BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, Pilani
Pilani Campus
AUGS/ AGSR Division

SECOND SEMESTER 2020-21
COURSE HANDOUT

Date: 16.01.2021

In addition to part I (General Handout for all courses appended to the Time table) this portion gives further specific details regarding the course.

Course No	:	**ME F485**
Course Title	:	**Numerical Fluid Flow and Heat Transfer**
Instructor-in-Charge	:	**Dr. Shyam Sunder Yadav**
Instructor(s)	:	**----**
Tutorial/Practical Instructors:		**----**

1. Course Description: This course is an introduction to the various computational techniques for simulating fluid flow and heat transfer. We focus on the Finite difference discretization technique on structured Cartesian grid, Finite volume discretization technique on unstructured grids, Numerical solution of steady and transient convection-diffusion equation, Solution techniques for compressible and incompressible Navier-Stokes equations, Various methods for solving system of linear equations, Numerical techniques for simulating turbulent flows.

2. Scope and Objective of the Course: This course is intended to develop the numerical skills for solving the equations governing fluid flow, heat & mass transfer and related transport phenomena. The students first learn how to derive the governing equation using fundamental laws of mass, momentum and energy conservation. Once the equations are derived, the student will learn how to simplify and classify the equations mathematically and how to interpret their physical and mathematical behavior. Subsequently the course focuses on the different discretization techniques for the governing equations like the finite difference and finite volume method. Finally, the students will learn different CFD techniques for compressible and incompressible flows and turbulent flows.

As part of this course, the students have to complete a CFD project using an open source flow solver. They can write their own code as well in any of the programming languages. Following solvers can be used: OpenFOAM, SU2, Gerris Flow Solver, IBAMR, preCICE library, IB2D etc. Any other open source code or Ansys Academic version can also be used for the project.

3. Text Books:

T1: Versteeg and Malajasekra: An introduction to computational fluid dynamics: The finite volume method, 2^{nd} edition, Pearson

4. Reference Books:

R1: JH Ferziger, M Peric, Computational methods for Fluid Dynamics, Springer, 2020, 4^{rd} Edition.

R2: Numerical Methods in Heat, Mass, and Momentum Transfer

https://engineering.purdue.edu/~scalo/menu/teaching/me608/ME608_Notes_Murthy.pdf

5. Course Plan:

Module No.	Lecture Session	Reference	Learning outcomes
1	CFD: Applications and Impact	T1, chapter 1	Why CFD is important? Where it has been applied? General CFD work flow procedure.
2	Derivation of Governing equations of fluid dynamics Classification and characteristics of governing equations Forms of equation for compressible flow	T1, chapter 2, R1 chapter 1	What are the equation which govern fluid dynamics? How to derive these? What is their physical significance? How to classify equations into hyperbolic, parabolic and elliptic types? Characteristics of different equation types, Forms of governing equations suitable for compressible flows
3	Introduction to Finite difference method, Finite difference schemes for model equations, Explicit and Implicit approaches Consistency, stability and convergence of numerical schemes, Numerical diffusion and dispersion, Artificial viscosity	R1 chapter 3	Introduction to Finite difference method, Finite difference schemes for model hyperbolic, parabolic and elliptic equations, Explicit and Implicit approaches, Concepts of consistency, stability and convergence, Aspects of Numerical dissipation and dispersion; Artificial viscosity
4	Solution techniques for system of linear equations	T1 chapter 5, R1 chapter 5	Solution techniques for system of linear equations, Various Direct and Iterative techniques
5	Pressure velocity coupling for incompressible flows, Need for staggered grids, Projection method for incompressible flows using Finite Difference method	Lecture notes	Solution of incompressible flow problems using Finite Difference Method, Lid driven cavity problem
6	Lax-wendroff and Maccormack scheme using Finite different method Applications of Maccormack scheme	Lecture notes	Lax-Wendroff scheme and MacCormack's scheme for compressible Navier-Stokes equations, Numerical solution of quasi-1D nozzle flow, 2D Prandtl-Meyer expansion wave

5	**Introduction to finite volume method** **FVM for diffusion equation on unstructured and structured grids** **FVM for convection-diffusion equation on structured and unstructured grids** **FVM for transient equations**	**T1 chapter 4, 5** **R2 chapter 3,4,5**	Introduction to finite volume method, Finite volume method for steady and unsteady convection, diffusion equations on structured and unstructured grids
7	**SIMPLE family of algorithms for incompressible flows on structured and unstructured grids using FVM**	**T1 chapter 6, 11** **R1 chapter 7,8,9**	Pressure correction technique for incompressible Navier Stokes equations like SIMPLE, SIMPLER, SIMPLEC, PISO algorithms for pressure velocity coupling
8	**Computational models for Turbulent flows**	**T2 chapter 3,** **R1 chapter 10**	Governing equations for Turbulent flows, RANS models, LES, DNS

6. Evaluation Scheme:

Component	**Duration**	**Weightage (%)**	**Date & Time**	**Nature of component (Close Book/ Open Book)**
Mid-Semester Test	TBA	25	As per AUGSD	Open book
Comprehensive Exam	TBA	35	As per AUGSD	Open book
Objective Quiz 1	TBA	10	TBA	Open book
Objective Quiz 2	TBA	10	TBA	Open book
CFD Project	-	20	TBA	Open resources

7. Online Consultation Hour: Will be decided in the class.

8. Notices: Personal emails will be sent

9. Make-up Policy: No makeup for any component

10. Note (if any): You should have a laptop with Ubuntu 18.04 or 20.04 installed along side Windows 10 which you will use to complete the CFD project. You have to give a live demonstration of the procedure you followed while completing the project. You have to submit a project report consisting of the following: Abstract summary, Introduction to the problem including the previous works / literature on the problem, Governing equations, Procedure followed, Results and discussions and finally, Conclusions.

Instructor-in-charge
ME F485 NFFHT