

Syllabus, Theoretical Fluid Dynamics
Spring 2023

Classroom: XXXX

Instructor: Laura Miller

office: ENR2 N210 or BSW 227 (Lab)

e-mail: lauram9@math.arizona.edu

Office Hours: XXXX

Homepage(s): XXXX

Notes + Slides: Class notes are posted on the class homepage.

Pre-requisites: No formal requirements, however, all students are assumed to have a basic practical knowledge of real and complex variables, linear algebra, differential equations, and discrete mathematics. Knowledge of general physics and/or engineering will be useful but not required.

Course Description: This is a one-semester course in theoretical fluid dynamics that is focused on fundamental topics that all applied mathematicians should know to work in the field of fluids. Topics to be covered include the Eulerian and Lagrangian descriptions of a fluid, conservation laws, the equations of fluid motion, potential flows, viscous stresses, vorticity kinematics, potential flow, viscous flows, Stokes flow, boundary layers, instabilities, turbulence, dispersive waves, nonlinear Schrödinger equation, and KdV equation. To complement the theoretical component of the course, students will visit the Mathematical Fluids Lab in BSW 227 for demonstrations.

Topics to be Covered:

Week 1: Eulerian and Lagrangian descriptions of a fluid and definitions

Week 2: Conservation laws and potential flows

Week 3: Potential flows continued, Kelvin's theorem

Week 4: Moving through fluids

Week 5: Viscosity Navier-Stokes equations

Week 6: Stokes flow

Week 7: The wake and boundary layers

Week 8: Instabilities

Week 9: Turbulence I

Week 10: Turbulence II and mixing

Week 11: The boundary layer II

Week 12: Linear waves

Week 13: Weakly nonlinear waves

Week 14: Nonlinear Schrödinger and KdV equations

Weeks 15-16: Project Presentations

Books & Notes: This course will draw from many books, graduate-level course notes, and research papers. We will explain major concepts briefly but self-consistently in our notes, in parallel providing references to other texts where much more detailed, and often complementary, presentation of the material can be found. Some (but not all) of these references are available online. Here we provide an incomplete list of major sources used repeatedly throughout the course:

- Falkovich, G. (2011). *Fluid mechanics*, Second edition. Cambridge University Press.
- Childress, S. (2009). *An introduction to theoretical fluid mechanics* (Vol. 19). American Mathematical Soc.
- Acheson, D. J. (1990). *Elementary fluid dynamics*: Oxford University Press.
- Batchelor, G. K. (2000). *An introduction to fluid dynamics*. Cambridge university press.
- Landau and Lifshitz, *Fluid Mechanics* (2nd Ed.), Pergamon Press 1987.

Learning Outcomes

By the end of the semester, students will be able to

- Apply the fundamental concepts of fluid dynamics to conduct theoretical work in the field of fluids.
- Derive the equations of fluid motion and solve them for special cases.
- Use dimensional analysis to derive relevant dimensionless numbers.
- Use specific vocabulary and terminology to effectively communicate theory, techniques, and results.
- Mathematically describe and analyze instabilities in a fluid due to the nonlinearity of the equations of fluid motion.
- Mathematically describe and analyze small amplitude surface waves.

Procedures and Grading for Homework and Projects

Homework will be available ahead of time (at least 7-10 days before the deadline) on the class webpage. Each homework should be submitted electronically via D2L in latex format (.zip containing latex and other source file + .pdf uploaded before the deadline, following instructions on the course website). To account for homework assignments missed for curriculum under circumstances beyond

your control, your single lowest homework assignments for the semester will be automatically dropped. This means that if you miss a homework assignment for ANY reason, legitimate or otherwise, it will count as a drop. All submissions (Homework, Project) will be due electronically (.zip containing latex and other source files + .pdf uploaded following instruction on the course website) according to the schedule (see below, note schedule may change so check for updates).

