CAE 405/505: Applications of Computational Fluid Dynamics in Engineering
MMAE 517: Computational Fluid Dynamics

Spring 2024
3 credit hours

Computational Fluid Dynamics
Illinois Institute of Technology
Department of Civil, Architectural and Environmental Engineering

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Course Unique Number(s)
CAE 405 Section 01: 53109 (undergraduate) – In class
CAE 505 Section 01: 53112 (graduate) – In class
CAE 505 Section 02: 53113 (graduate) – Online
MMAE 517 Section 01: 53131 (graduate) – In class

Classroom, Meeting Time, and Instructional Method
SB 112J, Thursdays 10-12:40

Course Website
All content will be provided on Blackboard

Prerequisites
Instructor's permit required. Students are expected to have had at least an undergraduate fluid mechanics and/or heat transfer course, math through differential equations, and numerical analysis.

Instructor
Mohammad Heidarinejad, Ph.D., P.E. Assistant Professor, Architectural Engineering
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Teaching Assistants
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Saman Haratian, PhD student in Architectural Engineering
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Office Hours
Instructor: Wednesdays 8-10 am. I have an open door policy. Please feel free to stop by when you see my office door is open. Or, you can email me to schedule an appointment.

TA (Saeed Farhoodi): Mondays from 2 to 4 pm.
TA (Saman Haratian): Wednesdays from11am-1pm.

Also, if you need to see TAs outside of the office hours, please email them to schedule an appointment.

Course Catalog Description
This course is being cross listed between the CAE and MMAE courses:

CAE 405/505: The course introduces concepts of computational fluid dynamics (CFD) and focuses on engineering applications of CFD. Students will learn how to use CFD tools to model internal and external flows in a wide range of architectural, chemical, civil, and mechanical engineering applications. Projects offer students flexibility in selecting their applications. Example semester long projects include design of room air distribution systems, indoor and outdoor air quality, natural ventilation, heat transfer coefficient calculations, pipe flow, rotating reference frame, and more.

MMAE 517: Classification of partial differential equations. Finite-difference methods. Numerical solution techniques including direct, iterative, and multigrid methods for general elliptic and parabolic differential equations. Numerical algorithms for solution of the Navier-Stokes equations in the primitive-variables and vorticity-stream function formulations. Grids and grid generation. Numerical modeling of turbulent flows. Additional Prerequisite: An undergraduate course in numerical methods.

Instructor's Course Objectives and Learning Outcomes
To introduce students to both theory, fundamentals, and hands-on applications of computational fluid dynamics (CFD) to meet the requirements of both courses. The course starts with emphasizing on the fundamentals and after the midterm exam, the fundamentals will be applied to an engineering application.

By taking this course, CAE 405 students will be able to:

1. Understand numerical solutions that arise in engineering applications, especially heat transfer and fluid mechanics (up to five independent variables, including spatial coordinates, time, and species)
2. Learn underlying equations of the finite volume method and pressure-based methods
3. Deploy the fundamentals of CFD to engineering applications using a computer software package
4. Prepare and run CFD models for the engineering problems using computer software packages
5. Post process CFD results using computer software packages and prepare technical reports

By taking this course, CAE 505 and MMAE 517 students will be able to:

1. Understand numerical solutions that arise in engineering applications, especially heat transfer and fluid mechanics (up to five independent variables, including spatial coordinates, time, and species)
2. Learn underlying equations of the finite volume method and pressure-based methods
3. Deploy the fundamentals of CFD to simple engineering applications using programming languages
4. Deploy the fundamentals of CFD to engineering applications using a computer software package
5. Prepare and run CFD models for the engineering problems using computer software packages
6. Post process CFD results using computer software packages and prepare technical reports

Textbook
Versteeg, H.K. and Malalasekera, W. An introduction to computational fluid dynamics: The finite volume method, 2nd edition, 2010, Pearson.

References (optional; will be given handouts when necessary)
I will rely on several materials in this course. These materials are entirely optional for the student; handouts will be given when necessary, so that no one is required to purchase these items.

Anderson, J., Computational Fluid Dynamics, 1st Edition, McGraw-Hill, 1995.

Ferziger, J.H., Perić, M., Street R.L., Computational Methods for Fluid Dynamics 4th edition, 2020, Springer.

