Unique Number: 16625 **Where:** ECJ 1.324 **When:** Tuesday and Thursday, 9:30-11:00 am

Instructor: Spyros A. Kinnas
Office: ECJ 8.610
Phone: 475-7969
E_mail: *kinnas@mail.utexas.edu*

Course web site: *https://cavity.caee.utexas.edu/kinnas/COURSES/cfd.html*

Office hours: (ONLINE) Monday 2-3pm and Wednesday 11am-12 noon; You may also email questions to: *kinnas@mail.utexas.edu*

Objectives: Cover the *fundamentals* of computational methods and their *application* to fluid mechanics problems in Civil, Environmental, or other types of Engineering. More emphasis will be given to *incompressible* fluids, and finite volume methods.

Philosophy: Understand the basics through theory, examples, and *hands-on experience* by coding a method from scratch, rather than using an *of-the-shelf* commercial CFD package.

Prerequisites: A graduate course in fluid mechanics (e.g. CE380S). Graduate standing or consent of instructor.

Computer: Knowledge of any programming language (Fortran, C, Matlab, Python, etc.) is expected. Most homework assignments and the term project will require considerable computer programming.

Textbook: *Computational Methods for Fluid Dynamics* by J.H. Ferziger, M. Perić, and R. L. Street; Springer, 4th edition, 2020.

Supplemental Class-notes: To be posted on the class web-site regularly.

Grading: Homework: 60%; 1 Exam: =X%; Term Project: (40-X) % with 15<X<25. The value of X which results into the highest total grade will be used. Any problems, personal or other, affecting grades should be brought to the instructor's attention. *Plus/minus grades* will be assigned for the final grade.

Homework policy: Original assignments must be submitted by each student. Students must submit their solutions **by 11:59pm (via Canvas) on the assigned due date**. Most of the problems will require considerable computer programming. The utilized discretization and the corresponding results should be presented on *computer generated graphs*. The homework has to be *neat* and *orderly*.

Term Project policy: Each student should provide, **by November 8**, after consultation with the lecturer and their advisor, a two-page proposal for their term project. This project should address an application of a numerical method on a *realistic* fluid mechanics problem. It can be an integral part of the student's thesis or research. Considerable effort must be devoted in the formulation of the problem, numerical implementation, programming, interpretation of the results, convergence studies of the results of the proposed method, and comparisons with analytical solutions (for simplified geometries or conditions) or data from existing experiments (if available). Each of the students must submit a *comprehensive report* (typed) on his or her project.

Examinations/Reports:

- Final Exam, Monday, December 13, 9-12
- Term Project report due on Tuesday, December 14, at 5:00 pm

Failure to attend the exam will lead to a mark of zero. The only exception will be for documented medical emergencies.

Evaluation: An evaluation of the course and instructor will be conducted at the end of the semester using the approved UT Course/Instructor evaluation forms.

Academic Dishonesty Policy: Sharing of Course Materials is Prohibited: No materials used in this class, including, but not limited to, lecture hand-outs, videos, assessments (quizzes, exams, papers, projects, homework assignments), in-class materials, review sheets, and additional problem sets, may be shared online or with anyone outside of the class unless you have my explicit, written permission. Unauthorized sharing of materials promotes cheating. It is a violation of the University's Student Honor Code and an act of academic dishonesty. I am well aware of the sites used for sharing materials, and any materials found online that are associated with you, or any suspected unauthorized sharing of materials, will be reported to Student Conduct and Academic Integrity in the Office of the Dean of Students. These reports can result in sanctions, including failure in the course.

For more information on Academic Dishonesty, UT Honor Code (or statement of ethics), and an explanation of what constitutes plagiarism, see the Dean of students' website and University General Information Catalog at: http://deanofstudents.utexas.edu/conduct/ and http://catalog.utexas.edu/general-information/appendices/appendix-c/student-discipline-and-conduct/

COVID Caveats: Important Safety Information: COVID-19 Update: While we will post information related to the contemporary situation on campus, you are encouraged to stay up-to-date on the latest news as related to the student experience: https://protect.utexas.edu/

Attendance: Not required, but highly recommended!