Schedule (tentative, subject to change, check D2L often):

	Due Date	Time (Tucson)	Topic
HW 1	Feb 5 (Sunday)	11:59 pm	Potential Flows
HW 2	Feb 19 (Sunday)	11:59 pm	Viscous Flows
HW 3	March 19 (Sunday)	11:59 pm	Wakes and Instabilities

HW 4	April 2 (Sunday)	11:59 pm	Turbulence
HW 5	April 16 (Sunday)	11:59 pm	Boundary Layers and Waves
HW 6	April 30 (Sunday)	11:59 pm	Schrödinger and KdV
Presentations	Weeks 15-16		

Procedure and Grading: The total number of points available on tests and homework is 500 = 300 (homework) + 200 (project). After submission of each homework, the instructor will release the grade with feedback. Grades will be no lower than set forth in the following table:

$450 \leq \text{points}$	90% to 100%	A
$400 \leq \text{points} \leq 449$	80% – 90%	B
$350 \leq \text{points} \leq 399$	70% – 80%	C
$300 \leq \text{points} \leq 349$	60% – 70%	D

0 ≤ points ≤ 299

0% – 60%

E

Withdrawing: You may withdraw from the course with a deletion from your enrollment record through September 19 using UAccess. You may withdraw with a grade of "W" through Nov 1 using UAccess. After that date the dean's approval is required for withdrawal.

Incompletes: The grade of I will be awarded if all the following conditions are met:

1. The student has completed all but a small portion of the required work.
2. The student has scored at least 50% on the work completed.
3. The student has a valid reason for not completing the course on time.
4. The student agrees to make up the material in a short period of time.
5. The student asks for the incomplete before grades are due, 48 hours after the final exam.

Accessibility and accommodations: It is the University's goal that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please let me know immediately so that we can discuss options. You are also welcome to contact Disability Resources, (520) 621-3268, to establish reasonable accommodations. Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.

Attendance and Protocol: You are expected to be familiar with the University Class Attendance policy. It is your responsibility to stay informed of any announcements, syllabus adjustments, or policy changes. All holidays or special events observed by organized religions will be honored for those students who show affiliation with that particular religion. Absences pre-approved by the UA Dean of Students (or Dean's designee) will be honored. You are expected to behave in accordance with the Student Code of Conduct and the Code of Academic Integrity.

Subject to change: The information contained in the course policy, other than the grade and absence policies, is subject to change with reasonable advance notice, as deemed appropriate by the instructor.

Additions to syllabus due to COVID-19 situation:

Course modality: This class is scheduled to be taught in person modality. We will be meeting for lectures in person in MTL 124, unless UArizona changes the attendance policy, according to the class schedule. Some lectures may be conducted primarily via zoom, in which case all students will be notified (at least) a week in advance. All in person meetings will also be synchronously conducted via zoom to allow remote attendance.

Classroom attendance:

- If you feel sick, or may have been in contact with someone who is infectious, stay home. Except for seeking medical care, avoid contact with others and do not travel.
- Notify your instructor(s) if you will be missing a course meeting or an assignment deadline.
- Non-attendance for any reason does not guarantee an automatic extension of due date or rescheduling of examinations/assessments.
- Please communicate and coordinate any request directly with your instructor.
- If you must miss the equivalent of more than one week of class, you should contact the Dean of Students Office DOS (deanofstudents@email.arizona.edu) to share documentation about the challenges you are facing.

Other important information:

- Voluntary, free, and convenient COVID-19 testing is available for students on Main Campus.
- If you test positive for COVID-19 and you are participating in on-campus activities, you must report your results to Campus Health. To learn more about the process for reporting a positive test, visit the Case Notification Protocol- <https://covid19.arizona.edu/test-trace-treat/positive-case-protocol-students>
- The COVID-19 vaccine and boosters are available for all students at Campus Health - <https://health.arizona.edu/covidvaccine>
- Visit the UArizona COVID-19 page for the most up-to-date information - <https://covid19.arizona.edu/>

Academic Advising: Academic advising: If you have questions about your academic progress this semester, or your chosen degree program, please note that advisors at the Advising Resource Center can guide you toward university resources to help you succeed.

Life Challenges: If you are experiencing unexpected barriers to your success in your courses, please note the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office can be reached at 520-621-2057 or DOS (deanofstudents@email.arizona.edu).

Physical and mental-health challenges: If you are facing physical or mental health challenges this semester, please note that Campus Health provides quality medical and mental health care. For medical appointments, call (520-621-9202. For After Hours care, call (520) 570-7898. For the Counseling & Psych Services (CAPS) 24/7 hotline, call (520) 621-3334.

Remain Flexible: If pandemic conditions warrant, the University may require that we return to remote operations. If that is the case, we will notify you by D2L Announcement and email that we are moving to remote operations.

Class Recordings: All lectures will be recorded via zoom. Students must access content in D2L only. Students may not modify content or re-use content for any purpose other than personal educational reasons. All recordings are subject to government and university regulations. Therefore, students accessing unauthorized recordings or using them in a manner inconsistent with UArizona values and educational policies are subject to suspension or civil action.