Hirsch, C., Numerical Computation of Internal and External Flows: The Fundamentals of Computational Fluid Dynamics. Vol 1, and 2, Butterworth-Heinemann, 2007.

Hoffmann, S. Chiang, K., Computational Fluid Dynamics (Vol. 1), 4th Edition, Engineering Education System, 2000.

Khalol, I. and Lakkis, I., Computational Fluid Dynamics, 1st Edition, McGraw Hill, 2023.

Lawrence, K.L., Ansys Tutorial Release 2023: structural & thermal analysis using the Ansys mechanical APDL release 2023 environment, SDC Publications, 2023.

Moukalled and Darwish, The Finite Volume Method in Computational Fluid Dynamics: An Advanced Introduction with OpenFOAM® and Matlab, Springer, 2016.

Patankar, S.V., Numerical heat transfer and fluid flow (computational methods in mechanics & thermal sciences) 1st edition, 1980.

Rodriguez, S., Applied Computational Fluid Dynamics and Turbulence Modeling., Springer, 2019.

Tu, J., Yeoh, G.H., Liu, C., Tao, Y., Computational Fluid Dynamics: A practical approach, 4th Edition, Butterworth-Heinemann, Elsevier, 2024.

Matsson, J.E., An introduction to Ansys Fluent, 2022, SDC Publications, 2022.

Homework Assignments
There will be a total of 5 homework assignments. Homework sets will be assigned based on lecture coverages. The homework will involve hand calculations, development of spreadsheets, creating models, coding, and/or learning the fundamentals and data analysis. You must work on the homework assignments individually. Graduate students and/or MMAE 517 students may have additional questions to work on.

Simple Course Project
To transition between the fundamentals and the application, there will be a mini project focused on modeling one of the CFD benchmarks using the software application. Graduate students and/or MMAE 517 students may have additional questions to work on.

Advanced Course Individual Project
The course individual project focuses on application of CFD in engineering. The instructor will provide a range of engineering topics with initial references that students can select in coordination with the instructor. However, the instructor also allows PhD students to pick topics relevant to

their research or interested topics. For the PhD students working on their desired topic, a proposal should be submitted to the instructor at least two weeks in advance to the project overview lecture with the topic introduction, reason for the selection of the topic, and also initial references to validate the CFD results. This individual project has several deliverables described in the project assignment document. Each student is required to present the individual report during and at the end of the semester. Graduate students will complete additional sections of course individual project. A short video of the project overview should be recorded that will be uploaded on the YouTube channel. For the final presentations, the instructor will invite external guest reviewers.

Late Homework Assignment and Report Policy

Homework assignments and project reports are due at the midnight on the day that it is due. Homework assignments and project reports will receive an absolute 5-point deduction for every day that it is late.

Exam

There will be one open note midterm exam focused on the fundamental concepts learned in the course. Each student is responsible for working on exam individually. Graduate students and/or MMAE 517 students may have additional questions to work on.

Grading

For all students, course grades will be determined by the total number of points accumulated through assignments, exams, and course project. The percentage of total points required for various letter grades is also given.

Grading	Quantity	% of Total for Each	% of Total
Assignments	5	4	20
Midterm Exam	1	30	30
Simple Project	1	7	7
Main Project Overview Video	1	4	4
Main Project Presentation	1	13	13
Project Report	1	26	26

CAE 405:

Grading scale	A	B	C	D	E
Undergraduate	90% and up	80.0-89.9%	70.0-79.9%	60.0-69.9%	<60.0%

CAE 505/MMAE 517:

Grading scale	A	B	C	E
Graduate	90% and up	80.0-89.9%	70.0-79.9%	<70.0%

Bonus Activities

Each semester students usually ask for bonus points. Bonus points can account for up to an extra 5 points. Students should consult with the instructor before starting to work on this bonus activity.

Attendance

All students are expected to attend classes regularly. Excessive absences may be grounds for a failing grade. Students should familiar themselves with the attendance Illinois Tech's attendance policy here: http://bulletin.iit.edu/undergraduate/academic-policies-procedures/registration/

Personal Problems
If you have illness or personal problems that will affect your performance during the course of the semester, please let me know as soon as possible. "After the fact" provides little protection unless there are extreme circumstances. Contact the instructors by phone or e-mail at any time.

