Course Number: PHYS 695

Course Title: Applied Fluid Mechanics

Instructor: Prof. Rainald Löhner

Brief Description: This course covers the application of fluid mechanics to current problems in science and industry. Heavy emphasis is placed on numerical techniques to compute and evaluate flows, i.e. techniques from Computational Fluid Dynamics. Topics covered include: conservation laws of mass, momentum, and energy; derivation of the Navier-Stokes equations; description of compressible and incompressible flows; introduction to laminar, turbulent and non-newtonian flows; and an introduction to the basic physical and mathematical foundations of computational fluid dynamics. In addition, numerical methods of finite difference and finite volume schemes are presented to solve the Navier-Stokes equations. Students will be introduced to the art of writing computer codes to solve the partial differential equations relevant to flows. An overview of mesh generation methods will be covered. The Delaunay method and the advancing front method will be discussed in detail. A series of applications of classic fluid mechanics problems will be introduced. For these real applications, the course will utilize a Computational Fluid Dynamics software package (open source or commercial), demonstrating the entire workflow of a simulation: setup, solution and visualization of flow problems.

Requirements:

- Graduate Standing or Permission of Instructor
- PHYS 620 (Continuum Mechanics) or PHYS 705 (Classical Mechanics) or Permission of Instructor

Course Objectives:

- To learn basic principles of fluid mechanics;
- To familiarize students with the derivation of numerical schemes to solve the partial differential equations describing flows, with particular emphasis on finite volume schemes;
- To learn coding, debugging and assess the accuracy of numerical schemes to solve the partial differential equations describing flows;
- To be able to use CFD packages in order to compute and evaluate complex 3-D flows in physics and engineering.

Location: Exploratory Hall, Room 1004

Time: Thursday 4:30pm

PHYS695 (Applied Fluid Mechanics): Contents

Contents

- Introduction to fundamental concepts in fluid mechanics
- Governing Equations: Conservation laws of fluid motion and boundary conditions
- Compressible and incompressible flows; laminar, turbulent and non-newtonian flows
- Finite difference methods (FDM): transient heat equation
- Tessellating the computational domain (grid generation)
- Finite volume method (FVM): integral formulation, approximation of integrals
- FVM for diffusion problems

- FVM for convection and diffusion problems
- Solution algorithm for pressure-velocity coupling in steady flows
- FVM for unsteady flows
- Implementation of boundary conditions
- Application: Shallow waters equations
- Application: Renewable energy and fluid mechanics: wind turbines

Textbooks

- P.K. Kundu, I.M. Cohen and D.R. Dowling - Fluid Mechanics, 6th Edition, Academic Press, 2015.
- H.K. Versteeg and W Malalasekera - An Introduction to Computational Fluid Dynamics: The Finite Volume Method, 2 nd Edition, Pearson Education Limited, 2007.
- R. Löhner - Applied CFD Techniques, 2 nd Edition, J. Wiley & Sons, 2008.
- R.J. Leveque - Finite Volume Methods for Hyperbolic Problems, Cambridge University Press, 2002.
- G.K. Batchelor - An Introduction to Fluid Mechanics, Cambridge University Press, reprinted 2002.
- K.A. Hoffmann and S. T. Chiang - Computational Fluid Dynamics for Engineers, Vols. 1 and 2, Engineering Education System, 1993.
- J.C. Tannehill, D. A. Anderson and R. H. Pletcher - Computational Fluid Mechanics and Heat Transfer, 2 nd Edition, Taylor & Francis, 1997.
- C. Hirsch - Numerical Computation of Internal and External Flows, Vols. 1 and 2, Wiley, 1988.

PHYS695 (Applied Fluid Mechanics): Teaching and Evaluation

Evaluation

- Mid-Term Exam
- Final Exam
- Exams Are Closed Book (Instructor Believes in Having the Basic Information Required to Operate in One's Brain, Not in the Cloud)

Projects

- Write 1-D Code for Transient Heat Equation With Source Term
- Write 1-D Code for Advanced High Resolution Compressible Euler Equations
- Write 2-D Code for Shallow Water Equations
- Projects Are Written In Class (Instructor Has Seen and Shares the Temptation of Copying Codes from the Internet)

Methods of Instruction

- Overheads, Blackboard
- Notes posted in Student-Accessible Directory