BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE-PILANI - HYDERABAD CAMPUS

SECOND SEMESTER 2021 - 2022

(COURSE HANDOUT PART II)

Date: 09/01/2023

In addition to part-I (general handout for all courses in the time-table), this handout provides the specific details regarding the course.

Course No.: ME G515

Course Title: COMPUTATIONAL FLUID DYNAMICS

Instructor-in-charge: Mrinal K. Jagirdar

Instructors: Pardha S Gurugubelli

1. **Course Description**:

   Philosophy of computational fluid dynamics (CFD), governing equations of fluid dynamics, mathematical behavior of partial differential equations, basics of the numerics: basic aspects of discretization, grids with appropriate transformations, and simple CFD techniques, applications, numerical solutions of quasi-one-dimensional nozzle flows, numerical solution of a two-dimensional supersonic flow, incompressible couette flow, and supersonic flow over a flat plate, advanced topics in CFD.

   Computational fluid dynamics (CFD) has become an essential tool in analysis and design of thermal and fluid flow systems in wide range of applications. Few prominent areas of them include meteorology (wind, hurricanes, floods, fires), environmental hazards (air pollution, transport of contaminants), heating, ventilation and air conditioning of buildings, energy systems, electronics, processes in human body (blood flow, breathing) etc. It gives an insight into flow patterns that are difficult, expensive or impossible to study using traditional (experimental) techniques.

2. **Scope and Objective:** The primary objective of this course is to highlight the physics of the considered problem and then select the set of governing equations and boundary conditions. The course aims to provide students with a working knowledge of a variety of computational techniques that can be used for solving engineering problems.

3. **Text Books**:

   T1. **John D Anderson,** "Computational Fluid Dynamics", Tata-McGraw Hill Publisher, 1st Edition, 1995.
   T2. **K Muralidhar & T Sundararajan**, "Computational Fluid Flow and Heat Transfer", Narosa Book Distributors Pvt Ltd, 2nd Edition, 2009.
   T3. **H K Versteeg & W Malalasekara**, "Introduction to Computational Fluid Dynamics: The Finite Volume Method", Pearson Education (Indian Reprint), 2nd Edition, 2007.

   Reference Books:

   R1. **S V Patankar**, "Numerical Heat Transfer and Fluid Flow", Taylor & Francis, 1st Edition, 1980.
   R2. **R H Pletcher, J C Tannehill & D A Anderson**, "Computational Fluid Mechanics and Heat Transfer", CRC Press, 3rd Edition, 2012.

4. **Course Plan**:

Lecture Nos.	Learning Objectives	Topics to be covered	Book
1-2	Introduction to CFD; Solution to linear algebraic equations	Direct solvers (LU decomposition, tri-diagonal algorithm); Iterative solution methods (under and over relaxation); Well-conditioned and ill-conditioned	T2
3-6	Introduction to governing equations	Models of flow; Governing equations: Continuity equation, Momentum equation, Energy equation	T1
7-10	Classification of partial differential equations	Parabolic, elliptic and hyperbolic equations; Well posed and ill posed problems; Initial and boundary conditions	T1

Lecture Nos.	Learning Objectives	Topics to be covered	Book
11-13	Finite volume method	Basic rules for control volume approach; Steady and unsteady heat conduction: 1-D, Extension to 2D & 3D problems	T3
14-16	FVM based discretization of convection and diffusion equations	1D convection diffusion, Discretization schemes and their assessment, Treatment of boundary conditions	T3
17-20	Discretization of Navier-Stokes equations	Discretization of the momentum equation: Stream function-Vorticity approach and Primitive variable approach; Staggered grid and Collocated grid, SIMPLE algorithm, SIMPLER algorithm	T3
21-23	Numerical solutions of ordinary differential equations	Euler explicit/implicit methods; Predictor corrector methods; Examples of initial value and boundary value problems	T2
24-27	Grids with appropriate transformations	Transformation of equations, Metrics and Jacobians, Compressed grids, boundary fitted systems, Elliptic grid generation, Adaptive grids.	T1
28-30	Finite difference methods	Taylor's series: Finite difference formulation, 1D & 2D steady state heat transfer problems; Boundary conditions; Unsteady state heat conduction	T2
31-33	Finite difference methods	Errors associated with FDM; Explicit method; Stability criteria; Implicit method; Crank Nicolson method; ADI	T2
34-36	Turbulent flows	Basics; DNS, LES and RANS models	T3
37-39	Compressible flows	Introduction: Pressure, velocity and density coupling	T1
40-42	Special topics & Seminars	Will be announced in the class	---

5. **Evaluation Scheme**:

Evaluation Component	Duration	Weightage (%)	Date & Time	Nature of Component
Mid-semester exam	90 min	25	TBA	**CB**
Assignment	---	5	To be announced in the class	OB
Lab	---	20	Continuous	OB
Project + Seminar	---	15	To be announced in the class	OB
Comprehensive Exam	180 min	35	TBA	**CB**

6. **Chamber Consultation Hour**: To be announced in the class room.
7. **Notices**: All notices concerning this course shall be posted at **CMS**, the institute's web based course management system.
8. **Make-up Policy**: Make-up for tests needs prior permission and strictly meant only for serious hospitalization cases with proper documents.
9. **Academic Honesty and Integrity Policy:** Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

Instructor-in-charge
ME G515