Syllabus

CLIMATE/SPACE 551:
Advanced Fluid Dynamics

Fall 2023 (4 Credits)

A course in fundamental fluid dynamics with an Earth, atmosphere, and space science spin

Course Description:

This class covers "how stuff moves." It gets into the math, so vector calculus is a major component of the work. The course covers dimensional analysis, so students will learn how to avoid solving tough equation sets. The class is directed towards first-year PhD students in the Department of Climate and Space Sciences and Engineering, but should be useful and interesting to graduate students across all fields of science, engineering, and mathematics.

Course Prerequisites:

Graduate standing.

Instructor:

Dr. Xianzhe Jia, Professor, Department of Climate and Space Sciences and Engineering
Room 1433, Climate and Space Research Building (on North Campus, 2455 Hayward St.)
Email: xzjia@umich.edu

Grader:

Alex Hoffmann (aphoff@umich.edu), CLASP PhD candidate

Class Sessions:

Mondays, Wednesdays and Fridays from **10:30 am – 12:20 pm**, in **GGBL Room 1025**. We'll take a break in the middle.

The class is mostly flipped, so *many of the class sessions are essentially the office hours*. Additional office hour times can certainly be arranged, as needed.

Flipped Class Structure:

You will have readings each week and I will send out details about the reading material in advance. In class, we will have student-led discussion and Q&A time about the topic and then, together, we will work through some examples. Please attempt the homework problems and get as far as you can prior to the homework-solving sessions, when we will go through the problems, *as a group*, *with students taking the lead*, in the class.

The first week will be a bit different; I will not flip it but rather talk a bit more than I will the rest of the course. Midterm exam weeks will be a bit different, with the exam replacing a class session (no class while you have the exam).

Textbook:

We will be using a ~150-page coursepack written by Professor Jeremy Bassis, so no textbook purchase is required for this course. Here are a few other books that you might find useful as references and supplemental resources:

Kundu, Pijush K., Ira M. Cohen, and David R. Dowling, *Fluid Mechanics*. Sixth Edition (2020). Academic Press/Elsevier.

Batchelor, G. K. (2012), *An Introduction to Fluid Dynamics*, Cambridge Univ. Press.

Tritton, D. J., *Physical Fluid Dynamics*. Second Edition (1988). Clarendon Press (Oxford Science Publications).

Vallis, Geoffrey K., *Atmospheric and Oceanic Fluid Dynamics*. Second Edition (2017). Cambridge Univ. Press.

Learning Objectives:

It is expected that, by the end of the course, students will be able to:

- Explain the conditions when groups of particles can be treated as a "fluid" and be able to describe conditions when the fluid approximation breaks down and particles cannot be treated as a fluid.
- Apply dimensional analysis to problems to make order of magnitude estimates, simplify differential equations and determine units of quantities, including integrals of distributions functions.
- Use dimensional analysis to determine geometrically and dynamically similar flow regimes and the non-dimensional numbers that govern these types of regimes. Examples considered in class will include the Reynolds and Rossby numbers, but students should be able to apply dimensional analysis to new problems and situations.
- Write down and provide a physical explanation for each of the terms in the equations describing conservation of mass and linear-momentum for a fluid.
- Explain the difference between Eulerian and Lagrangian reference frames and be able to write down equations that transform between reference frames.
- Linearize differential equations and use the linearized equations to obtain dispersion relations and/or growth rates of instabilities. Examples considered in class may vary, but could include sound waves, gravity waves, Rossby waves along with Rayleigh-Taylor instability, Kelvin-Helmholtz instability. Students should be able to apply the linearization procedure to new problems beyond those covered in class.
- Explain, using words and equations, the difference between stable and unstable flow.
- Explain, using words and equations, the difference between the phase and group speed of waves.
- Write down equations describing the Coriolis and Centrifugal forces and explain the effect of these forces using mathematical and physical arguments.

For PhD students in CLaSP, these learning objectives are the qualifying exam skill sheet.

Grading Apportionment:

This is a 4-credit class. There is a lot of work for it. Your overall course grade is made of several elements:

Homework Sets (9)	~4% each (35% total)	Weekly
Concept presentation (3)	5% each (15% total)	Present an equation or concept
Midterm Exams (3)	12% each (36% total)	HW set you do by yourself
Final Exam	14%	Stand and deliver at the whiteboard

See the detailed day-by-day course outline below for the specific due dates of these assignments and exams. Note that attendance is not part of the class grade, but the "presentation of a section" requires attendance on the day in which you present.

