ME 5311: Computational Methods of Viscous Flow
Spring 2019

Class meeting: Wednesday 5–7:30 pm, UTEB 476
Instructor: Prof. George Matheou
email: matheou@uconn.edu
Office hours: Monday 1–3 pm at UTEB 384
Please email instructor for questions and meetings at other times

Description
The course is an introduction to computational fluid dynamics (CFD), including thermal transport. The course will introduce the main computational techniques and methods and analyze their properties. Strong emphasis will be given to the implementation and application of the methods.

Course objectives
• To introduce the basic techniques used to numerically solve the governing equations of incompressible fluid flow, including transport of scalar quantities, such as heat.
• To introduce the basic methods for analysis of the numerical approximations, e.g., determination of the order of accuracy, resolving power, stability properties, etc.
• Students will be able to understand the link between the properties of the numerical approximations and the quality/features of the resulting numerical solution.
• Understand the practical aspects of the application of the numerical methods and develop an appreciation the tradeoffs, e.g., accuracy, efficiency, need to control different types of model error.
• Students will be able to use the acquired understanding of the methods as a basis for the development of their own methods and solution techniques, including the utilization of CFD software packages, and be able to assess the quality of numerical solutions in general.

Prerequisites
Good working knowledge of engineering mathematics, including calculus, linear algebra and differential equations. Some familiarity with fluid mechanics, including the governing equations of fluid motion and heat transfer. Basic programming skills.

Grading
The final grade is composed of 50% homework and 50% Term Project. Final letter grades will generally follow 90–100% for an A, 80–89.9% for a B, etc. Plusses and minuses will extend up and down 2 percentage points at each major breakpoint, e.g., A- = 90–91.9 and B+ = 88–89.9, etc. The instructor may adjust this scale in the final analysis, but in no case, will scores higher than those listed be required to achieve the stated letter grades.

Homework
There will be seven homework assignments during the first half of the semester (before the Spring break) and one longer-term assignments, i.e., “term project,” in the second half of the semester. Because homework solutions will be discussed in class, no late homework will be accepted, i.e., it will be graded 0. Assignments will be graded within a week. Feedback will be included in the graded assignments.

Programming and computing resources
Students are expected to write and execute computer code in a programming language of their choice, including Matlab. Most of the assignments will include implementation (i.e., programming), quantitative
analysis, and plotting of results. Students are expected to implement their own solution methods and use of specialized functions or routines, e.g., Matlab functions to invert matrices, are not allowed.

Assignment solutions will be posted in Matlab.

If you plan to use a programming language other than a commonly used one (e.g., use any language other than C, C++, Fortran, or Matlab) please contact the instructor. Also, if you do not have access to programming and computing resources, please contact the instructor to make the appropriate arrangements.

**Academic Honesty**

Students are encouraged to discuss assignments with each other, but no copying is allowed from any source. Please turn in your own work, based on your own effort and understanding. Students are expected to abide by UConn’s policy on academic integrity:


**Academic Accommodations**

The University of Connecticut is committed to protecting the rights of individuals with disabilities and assuring that the learning environment is accessible. If you anticipate or experience physical or academic barriers based on disability or pregnancy, please let me know immediately so that we can discuss options. Students who require accommodations should contact the Center for Students with Disabilities (CSD), Wilbur Cross Building Room 204, (860) 486-2020 or email csd@uconn.edu and follow the process for requesting accommodations.

**Textbooks**


**Further References**


P00      Pope, S. B., 2000, Turbulent Flows, Cambridge

QSS00    Quarteroni, A., R. Sacco and F. Saleri, 2000: Numerical Mathematics, Springer

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Topics</th>
<th>References</th>
<th>Assignment</th>
</tr>
</thead>
</table>
| 1 | January 23 | • Fundamentals  
• Error norms  
• Model equations: one-dimensional convection and diffusion equations | LPZ04 Ch. 1, 2, 3  
FP13 Ch. 1, 2 | Monte Carlo simulation, convergence |
| 2 | January 30 | • Interpolation and polynomial approximations  
• Spectral approximations  
• Finite difference approximations | QSS00 Ch. 8  
LPZ04 Ch. 2, 3 | Time integration, Lorenz equations, error norms, Lyapunov exponent |
| 3 | February 6 | • Modified equations  
• Finite difference approximations  
• Numerical dispersion, dissipation, and implicit filters | LPZ04 Ch. 2, 3, 11  
S04 Ch. 5 | First derivative approximations, one-dimensional advection equation |
| 4 | February 13 | • Solution of linear systems | FP13 Ch. 5 | Convection–diffusion problem |
| 5 | February 20 | • Heat transfer  
• Poisson equation | FP13 Ch. 3  
LPZ04 Ch. 3 | Numerical solution of Poisson equation |
| 6 | February 27 | • Grids and complex geometries  
• Finite volume methods  
• Verification and validation | LPZ04 Ch. 5  
FP13 Ch. 8 | Numerical solution of Poisson equation |
| 7 | March 6 | • Analysis of time marching methods | LPZ04 Ch. 6, 7 | Runge–Kutta stability analysis |
| 8 | March 13 | • Stability analysis  
• Review of weeks 1–8 | LPZ04 Ch. 8 | No assignment! |
| * | Spring Recess | | | |
| 9 | March 27 | • Navier–Stokes I  
• Fundamentals  
• Boundary conditions  
• The role of pressure  
• Conservation properties | FP13 Ch. 6, 7 | Project Part 1 assigned (due in two weeks) |
| 10 | April 3 | • Navier–Stokes II  
• Solution techniques | FP13 Ch. 6, 7 | |
| 11 | April 10 | • Navier–Stokes III  
• Spectral approximations | CHQZ06 | Project Part 2 assigned (Part 1 due) |
| 12 | April 17 | • Navier–Stokes IV  
• Multi-physics topics  
• Special numerical methods | FP13 Ch. 10, 11  
CHQZ06 | |
| 13 | April 24 | Introduction to computation of turbulent flows | FP13 Ch. 9  
P00 | Project Part 3 assigned (Part 2 due) |
| 14 | May 1 | Introduction to parallel computing techniques | CJV08, GLS99, GLT99 | |