AE 523: Computational Fluid Dynamics

Fall 2020

Lectures:	Pre-recorded, available on Canvas
Recitations:	Mon. 10-11am, Tue. 11am-noon, Wed. 1-2pm, Thur. Noon-1pm
Instructor:	Prof. Krzysztof Fidkowski (kfid@umich.edu)
GSI:	Miles McGruder (mmcgrude@umich.edu)
GSI Office Hrs:	To be arranged
Course website:	Canvas: umich.instructure.com
Resources:	Notes/codes on website, papers/books referenced in notes

Description:

Students successfully completing AE 523 will have: a working knowledge of key spatial and temporal discretizations, in the context of finite difference and finite volume methods; an ability to analyze and implement numerical solution techniques for steady and unsteady problems; and an understanding of the differences between various models of fluid flow and the associated numerical characteristics and challenges of each model.

Topics covered will include equation classification, finite difference discretizations, boundary value problems, iterative solution techniques, stability, consistency, and convergence analysis, time integration, the finite volume method, shock capturing, and example applications. Students entering this class should have some background in numerical analysis and fluid dynamics. Homework assignments and projects will require computer programming.

Lectures:

Lectures have been pre-recorded and will be made available on Canvas incrementally, each week. They will be time-stamped with a date of intended watching, but do not have to strictly adhere to this schedule. Note, however, that the material covered in the lectures will be used to formulate questions for homework, projects, exams, and quizzes (see below).

Recitations:

I will be holding synchronous recitations four times a week, as indicated above, on Zoom. These will consist of 15 minutes of me working through an example problem, followed by 45 minutes of office hours: questions and discussions. The example problem portion of each recitation will be recorded, but the office hours will not (so you do not have to be shy about asking questions). You are welcome to attend all, some, or none of these. If you do not attend, please watch the example problem recordings – you are responsible for knowing this material.

Piazza:

We will use Piazza, linked through Canvas, as the primary question and answer medium. You can post your questions and/or answer other students' questions. The instructors will be monitoring and responding continuously.

Grading:

4 Homeworks	30%
2 Projects	30%
Quizzes	10%
Midterm	15%
Final	15%

Grades on assignments, exams, and quizes will be given as percentage points out of 100%. Individual

assignments/exams may be curved in special circumstances. The final course grade will be converted from percentage points to the 4.3 grading scale linearly, with $100\% \to 4.3$ and $0\% \to 0$. Letter grades will then be given according to: $A+ = 4.3, A = 4.0, A- = 3.7, B+ = 3.3, B = 3.0, \ldots$.

Assignment Submission:

All assignments must be uploaded electronically to the course website (Canvas). Project reports must be typed and submitted as technical reports in `.pdf` format. Homework assignments need not be typed, but if they are hand-written, the writing should be neat, and they should be scanned and uploaded. If using your phone, use a scanning application that makes legible, high-quality `.pdf` documents, instead of just uploading pictures. The source files of all codes written for a homework or project must be uploaded as a separate .zip file. However, **you must always upload a stand-alone .pdf file (not in the .zip) of your writeup** so that it can be graded on Canvas.

Late assignments and projects will be penalized 0.5 points per hour late (the clock does not stop on weekends). Unless otherwise noted, no assignments will be accepted after 72 hours late. Extensions for non-emergency special circumstances must be requested at least 24 hours in advance of the due date.

Collaboration:

For homework and projects, high-level discussions of concepts among students are allowed, but all submitted work must be your own. That is, each student must work through and write up each assignment without looking at the work of other students. Examples of acceptable collaboration include discussing the general approach to a problem and relevant theorems/equations, and comparing intermediate and final answers after finishing a problem. Examples of unacceptable collaboration include: turning in a photocopy or an identical printout of a plot, code, or problem solution; looking at another student's work prior to completing a problem on your own; or working on a code together with another student. Unacceptable collaboration will result in zero credit for those involved and possible reporting to the Engineering Honor Council.

Programming:

Computer programming will be required on assignments and projects. Any programming language can be used, though in-class demonstrations and sample codes will be given in Python. Debugging a code can be time consuming, but it is also a worthwhile skill to master. If you are stuck and cannot find an error, check Piazza for similar issues or make your own posting, make use of recitations/office hours. and/or email your question and code to the instructor for input.

Reading and Quizzes:

On the Canvas website you will find typed notes with the course material. This is required reading, and the relevant sections for each week are given on the calendar at the end of the syllabus. You will have quizzes via Canvas on the relevant readings. Lecture material will also be covered on the quizzes. These will be multiple-choice questions, to be completed on your own time before 11:55pm on the due dates indicated on the calendar. Each quiz will be based on readings and lectures from the previous week – for example, Quiz 1 will cover readings 1.1–1.7 and lectures from the first week.

Additional Resources (optional):

- Hirsch, C. Numerical Computation of Internal and External Flows I and II.
- Leveque, R. Numerical Methods for Conservation Laws. Lectures in Mathematics. ETH Zurich.
- Briggs, W.L. A Multigrid Tutorial.

Outline: HW = homework due, **Project** = project due, green = recitation date.

Week	M	T	W	Th	F	Topics	Readings
Aug 31						**Math and Programming Review**	*1.1 – 1.7*
Sep 07	Labor Day		**Quiz 1**		**HW1**	**Finite Difference Approximations**	*2.1 – 2.3*
Sep 14			**Quiz 2**			**Boundary Value Problems**	*2.4 – 2.6*
Sep 21			**Quiz 3**		**HW2**	Stencils, matrices, BCs	*3.1 – 3.3*
Sep 28			**Quiz 4**			Solvers, smoothers, multigrid	*3.4 – 3.7*
Oct 05			**Quiz 5**		**Project 1**		
Oct 12				**Midterm**		**Initial Value Problems**	
Oct 19						Fully/semi-discrete schemes	*4.1 – 4.3*
Oct 26			**Quiz 6**		**HW3**	Consistency and stability analysis	*4.4 – 4.6*
Nov 02			**Quiz 7**			**Conservation Laws**	*5.1 – 5.3*
Nov 09			**Quiz 8**		**HW4**	The finite volume method	*5.4 – 5.7*
Nov 16			**Quiz 9**			Characteristics and weak solutions	*6.1 – 6.2*
Nov 23	Thanksgiving Break						
Nov 30			**Quiz 10**		**Project 2**	High resolution schemes	*6.3 – 6.4*
Dec 07			**Final**			**Review**	
Dec 14							

The midterm will be a written "take-home" exam given out at noon on Wednesday, October 14th. It will be due at 11:55pm on Friday, October 16th. The final exam will be oral, administered after classes end over a 30-minute pre-arranged time slot.