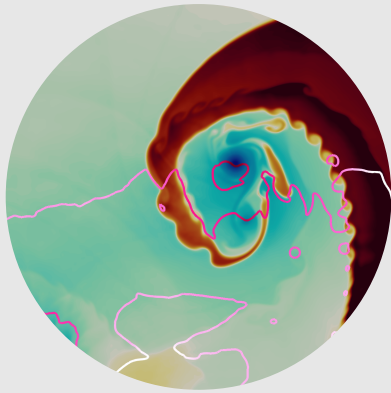




Computational Fluid Dynamics

AE 4040 - Fall 2026

Course Info



Prereq: AE 2010, MATH 2551, AE 3030



Tue, Thu



8:00-9:15AM



Klaus Advanced Computing 2443

Instructor Info



Sriram Kalathoor



Office Hrs: TBD



Office Hrs: TBD



Office Hours Location: TBD



Canvas



sriram2@gatech.edu

TA Info



Youjie Zhang



TBD



TBD



yzhang3988@gatech.edu

Overview

Computational Fluid Dynamics (CFD), sometimes referred to as Computational Fluid Mechanics, a senior year undergraduate elective, is the science of using numerical methods and computer algorithms to solve and analyze fluid mechanics problems. In this course, we apply ideas from AE 2010 and 3030 (Thermofluids and Aerodynamics) to some practical aerospace engineering problems.

This course is divided into three segments, that will all be covered concurrently. The first segment will deal with functions and operators, in particular, partial differential equations, and their properties. The second segment will deal with discretization, numerical differentiation and integration, and stability. The third segment will deal with practical applications of these ideas using commercial software.

Material

Required Texts

None. Class notes will be posted on Canvas website ahead of time. You are encouraged to bring a copy (printed or electronic) to mark-up during lectures. The lecture notes will closely follow the notes posted.

Recommended Text

► *Applied Computational Aerodynamics* by RM Cummings, WH Mason, SA Morton and DR McDaniel, Cambridge University Press, 1st Edition, 2015

Advanced Texts

► *Computational Fluid Dynamics* by JD Anderson, McGraw-Hill, 1st Edition, 1995

► *Computational Fluid Mechanics and Heat Transfer* by RH Pletcher, JC Tannehill and DA Anderson, CRC Press, 4th Edition, 2020

Grading Scheme

10% Attendance/Participation

33% → $3 \times 11\%$ 3 in-class exams (initially equal weights)

30% → $3 \times 10\%$ 3 HW Assignments (initially equal weights)

35% Final Project

2% Extra credit (format TBD in November)

110% *Total possible percent score*

All pieces of evaluation except the extra credit are mandatory; any unapproved missed work will result in an automatic C or lower. (see page 2)

Grades will follow the percentage scale as:

$$A \geq 90; \quad 90 > B \geq 80; \quad 80 > C \geq 60; \quad 60 > D \geq 50; \quad 50 > F$$

I might deviate from this grading scheme depending on class performance, but I will only curve in your favor.

Learning Objectives

By the end of the course, you will be able to

1. Categorize and assess the nature of partial differential equations
2. Use Taylor series to compute finite difference approximations for differential operators
3. Apply boundary conditions on discretized equations
4. Generate algorithms to perform numerical differentiation and integration
5. Use commercial solver(s) and apply the above ideas to solve fluid mechanics problems
6. Visualize fluid dynamics quantities and come up with educated representations and conclusions regarding flow behavior

FAQs

? Why do I need thermo/aero for this course?

! Because the central ideas behind CFD rely on the a good understanding of thermo-fluids, in particular, the equations in 2010/3030

? What's different about this course from AE3030?

! In 3030, we learned about how a plane flies, and how to assess how *well* it flies. In 4040, we will actually assess that performance!

? What's the most fun thing I'll learn in this course?

! CFD is often called *Colorful Fluid Dynamics*, and you will learn to make *extremely* pretty flow visualizations!

? What is the one rule of class that you absolutely stand by?

! *"There is no such thing as a stupid question."*

? How closely will you follow the prescribed book?

! The book is an organized version of the lecture. I will teach using the board, you'll have notes uploaded to annotate on. You don't need to buy the textbook, but it's a useful reference to have.

? What's an interesting CFD fact?

