. C. Hirsch, "*Numerical Computation of Internal and External Flows: Volume 2, Methods of Inviscid and Viscous Flows*", John Wiley & Sons, 2007.
3. H. K. Versteeg and W. Malalasekera, "*An Introduction to Computational Fluid Dynamics: the Finite Volume Method*", Longman Scientific & Technical, 1996.