COMPUTATIONAL FLUID DYNAMICS

II Semester

Course Code: 19ME2207

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Prerequisites: Fluid Mechanics and Heat Transfer

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

CO1: Explain momentum and energy balance equations, physical behavior, definitions of finite difference, finite volume methods, and turbulence modelling.
CO2: Apply finite difference solutions to heat transfer in slab, fin, rectangular geometry and long cylinder.
CO3: Explain ADI method and vorticity-stream function method by FDM, discretisation using finite volume method, and implementation of boundary conditions, Thomas algorithm.
CO4: Apply finite volume method to steady and transient diffusion , and convection-diffusion problems, and properties of discretisation schemes.
CO5: Explain upwind differencing for convection-diffusion problems, SIMPLE and SIMPLER algorithms.

UNIT-I **(10-Lectures)**

Governing equations: Mass, momentum and energy balance equations - Conservation form of the governing equations of fluid flow - Potential flow model, Buoyancy-driven convection and Boussinesq approximation.
Physical behavior: Classification of partial differential equations according to physical behavior as elliptic, parabolic and hyperbolic equations.
Finite difference method: First and second derivatives in finite difference form using truncated Taylor series - grid generation, discretization.
Finite volume method: concept of control volume, grid generation, discretization.
Introduction to turbulence modelling: Reynolds-averaged Navier-Stokes (RANS) equations for incompressible flow – turbulence models for RANS equations – the standard - model – Wilcox - model.

Learning outcomes: At the end of this Unit, the student will be able to

1. Explain momentum and energy balance equations, classification according to physical behaviour. (L2)
2. Define finite difference and finite volume methods. (L1)
3. Summarize various turbulence models. (L2)

UNIT-II: **(10-Lectures)**

Finite difference method: (a) One dimensional steady heat conduction through a slab/rod with uniform heat source, (b) steady state heat transfer through a rectangular/circular fin, (c) steady state two-dimensional heat conduction in rectangular geometry with uniform heat source, (d) steady radial heat conduction in a long solid cylinder, (e) Transient one-dimensional heat conduction by explicit and Crank-Nicolson’s implicit methods.
Learning outcomes: At the end of this Unit, the student will be able to

1. Apply finite difference solutions to heat transfer in slab, and fin. (L3)

2. Solve heat transfer problems in rectangular geometry and long cylinder. (L6)
3. Analyse transient heat conduction by explicit and implicit methods. (L4)

UNIT-III: **(10-Lectures)**

ADI method: Solution of transient two-dimensional heat conduction equation by Alternating Direction Implicit method.
Vorticity-Stream function method: Definitions of vorticity and stream function - problem of two-dimensional incompressible viscous flow in a lid-driven cavity by vorticity-stream function method
Finite volume method: Application to one-dimensional steady state heat conduction in a slab/rod with source term - Implementation of boundary conditions - solution using Thomas algorithm.

Learning outcomes: At the end of this Unit, the student will be able to

1. Illustrate ADI method for 2-D transient heat conduction equation. (L2)
2. Demonstrate vorticity-stream function method flow in lid driven cavity. (L2)
3. Explain finite volume method 1-D steady heat conduction in a slab and solution by Thomas algorithm. (L2)

UNIT-IV: **(10-Lectures)**

Steady diffusion: Finite volume method for heat transfer from a fin - grid generation - discretization - solution – finite volume method for two-dimensional diffusion problem
Transient diffusion: Finite volume method for one-dimensional transient heat conduction – explicit and implicit schemes.
Convection-diffusion: One-dimensional convection diffusion using central differencing scheme
Properties of discretisation schemes: Conservativeness, boundedness, transportiveness.

Learning outcomes: At the end of this Unit, the student will be able to

1. Apply finite volume method to steady and transient diffusion problems. (L3)
2. Solve convection-diffusion by central differencing scheme. (L3)
3. Discuss properties of discretization schemes. (L6)

UNIT-V: **(10-Lectures)**

Upwind differencing scheme: One-dimensional convection diffusion using upwind differencing scheme - assessment of central and upwind differencing schemes for conservativeness, boundedness and transportiveness – hybrid differencing scheme.
Pressure linked momentum balance equations: u- and v- momentum balance equations with pressure gradient in internal flow - concept of staggered grid
SIMPLE algorithm: Discretisation of momentum equations – pressure correction equation – under relaxation – flowchart for SIMPLE algorithm – SIMPLER algorithm – pressure equation – flow chart for SIMPLER algorithm.

Learning outcomes: At the end of this Unit, the student will be able to

1. Develop upwind differencing scheme to a given convection-diffusion problem. (L3)
2. Explain the concept of staggered grid for pressure linked equations. (L2)
3. Show flow charts for SIMPLE and SIMPLER algorithms. (L2)

TEXT BOOKS:

1. K. Muralidhar and T. Sundararajan, *Computational Fluid Flow and Heat Transfer*, Second Edition, Narosa Publishing House, New Delhi, 2014.
2. H. K. Versteeg and W. Malalasekera, *An Introduction to Computational Fluid Dynamics: the Finite Volume Method*, Second Edition, Pearson, Prentice-Hall, 2007

REFERENCE BOOKS:

1. J.H. Ferziger and M. Peric, *Computational methods for fluid dynamics*, 3rd Edition, Springer-Verlag Publishers, 2002.
2. S.V. Patankar, *Numerical Heat Transfer and Fluid Flow*, First Edition, Hemisphere Publishing Corporation, USA, 1980.
3. John D. Anderson, Jr., *Computational Fluid Dynamics*: *The Basics with Applications*, Second Reprint, Tata McGraw-Hill Edition, 2012.