ME 5311 – Computational Fluid Dynamics

GENERAL INFORMATION - SPRING 2026

CLASS MEETING: W: 5:00 p.m.–7:30 p.m., PWEB 476

INSTRUCTOR: Dr. Xinyu Zhao

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OFFICE HOURS: by appointment in person or through Teams

TEXT: *Turbulent flows,* by S. B. Pope, Cambridge University Press, 2000
A First Course in Turbulence, H. Tennekes and J. Lumleys, MIT Press, 1972
An introduction to Computational Fluid Dynamics: The Finite Volume Method, 2nd Edition, by H. K. Versteeg and W. Malalasekera, Pearson Education Limited, Harlow, 2007.

GRADE DETERMINATION:

Video quizzes/individual assignments	20%
Projects (three projects)	60%
Term paper&presentation	20%
Total	100%

Final letter grades will generally follow 90-100% for an A, 80-89.9% for a B, etc. Plusses & minuses will extend up and down 2 percentage points at each major break point, 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.

VIDEO QUIZZES: Video lectures of a particular topic will be provided by the Friday ahead of the Lecture date. The students are expected to watch the lectures and complete the video quizzes/assignments before the class. The video lectures are counted towards lecture time. **Video quizzes submitted after the designated class time will be graded 0.**

PROJECTS: There will be three projects with equal credits as detailed in the syllabus. Each student needs to write their own programs. Grading will be based on the project reports and the coding.

TERM PAPER&PRESENTATION: Preparation of 10-page technical report on a topic related to numerical analysis selected by the student in consultation with the instructor. The report includes a literature review of the selected topic, and a simple coding example of the reviewed topic. At the end of the first six weeks of the course, the student prepares a two-page interim summary with references for distribution to the class for review. The final oral presentation is in the form of a recorded presentation (15 mins) shared with the entire class. The last week of class is dedicated to a Q&A session for each presentation in person. Designated students will ask questions following the oral presentations to stimulate class discussion. Other students are also encouraged to ask their questions. In-class questions and discussions are also highly encouraged.

COURSE OBJECTIVES AND OUTCOMES: The course is an introduction to the fundamentals of 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. The course is not training on how to use commercial CFD software, and we do not use or discuss such software in the class. The course serves the needs of students that conduct CFD-related research or students who want to develop an in-depth understanding of the subject to critically assess the results CFD software.

Additionally, this course focuses on the different methods for turbulence modeling. The target is that the student will understand the details of different turbulence models, and their applications in thermal fluids. The course is also aiming at improving the students' technical writing and oral presentation skills. A significant programming component is involved in this course, and some guided self-learning on the numerical details is another important aspect.

ACADEMIC HONESTY: The work on the homeworks and projects is to be yours alone. Failure to abide by this rule, or the commission of any other deliberately dishonest act, may result in failure of the course. Unauthorized use of a solutions manual and use of students' assignments or solutions from previous semesters are deliberately dishonest acts. For University & College policies on academic integrity see https://policy.uconn.edu/2023/07/11/academic-scholarly-and-professional-integrity-and-misconduct-aspim-policy-on/.

E-MAIL: Students are encouraged to ask questions, etc., via e-mail or through the discussion board on HuskyCT, which is a good way to share information with the class.

Lecture		Topics	Assignment
1	January 21	• Introduction to CFD • Basic computing • Finite-volume versus finite-difference methods	
2	January 28	• Derivation of N-S equations (video) • Boundary layer approximation • Classification of PDEs	Video Quiz
3	February 4	• Numerical differentiation and order of accuracy • Solution procedure of CFD • Verification and validation	Project 1 assigned
4	February 11	• Stability versus accuracy of a convection-diffusion problem • Dispersion and Dissipation • Solution of linear system	Video Quiz
5	February 18	• SIMPLE algorithm (video) • Other solution algorithms • Boundary treatment	Project 1 due Video Quiz
6	February 25	• Basic Scaling of Turbulence • Basic Kolmogorov theory (spectral subranges, k-5/3, etc.) • The basic three scales of turbulence: large-eddy, Taylor, Kolmogorov	2-page interim report due Video Quiz
7	March 4	• Decomposition of fluctuating turbulence variables • Physical space: means + fluctuations, correlations, moments, pdf • Scale space: Fourier decomposition	Project 2 assigned Video Quiz
8	March 11	• Reynolds average vs. filtering • Equation for mean/filtered velocity • Equations for Reynolds stress, component kinetic energy, and turbulent kinetic energy	Video Quiz
Spring Recess (Mar 15- Mar 22, 2026)			
9	March 25	• Algebraic closure schemes • Prandtl's Mixing Length • Baldwin-Lomax Model	Video Quiz
10	April 1	• One and two equation models • Modeling the turbulent kinetic energy and viscous dissipation rate equations • k-epsilon and k-w model	Project 2 due Project 3 assigned Video Quiz
11	April 8	• Reynolds stress model • Statistical methods in turbulence modeling	Video Quiz
12	April 15	• Introduction to direct numerical simulations • Introduction to parallel computing	Video Quiz
13	April 22	• Data postprocessing, visualization, and analysis	Project 3 due Term paper presentation due
14	April 29	Term paper Q&A	Term paper due

Additional reference books:

1. Suhas V. Patankar. Numerical heat transfer and fluid flow.
2. J. D. Anderson, JR. Computational Fluid Dynamics: The basics with applications. McGraw-Hill Companies, Inc. 2005
3. T. Poinsot and D. Veynante. Theoretical and Numerical Combustion, 2nd Ed. R. T. Edwards, Inc. 2005
4. R. L. Panton. Incompressible flow, 2nd Ed. John Wiley & Sons, Inc. 1996

Online resources:

Thermochemistry: http://webbook.nist.gov/chemistry/fluid
FORTRAN: http://www.personal.psu.edu/faculty/j/h/jhm/ME540/index.html Numerical combustioin: http://elearning.cerfacs.fr
Fluent learning module: https://confluence.cornell.edu/display/SIMULATION/FLUENT+Learning+Modules
12 steps to Navier-Stokes: https://lorenabarba.com/blog/cfd-python-12-steps-to-navier-stokes/