! One of the largest CFD simulations was carried out here at GT, over 35 trillion grid points!

Evaluations and Class Participation

The course has six interim evaluations; two in-class exams and three homework assignments. At the end of the semester, the highest HW will count for 50% more (i.e. weighted at 16.5%) and the lowest HW will count for 50% less (i.e. weighted at 5.5%). This policy also applies to the 3 exams (i.e. weighted at the end at 15%, 10% and 5%) highest-to-lowest.

You will have to attempt an exam/assignment for it to be eligible for this weighting. By "attempt" we will mean an honest, serious attempt at the assignment, showing the time and effort expected for an assignment worth a significant percent of the grade (i.e. minimal/low effort, procedural submissions will not be considered an "attempt"). The instructor has the right to determine if a submission is considered an honest and serious attempt. All pieces of evaluation (3 HWs, 3 exams, and the final project) are mandatory. Any missed submissions without prior approval will result in a C or lower (depending on what your overall grade works out to be).

Since participation is a graded component of the course, students are expected to attend all the lectures. Participation will be assessed individually via either in-class questions, flash cards, before/after/in-class discussion. To a limited extent, participation in the Canvas discussion board and office hours will count toward participation. The mandatory attendance policy will not be in effect during the first week of classes, the week of Fall break, and the week of Thanksgiving.

Opportunities for extra credit will be provided through the course. A total of 2% will be awarded in a format to be determined in November (based on overall class HW/exam performance)

Final Project

Instead of an in-class final exam, we will have a final simulation project. Students will submit a proposal for their final project during the 3rd week of the class, and work toward the project through the semester. The content required to work on the project will be covered concurrently with other course content. A format for the final project report will be made available on Canvas. The project report will be due on Canvas by Dec 04, 11:59PM. Topics for the project will have to be submitted no later than the end of the fourth week of classes (Friday, Sep 12th).

Attendance and Etiquette

Students are expected to keep their mobile phones on vibrate/silent mode, and avoid doing non-course-related activities as a courtesy to their fellow students.

Belonging Statement

I consider this classroom to be a place where you will be treated with respect, and I welcome individuals of all ages, backgrounds, and other identities. All members of this class are expected to contribute to a respectful, welcoming and positive learning environment for every other member of the class.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404) 894-2563 or dsinfo@gatech.edu, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please e-mail me as soon as possible in order to set up a time to discuss your learning needs.

Academic Integrity

The Georgia Tech Honor Code is central to the ideals of this course. Students are expected to be independently familiar with the Code and to recognize that their work in the course is to be their own original work that truthfully represents the time and effort applied. Violations of the Code are most serious and will be handled in a manner that fully represents the extent of the Code and that befits the seriousness of its violation. The Code can be found at <http://www.policylibrary.gatech.edu/student-affairs/code-conduct>

Tentative Class Schedule

MODULE 1: Introductory Material

Week 1	Math, thermo and aero review
	Introduction and motivation behind CFD
Week 2	Conservation equations for fluid mechanics; different forms of governing equations
	Applications of different forms of the governing equations

MODULE 2: Fundamentals of CFD

Week 3	Introduction to partial differential equations
	Classification of partial differential equations
	Homework 1 is assigned
	Project proposals due
Week 4	Behavior of partial differential equations; the effect of boundary conditions
	Taylor Series and finite difference approximations
	Finite difference applications to PDEs
Week 5	Finite difference applications to PDEs
	Linear stability analysis; implicit and explicit schemes
	Constructing stable schemes; the CFL number
	Homework 1 is due
Week 6	In-class exam 1
	Introduction to grid generation; structured and unstructured grids
	Grid topologies
	Homework 2 is assigned
Week 7	The Navier-Stokes Equations; mathematical behavior
	Discretization of the Navier-Stokes equations
	Application to incompressible flows
Week 8	No class on October 6th — Fall Break
	Application to incompressible flows (contd.), the SIMPLE algorithm
	Application to compressible flows
	The role of boundary conditions
	Homework 2 is due