Dropping policy:

Graduate Students - drop policy for long sessions: From the 1st through the 4th class day, graduate students can drop a course via the web and receive a refund. During the 5th through 12th class day, graduate students must initiate drops in the department that offers the course and receive a refund. After the 12th class day, no refund is given. **No class can be added after the 12th class day**. From the 13th through the 20th class day, an automatic Q is assigned with approval from the Graduate Advisor and the Graduate Dean. From the 21st class day through the last class day, graduate students can drop a class with permission from the instructor, Graduate Advisor, and the Graduate Dean. **Students with 20-hr/week GRA/TA appointment or a fellowship may not drop below 9 hours.**

Undergraduate Students: From the 1st through the 12th class day (4th class day in the summer sessions), an undergraduate student can drop a course via the web and receive a refund, if eligible. From the 13th (5th class day in the summer sessions) through the university's academic drop deadline, a student may Q drop a course with approval from the Dean, and departmental advisor.

Emergency Preparedness Plan: Emergency Preparedness means being ready. It takes an effort by all of us to create and sustain an effective emergency preparedness system. You are your own best first responder. Please use https://preparedness.utexas.edu/welcome-emergency-preparedness as a resource to better understand emergency preparedness at the university, and how you can become part of and contribute to the preparedness community. To monitor emergency communications for specific instructions, go to utexas.edu/emergency. To report an issue (none emergency) call 512-471-4441. In case of emergency, call 911.

IMPORTANT NOTE: The University of Texas at Austin provides, upon request, appropriate academic accommodations for qualified students with disabilities. For more information, contact the Division of Diversity and Community Engagement, Services for Students with Disabilities, 512-471-6259 (Videophone: 512-410-6644) or http://diversity.utexas.edu/disability

All other university policies not explicitly included on this syllabus can be found on the General Information Catalog: http://catalog.utexas.edu/general-information/

TOPICS TO BE COVERED:

- Review of fluid mechanics: Navier-Stokes equations, Euler equations, potential flow, and the advection-diffusion equation. Review of related calculus: physical meaning of gradient of a scalar, substantial derivative, and vorticity. Navier-Stokes equations in common orthogonal curvilinear coordinate systems, and in rotating systems. This course will primarily deal with INCOMPRESSIBLE flows (i.e. water or air at low Mach numbers) and one contaminant or one species dispersed in the main fluid.

- Finite difference methods: Order of approximation of the differential equation and of the boundary conditions, uniform and non-uniform grids, truncation error and discretization error, convergence rate, application to the 1-D advection-diffusion equation, and tridiagonal matrix algorithm.

- Treatment of unsteady terms in finite difference and finite volume methods: explicit and implicit methods; two-level, predictor-corrector, multi-level, and Runge-Kutta methods; stability (heuristic and von-Neumann), Courant number, treatment of convective terms (Up-wind method, Lax method, Lax-Wendroff method, and Leapfrog method), dissipative and dispersive schemes.

- Finite volume methods: formulation, cell and node-based schemes, treatment of convective and diffusive fluxes, and of source terms, approximation of quantities at the faces of a cell (upwind, linear interpolation, QUICK scheme). Application to the solution of advection-diffusion equation in 2-D.

- Application of finite volume methods to the solution of the Euler equations and the Navier-Stokes equations. The Poisson equation for the pressure, collocated and staggered grid arrangements. Pressure-correction methods (SIMPLE/C/R, PISO). Artificial compressibility methods. Methods for the solution of resulting linear and non-linear system of equations.

- Numerical modeling of turbulence (Reynolds-Averaged approach)

- Gridding (structured, unstructured, multi-block, overlapping grids)

- Advanced topics (if time allows): free-surface flows; cavitating or multi-phase flows; Large Eddy Simulation (LES); Direct Numerical (Navier-Stokes) Simulations (DNS).