Introduction to Computational Fluid Dynamics

AME 535b, 3 Units, Spring 2025

Lecture 2:00-3:20, TTh, DMC 155 and online

Instructor	**Prof. J.A. Domaradzki, OHE 412D**, jad@usc.edu; (213) 740-5357
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Instructor Office Hours	TBD
TA	TBD
TA Office Hours	TBD

Course Objectives:

The goal of the course is to provide a description of advanced techniques which proved successful for specific flows encountered in aerospace and mechanical engineering and are presently used in industrial and research CFD codes. This includes both numerical methods as well as turbulence modeling techniques. The students should become proficient in designing and modifying computer programs and interpreting physical information generated by these programs. Specific topics in the syllabus can be modified based on input from students in class. The required background is knowledge of fundamental techniques used to discretize and solve partial differential equations describing diffusion and advection processes in one and two dimensions. Such a background is provided, for instance, by the AME 535a course.

Recommended Preparation:

AME 526 (or an equivalent course in partial differential equations) and AME 535a or an equivalent course in elementary CFD. The numerical programs written in Matlab will be provided as part of the coarse materials. Therefore, working knowledge of Matlab is required to complete many homework assignments. Otherwise, students may need to implement the algorithms from scratch in a computer language of their choice.

Lecture Schedule:

Week	Dates	Topics
1		Inviscid compressible flow; 1-D Euler equations; shocks; artificial viscosity.
2		Flux Corrected Transport method; Total Variation Diminishing schemes; Essentially Non-Oscillatory schemes.
3		Incompressible flows; artificial compressibility method.
4		Staggered grids; Marker and Cell method.
5		Projection methods; SIMPLE-type formulations.
6		High order compact finite difference methods.
7		High order spectral methods.
8		Generalized curvilinear coordinates
9		Numerical implementation of curvilinear coordinates; application to Laplace equation.
10		Introduction to the physics of turbulence; Reynolds equations; Kolmogorov theory.
11		Numerical simulations of turbulent flows; closure problem; turbulent/eddy viscosity concept.
12		Algebraic and mixing length models. Turbulent kinetic energy equation.
13		One and two-equation turbulence models (k-epsilon and k-omega).
14		Large eddy simulation methodology.
15		Subgrid scale models for LES.
	May 8	Final Exam

Course Materials:

Handouts, notes, and programs will be posted on the class website.

The required textbook

- C.A.J. Fletcher, Computational Techniques for Fluid Dynamics 2, Springer-Verlag.

It is available through a publisher's website

https://link.springer.com/book/10.1007/978-3-642-58239-4

where it can be purchased as eBook or accessed for free through USC. The best way is to Install the LibKey Nomad browser extension

https://libguides.usc.edu/libkey

After LibKey Nomad is installed, you may use directly the publisher URL and after a link to full-text is clicked a "View E-Book" button will appear which will take you to web page where the textbook can be downloaded. Access through USC directly may be sometimes confusing because a search function is less robust. You should login to USC libraries https://libraries.usc.edu/ (note you have to sign in with your USC credentials in the top right corner) and type "C.A.J. Fletcher, Computational Techniques for Fluid Dynamics, Vol. I" in the search box. That procedure will take you to the textbook and several related books, including Vol. II and the solution manual. Finally, you may try to find it through many textbook websites. Start with a search word `textbooks' in Google.

Additional textbooks in CFD (not required):

- J.H. Ferziger and M. Peric, Computational Methods for Fluid Dynamics, Springer-Verlag.
- R. Peyret and T.D. Taylor, Computational Methods for Fluid Flow, Springer-Verlag.
- J.C. Tannehill, D.A. Anderson, and R.H. Pletcher, Computational Fluid Mechanics and Heat Transfer, Taylor & Francis.
- J. Tu, G.H. Yeoh, and C. Liu, Computational Fluid Dynamics, A Practical Approach, Elsevier.

Grading:

- 20% Homework (normally assigned each week).
- 40% Midterm (take home programming project, focused on numerical techniques).
- 40% Final (oral, focused on turbulence modeling).

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Support Systems:

A number of USC's schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the *American Language Institute* http://dornsife.usc.edu/ali, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs* http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information http://emergency.usc.edu* will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.

Student Counseling Services (SCS) – (213) 740-7711 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.
engemannshc.usc.edu/counseling

National Suicide Prevention Lifeline – 1 (800) 273-8255
Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. www.suicidepreventionlifeline.org

Relationship and Sexual Violence Prevention Services (RSVP) – (213) 740-4900 – 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender-based harm. engemannshc.usc.edu/rsvp

Sexual Assault Resource Center
For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: sarc.usc.edu

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086
Works with faculty, staff, visitors, applicants, and students around issues of protected class. equity.usc.edu

Bias Assessment Response and Support
Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. studentaffairs.usc.edu/bias-assessment-response-support

The Office of Disability Services and Programs
Provides certification for students with disabilities and helps arrange relevant accommodations. dsp.usc.edu
Student Support and Advocacy – (213) 821-4710
Assists students and families in resolving complex issues adversely affecting their success as a student: personal, financial, and academic. studentaffairs.usc.edu/ssa

Diversity at USC
Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. diversity.usc.edu

USC Emergency Information
Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. emergency.usc.edu

USC Department of Public Safety – UPC: (213) 740-4321 – HSC: (323) 442-1000 – 24-hour emergency or to report a crime.
Provides overall safety to USC community. dps.usc.edu

Page last updated: November 22, 2024.
Weekly information will be updated without notice. Change in policies, important dates, and project content will be announced in class.