Details of Homework Sets and Midterms:

Homework assignments will be released at least one week before their due dates. We will usually spend at least one class session working through these problems together as a group. You should work on them before these sessions so that you can fully participate in, and even lead, these discussions. Even though we will do them together, please write/type up your homework set answers and turn them in.

For both homework and midterm exams, if you use Maple/Mathematica/Matlab/Python/etc, please include relevant code and output as an appendix to the assignment submission. All work should be clearly written using ample space and exposition to demonstrate clear thought.

When we have a midterm exam, it will be released on Canvas and due 24 hours later. There will be no homework set those weeks and usually no class the day during/following the exam.

Student Collaboration:

I encourage collaboration and peer tutoring. Please help each other learn the material and get through the work. I will be there for all of the in-class sessions to help with them, too. When it comes to actually writing/typing up the submission, though, I expect each of you to do your own work. You learn very little by copying another's answers.

For the midterm exams, I am holding you to the Engineering Honor Code and expect that each of you will do your own independent work and submission without any input or aid from others. For these grading elements, you should do it all yourself. Any questions should be directed to Prof. Jia.

In-class Presentations:

Three times (once each "section" of the course, as divided by the midterms), you will present in class one of the equations or concepts in the coursepack. For each presentation round, I'll draw names for people to select which topic they would like to present. When we cover that chapter, you will take over and give a 3 to 10 minute presentation of the material. Talk to me if you are struggling to figure out how to present your topic. These are whiteboard-only sessions (in GGBL 1025); no Powerpoint slides, please.

The Final Exam:

On or near the last day of class, we'll draw names for people to select a 30-minute appointment time, which will be during the December class times and held in GGBL 1025. I will also distribute the list of topics at this time (if not earlier), which will be an expanded version of the Learning Objectives above. At each person's final exam, I will randomly draw three topics from the list and you will then discuss these topics. Whiteboard only; no Powerpoint slides.

Grading Rubric:

Grading of each homework or exam problem will be numerical on a 8-point nominal scale. The meaning of the point scale is as follows:

- 8 points: a complete answer of what I was expecting
- 7 points: mostly correct but a one or two minor errors
- 6 points: sort of correct but several (or many) little things wrong
- 5 points: going towards correct but a major error somewhere
- 4 points: a couple pretty big errors in the reasoning
- 3 points: really not that close at all to what was expected
- 2 points: attempted but not done and completely off target
- 1 point: barely started

For the presentation and the final exam, there are criteria on which you will be graded

- Delivery: presentation style, speaking clarity, audience engagement
- Physics: understanding of equations and concepts
- Q&A: ability to handle questions about the topic

In the final exam, there are actually three Physics criteria, one for each topic. Each of these criteria will be assessed on the 8-point scale above.

Course Grade Policy:

Your overall grade in the course will be based on these percentages:

- 97 – 100 %: A+
- 93 – 96: A
- 89 – 92: A-
- 85 – 88: B+
- 81 – 84: B
- 77 – 80: B-
- 73 – 76: C+
- 0 – 72: Something lower than C+

In between: I will round.

Compare this with the individual-problem grading rubric above. A score of 7 on all problems/criteria will result in an B+ in the course. I am expecting, though, that most of the HW and presentation grades will be high. If you are perfect on those, then a score of 6 on all midterm and final problems will result in a high B+ score. It will be hard to get an A+ in this course, but also hard to get something lower than a C+ (assuming that you do the homework sets in class with everyone else).

Just for reference, the Rackham Graduate School requires its students to maintain an overall GPA of 3.0 (B) to be in good academic standing, and CLaSP requires an overall GPA of 3.3 (B+) to advance to candidacy (in addition to passing the qualifying exam).

Extra Credit:

There will be one opportunity for extra credit near the end of the course: turning in the receipt acknowledging that you filled out the course evaluation. If you upload a screen shot/pic/PDF of the page showing that you submitted it, then you will receive 2 percentage points extra towards your overall course grade. This will not be reflected in Canvas but will be added afterwards.

I highly value your feedback about the course and look forward to reading your comments on what went well and what could be done differently. I strive to improve my teaching skills every term.

