COMPUTATIONAL FLUID DYNAMICS

Course Code: 15ME2312

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Pre requisites: Fluid mechanics, heat transfer and basic numerical methods

Course Outcomes: At the end of the course, the student will be able to

CO1: Explain different flow models and classification of differential equations, grid generation, discretisation

CO2: Apply finite difference method to steady state and transient heat conduction problems

CO3: Explain ADI method and vorticity-stream function method by FDM, discretisation using finite volume method, and implementation of boundary conditions

CO4: Apply finite volume method to convection-diffusion problems, and properties of discretisation schemes

CO5: Explain upwind differencing, application of FVM to solve pressure-linked flow problems using SIMPLE algorithm

UNIT-I (10-Lectures)

Mass, momentum and energy balance equations - Conservation form of the governing equations of fluid flow - Potential flow model, Buoyancy-driven convection and Boussinesq approximation, definitions of stream function and vorticity - Classification of partial differential equations according to physical behaviour as elliptic, parabolic and hyperbolic equations. Finite difference method - Approximation of first and second derivatives from Taylor series.

Finite difference method: grid generation, discretisation of differential equations - the problem of one-dimensional steady state heat conduction in a slab/rod.

UNIT-II (10-Lectures)

A few selected applications of finite difference method with uniform grid size to solve partial differential equations in Cartesian coordinates: (a) Heat dissipation through a fin, (b) problem of steady state two-dimensional heat conduction, (c) Transient one-dimensional heat conduction equation (i) by explicit method, and (ii) by Crank-Nicolson's implicit scheme

UNIT-III (10-Lectures)

Solution of transient two-dimensional heat conduction equation by Alternating Direction Implicit method.

Vorticity-Stream function method to solve the problem of two-dimensional incompressible viscous flow in a lid-driven cavity

Finite volume method: Concept of control volume, grid generation, discretisation - Application to one-dimensional steady state heat conduction in a rod with source term - Implementation of boundary conditions - Solution method using Thomas Algorithm.

UNIT-IV (10-Lectures)

Application of finite volume method to solve the problem of heat transfer from a fin. Finite volume method for two-dimensional diffusion problem - two-dimensional grid - discretisation and solution.

Finite volume method for one-dimensional convection diffusion using central differencing scheme.

Properties of discretisation schemes: conservativeness, boundedness, transportiveness.

UNIT-V (10-Lectures)

The upwind-differencing scheme. Assessment of central and upwind differencing schemes for conservativeness, boundedness, transportiveness.

Finite volume method to solve momentum balance equations for two-dimensional internal flow with pressure gradient: Concept of staggered grid and two-dimensional grad for u- and v-velocity components -

Discretisation of x- and y-momentum balance equations - Pressure correction method using SIMPLE algorithm

TEXT BOOKS

1. K. Muralidhar and T. Sundararajan, "*Computational Fluid Flow and Heat Transfer"*, Narosa Publishing House, New Delhi, 2003 (For Units-I, II and partly III)
2. H. K. Versteeg and W. Malalasekera, " *An Introduction to Computational Fluid Dynamics: the Finite Volume Method"*, Second Edition, Pearson, Prentice-Hall, 2007 (For Units-III (partly), IV and V)

REFERENCE BOOKS

1. T.J. Chung, *Computational Fluid Dynamics*, Cambridge University Press, 2002
2. S.V. Patankar, *Numerical Heat Transfer and Fluid Flow*, Hemisphere Publishing Corporation, USA, 1980
3. Gautam Biswas and Somenath Mukherjee, *Computational Fluid Dynamics*, Narosa Publishing House, New Delhi, 2014
4. J.C. Tannehill, D.A. Anderson and R.H. Fletcher, *Computational Fluid Mechanics and Heat Transfer*, Second Edition, Taylor and Francis, 1997