Students with Disabilities
Reasonable accommodations will be made for students with documented disabilities. In order to receive accommodations, students must obtain a letter of accommodation from the Center for Disability Resources. The Center for Disability Resources (CDR) is located in the IIT Tower, telephone (312) 567-5744 or email: disabilities@iit.edu.

Academic Honesty
It is your responsibility to be familiar with IIT's Code of Academic Honesty. The Code of Academic Honesty can be found online:
https://web.iit.edu/student-affairs/handbook/fine-print/code-academic-honesty

You must submit your own work for homework. You are encouraged to discuss and even work with other students on homework (unless explicitly told otherwise), but material that is submitted must be your own work. For group project assignments, each group is to submit their own work. For a first violation of the IIT Code of Academic Honesty for a homework or project, the homework will receive a grade of zero for all involved students and the students will be reported to the Designated Dean for Academic Discipline (DDAD). For a first violation of the Code of Academic Honesty for a major project or an examination, the student will receive a failing grade for the course and the student will be reported to the DDAD. For a second violation, the student will receive also failing grade for the course and be reported to the DDAD.

Illinois Tech's Sexual Harassment and Discrimination Information
Sexual harassment, sexual misconduct, and gender discrimination by any member of the Illinois Tech community is prohibited. This includes harassment among students, staff, or faculty. Sexual harassment by a faculty member or teaching assistant of a student over whom they have authority or by a supervisor of a member of the faculty or staff is particularly serious. Such conduct may easily create an intimidating, hostile, or offensive environment.

Illinois Tech encourages anyone experiencing sexual harassment or sexual misconduct to speak with the Title IX Office for information on the resolution process and support options.

You can file a complaint electronically at iit.edu/incidentreport, which may be completed anonymously. You may also file a complaint in-person by contacting the Title IX Coordinator, Virginia Foster at 312.567.5725/ foster@iit.edu or the Deputy Title IX Coordinator 312. 567.5726/ eespeland@iit.edu.

If you are not ready to file a formal complaint but wish to learn about your rights and options, you may contact Illinois Tech's Confidential Advisor service at 773.907.1062. You can also contact a licensed practitioner in Illinois Tech's Student Health and Wellness Center at 312.567.7550.

For a comprehensive list of resources regarding counseling services, medical assistance, legal assistance and visa and immigration services, you can visit the Title IX Office's website at https://web.iit.edu/hea/resources.

Course Topics and Tentative Schedule (Subject to Change)

Week	Date	Topics	Due Date
1	01/11/24	*Fundamentals:* Introduction to the course and overview, airflow modeling, case studies, tensor notations, classification of PDEs, and conservation equations	
2	01/18/24	*Fundamentals:* Conservation equations	
3	01/25/24	*Fundamentals:* Introduction to turbulence modeling	Assignment #1
4	02/01/24	*Fundamentals:* Finite difference method for time independents problems	Assignment #2
5	02/08/24	*Fundamentals:* Finite volumes for time-independent problems (1)	
6	02/15/24	*Fundamentals:* Finite volumes for time-independent problems (2)	Assignment #3
7	02/22/24	*Fundamentals:* Finite volumes for time-independent problems (3) and intro to solving linear systems	Assignment #4
8	02/29/24	*Fundamentals:* Solving linear systems	Assignment #5
9	03/07/24	*Midterm Exam* *Guest speaker:* Dantec Dynamics, Inc.	
10	03/14/24	*Spring Break*	
11	03/21/24	*Application:* CFD application training and intro to Ansys Fluent Intro to CFD pre-processing focused on mesh, boundary conditions, initial conditions, wall effects, and models, CFD post-processing focused on data outputs, visualization, and data extraction. *Project Overview*	
12	03/28/24	*Application:* Validation and verification for CFD simulations Demonstration of creating mesh for a bluff body (1)	Mini Project
13	04/04/24	Student interim project presentations (max 3 minutes per student) *Application:* Demonstration of creating mesh for a bluff body (2)	Interim project presentations
14	04/11/24	*Guest speakers:* Ansys Intro to writing user defined functions (UDFs) and expressions	
15	04/18/24	Student interim project presentations (max 3 minutes per student) *Guest speakers:* Baumann Consulting	Interim project presentations
16	04/25/24	*Student project presentations (1)*	Main Project Presentation
17	05/02/24	*Student project presentations (2)*	Main Project Presentation
18	05/05/24	Final Report Submission	Final Report