Late Policy:

Assignments, whether homework, projects, or exams, are expected to be submitted by the listed due date and time. Assignments submitted late are reduced by 10% of the possible score. After 7 days, or when grades are returned on the assignment, whichever is first, the assignment will not be graded. Excused late submissions **must** be requested ***before*** the due date and time. A sudden injury or illness is about the only excuse I will accept after the due date.

Religious or School-Function-Related Absence

If students expect to miss classes as a consequence of their religious observance or are traveling with a U-M sports team or organization, then alternate arrangements will be made to accommodate missed academic work. It is the obligation of students to provide the instructor with reasonable notice of the dates on which they will be absent (*before* they occur). We will determine a mutually agreeable alternative timeline within the boundaries of the class (usually a shifted deadline).

Disability Access

If you think you may need an accommodation for a disability, then please inform the instructor early in the term. You should contact the Services for Students with Disabilities (SSD) office to be issued a Verified Individual Services Accommodation (VISA) form, to be given to the instructor. I will fully accommodate all such requests.

Student Mental Health and Wellbeing

If you or someone you know if feeling overwhelmed, depressed, and/or in need of support, then services are available. Grad school can be hard, but please know that you are not alone in having such thoughts and feelings, nor do you have to go through it alone. The first option is talking to a trusted friend or relative. For professional help, please contact Counseling and Psychological Services (CAPS) at 734-764-8312 or online at https://caps.umich.edu. You may also consult University Health Service (UHS) at 734-764-8320 and at https://www.uhs.umich.edu/mentalhealthsvcs, or for alcohol or drug concerns, see www.uhs.umich.edu/aodresources. For a listing of other mental health resources available on and off campus, visit http://umich.edu/~mhealth/.

Student Sexual Misconduct Policy

Title IX prohibits discrimination on the basis of sex, which includes sexual misconduct – including harassment, domestic and dating violence, sexual assault, and stalking. Sexual violence can undermine students' academic success and I encourage anyone dealing with sexual misconduct to talk to someone about their experience, so that they can get the support they need. Confidential support and academic advocacy can be found with the Sexual Assault Prevention and Awareness Center (SAPAC) on their 24-hour crisis line 734-936-3333 and at https://sapac.umich.edu. Alleged violations can be reported to the Office for Institutional Equity (OIE) at insitutional.equity@umich.edu

CLIMATE/SPACE 551: Advanced Fluid Dynamics
Course Conduct Statement

Prof. Xianzhe Jia , Email: xzjia@umich.edu

The College of Engineering has an honor code. This is taken seriously.
See the website: http://www.engin.umich.edu/students/honorcode/code/

Policy on Homework and Projects

You are encouraged to form study groups to work on homework problems and to study in other ways. You are allowed to consult with other students during the conceptualization of a problem. However, all written work, whether in scrap or final form, is to be generated by you alone. You are not allowed to possess, look at, use, or in any way derive advantage from the existence of solutions prepared in prior years, whether these solutions were former students' work product or copies of solutions that had been made available by others.

Unless arrangements are made with me beforehand, late assignments are marked down by 10% and will not be accepted after one week or when it is graded and returned, whichever is first.

Policy on Exams

You are to complete all examinations on your own, with only benefit of the allowed aids (for this class...nothing), and without looking at or talking about the examination work of others. If you see a violation of the Honor Code, then you are obligated to report it.

For those needing special accommodations, please provide me with the proper form at least two weeks before the first exam so that arrangements can be made.

All of the exams are take-home tests and probably do not require an excused absence. If you know that you have a major conflict with one (due to athletic travel, religious observances, etc.), then please let me know in advance so that we can make alternate arrangements. If you miss one due to a medical emergency, then you need a doctor's note explaining the situation.

On each exam, the Honor Pledge will be printed and you should sign/write your name under it. The Honor Pledge is as follows:

> *"I have neither given nor received unauthorized aid on this examination, nor have I concealed any violations of the Honor Code."*

The Honor Council policy is that I am not required to grade tests in which the signed Honor Pledge does not appear. The Honor Code remains enforced whether or not the student signs the Pledge.

During an exam, email or see the professor with any clarifying questions you may have. If an answer to a question is relevant to everyone, then it will be sent via a Canvas announcement.

Violations

Violation of this policy is grounds for the initiation of a report filed with the Dean's office and the case would come before the Honor Council of the College of Engineering. If you have any questions about this policy, then please do not hesitate to contact me.