SME5802 – 2015

Introdução à Mecânica dos Fluidos Computacional
Introduction to Computational Fluid Dynamics
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1. **Principles and equations of Fluid Mechanics**: The continuum hypothesis. Definition of fluid. Eulerian and Lagrangian frames. Material derivative and transport theorem. Conservation principles. Thermodynamics. Incompressibility. Viscosity. Non-newtonian behavior. Turbulence. Reference: Chapter 1 of Wesseling. Expected: 08/18.
2. **Discretization methods at a glance**: Prototype elliptic and parabolic equation. Strong formulation, integral formulation, weak formulation. Finite differences, finite volumes, finite elements. Other discretization schemes at a glance. Reference: Chapter 3 of Wesseling. Expected: 08/25.
3. **Fully developed flow**: Laminar fully developed flow. Boundary conditions. Parallel plates, circular pipe. Pipe of arbitrary cross section. Reference: TBD. Expected: 09/01.
4. **A bit of turbulence**: Turbulent pipe flow. Moody diagram. Turbulence model. Reference: TBD. Expected: 09/15.
5. **Diffusion, convection and upwinding**: Convection-diffusion equations. Term by term discussion. Boundary layers. Incorporating reaction terms. Discretization. Upwinding in finite volumes. Reference: Chapters 4 and 5 of Wesseling. Expected: 09/22.
6. **Incompressible Navier-Stokes equations and related models**: Navier-Stokes equations. Incompressibility. Vorticity. Bernoulli's principle. Streamfunction. The pressure. Projection structure. Buoyancy effects. Boundary conditions at walls, free surfaces, capillary surfaces, etc. Integral form. Reference: TBD. Expected: 09/29.
7. **Discretization of the incompressible Navier-Stokes equations**: Collocated and staggered grids. Finite volume formulations. Solution strategies: Monolithic and segregated. Deformable domains: Arbitrary Lagrangian-Eulerian formulation. Reference: Chapters 6 and 13 of Wesseling. Expected: 10/06.
8. **Hyperbolic conservation laws**: Hyperbolic equations and systems. Rankine-Hugoniot conditions. Traffic flow. Burgers' equation. Acoustic equations. Shallow water equations. Linearization. Reference: Chapters 1, 2 and 11 of LeVeque. Chapter 8 of Wesseling. Expected: 10/20.
9. **Finite volume methods for conservation laws**: Weak solutions and general scheme. Upwinding. First order schemes. Lax-Wendroff scheme. Godunov-type schemes. Riemann solvers. Application to the acoustic equations and to the linearized shallow water equations. Reference: Harten, Lax and van Leer (SIAM Review 25:36-61 (1983), Chapter 4 and 6 of LeVeque. Expected: 10/27.
10. **Finite volume methods for nonlinear systems**: Approximation of the shallow water equations. Shocks and rarefaction waves. Reference: Chapter 15 of LeVeque. Chapter 8 of Wesseling. Expected: 11/10.

Work load: 3 hours in class, 3 reading, 6 doing exercises and small projects, per week.

Grades: Oral examinations every week, plus a couple of small project reports.

Bibliography
WESSELING. Principles of Computational Fluid Dynamics.
LEVEQUE. Finite-volume Methods for Hyperbolic Problems.
HIRSCH. Numerical computation of internal and external flows.