MODULE 3: Advanced Ideas

Week 9	Introduction to turbulence; properties and analysis of turbulent flows Approximation and modeling of turbulent flows
Week 10	In-class exam 2 Approximation and modeling of turbulent flows (contd.) Filtering & Large Eddy Simulations
Week 11	Example final project demonstration + Q&A Advanced techniques: Total Variational Diminishing schemes Advanced techniques: Roe averaging and Riemann solvers
Week 12	Advanced techniques: Essentially Non-oscillatory schemes CFD Considerations: Accuracy, Verification & Validation Alternate Paradigms: The finite volume method Homework 3 is assigned
Week 13	The finite volume method (contd.) Alternate Paradigms: The finite element method
Week 14	The finite element method (contd.) Advanced Ideas: Non-linear stability; advanced visualization techniques Buffer class I; Miscellaneous topics per class interest Homework 3 is due
Week 15	Buffer class II; Miscellaneous topics per class interest No class on November 26th — Thanksgiving Break In-class exam 3
Week 16	Course outro; tying up loose ends; the CFD big picture Project reports due 10 December by 11:59PM

Miscellaneous Notes

Background

AE 2010 (Thermofluids), MATH 2551 (Multi) and AE 3030 (Aero) are prerequisites, we will be covering background material on a need-to basis. The ideal background for this class is a strong desire to master the material.

Grading

The class is designed to be challenging, but not be stressful in terms of evaluation and grading. However, much of your success in the class depends on attendance and informed participation. While notes will be posted ahead of time, these are for your annotation purposes, and are not a substitute for in-class lectures. From my historical experience, students without adequate

attendance in the lectures tend to have a harder time following the material. The exams will test theoretical ideas (and will be difficult, even tedious) but the homework will test more hands-on skills relevant to the course content. We will try to strike a balance between the theory and practice of CFD.

Syllabus/Scheduling

The syllabus and schedule are tentative. A lot of things happen in class, that can cause us to deviate from this schedule. If that occurs, we might decide to skip some topics or rearrange some of the content. We have buffer classes toward the end of the semester to accommodate these scenarios, if needed.

Communication

Canvas will be my primary means of communicating with the entire class. Please make sure to check the announcements page regularly. Please consider utilizing the Canvas discussion board for your questions; it helps solidify your ideas and connect with your classmates. I will be monitoring the discussion board on a regular basis and responding as needed (either to answer questions, or to clarify/add to someone else's answers).

Since the course is dense in content and we will be moving relatively quickly through concepts, if you need additional help, please reach out as soon as you identify problems. I understand that life happens, and I am willing to work with you to ensure your success in this course. If you have situations requiring sudden accommodations for any learning/support, please let me know at the earliest.

If scheduled office hours do not work for you, please also consider reaching out to schedule a different time with me. I can be reached via email or through Teams. I am willing to provide my phone number as well, on a need-to basis. Please do NOT use the messaging feature on Canvas to reach out to me; as an instructor for multiple courses, I frequently get 100+ messages and it is easy to miss messages.

While AE 4040 has historically been a "large" class, this semester's class size is the largest it has been in the past decade (I said this last year too and we just keep getting bigger and bigger...?). As such, it will be difficult (if not impossible) to use email to clarify general questions. If you have questions about the course content, concepts, HW, exams etc., please use the Canvas discussion board. Only consider emailing me if you have a question specific to your situation (for eg. you need to miss some lectures, or require an extension etc.)

This course is heavily discussion-centric, which means there will be a lot of talking. When I speak, I have an accent to my English, that might, at times, be hard to understand. If you find it difficult to follow my speech, or if I am talking too fast/softly, please ask me to repeat myself/slow down. (I promise I won't be offended.)

Lastly, if you are in need of any support or assistance, whether in this course or otherwise, please know that you can reach out to me. I might not have all the solutions to problems, but I am willing to work to identify workarounds.

Important Dates

Important dates for AE 4040 are listed here. Please always refer to the official Institute Calendar for up to date information.

Tuesday, Aug 25th	First Day of AE 4040 Class
Friday, Aug 28th	Phase II Registration ends
Monday, Aug 31st	Fee payment deadline
Monday, Sep 07th	Holiday (Labor Day)
Monday-Tuesday, Oct 05th & 06th	Holiday (Fall Break)
Saturday, Oct 31st	Withdrawal Deadline
Thursday-Friday, Nov 25th-26th	Institute Holiday (Thanksgiving)
Tuesday, Dec 08th	Last Day of AE 4040 Class
Tuesday, Dec 10th	Final project is due on Canvas
