PHY 400: Astrophysical Fluids
Spring 2025 Course Syllabus

Overview

A fluid can be summarized as a collection of objects, known as fluid elements, that retain average macroscopic properties (e.g., temperature, density, pressure) despite being governed by the motion and interaction of atoms at the microscopic level. A fluid description is self-consistent (or at least appropriate) if each fluid element contains many atoms, such that averaging over the distribution of these atoms yields a meaningful macroscopic quantity. In this class we will build up the fundamentals of fluid dynamics, keeping astrophysical applications in mind but with the understanding that the concepts are much more generally usable.

Course details

Instructor	**Eric Coughlin** **Email**: ecoughli@syr.edu **Office:** 263-4 Physics Bldg. **Office Hours:** Wednesdays, 12:00-1:00 PM (or by appt)
Meeting time	**MW 11:00 – 12:20, PB 106**
Concerns	Please contact me if you have any concerns.
Credits	3
Prerequisites/ Corequisites (400-only)	Prereq: PHY 302 or MAT 485 Coreq: PHY 517 or PHY 524
Blackboard	I will use Blackboard to convey course information and post grades.

Textbook

None

Grading

There will be no exams in this class; your grade will be determined by attendance, homeworks, and a final paper:

Homework & In-class Work+Participation – 50%
Final Paper – 50%

Your grade in this course is not curved. Thus, it is possible for every student in the class to get an "A". Your course grade will be based on the following scale:

		A	90-100	A-	85-89
B+	80-84	B	75-79	B-	70-74
C+	65-69	C	60-64	C-	55-59
D	40-54				
F	0-39				

Homework and In-class Work: We will have roughly biweekly homework assignments spread throughout the semester. These assignments will likely be challenging, and will probably contain some numerical components (though nothing too serious; see the learning objectives below for the motivation).

I will also try to do some in-class problem sets, or at least ``clicker''-type questions throughout the semester, which will be graded (mostly) on effort. These are simultaneously designed to get you to come to class and participate. Your completion of these additional problems, or just participation in the clicker questions, will also go toward your ``homework'' grade. There is also a small possibility that I will have you present something, and, if so, your presentation grade will also be included here.

Final Paper: We will have a final project that will consist of a written paper on an astrophysical topic, and the fluid dynamics thereof, of your choice (but approved by me). I will hand out a separate document that details the specifics of the paper and what should be included to receive full credit. ***The due date for this is April 28th, 2025, by 4pm (but you are welcome to get it to me sooner ☺).***

Grading at the 400 & 800 levels

This class consists of a special-topics undergraduate (PHY 400) and special-topics graduate (PHY 880) course, with comparable numbers of undergraduate and graduate students; in future years it will be two separate fluids courses, one at the 500-level and the other at the 700-level. To make the class appropriately difficult for each population, homework assignments will contain some problems that are **required only for graduate students**, and will be **extra credit for undergraduates**. Similarly, the final paper will be somewhat longer for graduate students.

Class learning objectives

The content of this course is focused on fluid dynamics, with the definition of a ``fluid'' given above, and its application in astrophysical settings. Our main learning goal is to understand the physics of fluids and apply that understanding to solve problems.

I also have a less well-defined goal, which is to have you gain some experience with ``real-world'' problem solving and to develop softer skills that will be useful in your professional lives. Some of your homework assignments will therefore contain numerical components – real scientific problems can almost never be solved entirely with pencil and paper – in which you will use computational software of your choice to solve problems and/or make plots (though I will likely make suggestions and give you hints as to what you might do to solve them). The final paper will also use LaTeX, which is a piece of software used to make professional-looking PDFs. In the future I may also include presentations as part of the course, but you (probably, I may still try to do this) get off easy this time around in this regard.

Calendar

Week	*Date*	*Specific Topics*	*Broader Topics*
1	1/13	Introduction; mechanics recap; math recap; fluid descriptions (Lagrangian vs Eulerian); coordinate systems (curvilinear coordinates)	Fluid equations
2	1/20	Fluid equations: continuity, momentum, and gas-energy equations; discussion of gravitational fields	Fluid equations
3	2/3	General equilibria; hydrostatic equilibrium; planar atmospheres	Equilibria
4	2/10	Wave equation; adiabatic sound speed; spherical oscillations and eigenvalues	Waves and perturbations
5	2/17	Shocks and contact discontinuities; Rankine-Hugoniot jump conditions	Discontinuities
6	2/24	Self-similarity; coordinate transformations; energy-conserving blastwaves	Strong Explosions
7	3/3	Incompressible flow; two-dimensional and steady flow; irrotational flow	Two-dimensional flow
8	3/10	Spring break!	Hooray!
9	3/17	Stream function and velocity potential; potential flow theory; complex variables	Two-dimensional flow
10	3/24	Stability of discontinuities; Kelvin-Helmholtz instability; Rayleigh-Taylor instability	Two-dimensional flow
11	3/31	Newtonian stresses and viscosity; dynamical vs kinematic viscosity; Navier-Stokes equations	Viscous flows
12	4/7	Two-dimensional viscous flow; Couette and Poiseuille flow; Stokes' first and second problems	Viscous flows
13	4/14	Boundary layer theory; self-similar transformations; boundary layers (Blasius+free-streaming jet)	Viscous flows
14	4/21	Black hole accretion	Viscous flows
15	4/28	Class is over (last class Th. 4/24)	Hooray!

Health & Wellness

What to do if you're not feeling well: One of the most important things you can do is to **stay home if you are sick. What to do if you're seriously sick:** If you have an illness or injury that interferes with your ability to do work in our class, *talk to me!* The Center for Disability Resources also helps students with short-term injuries and illnesses – concussions, broken bones, etc. If you are sick or hurt, we will work with you and with CDR to accommodate your condition.

Academic Integrity and Artificial Intelligence (AI)

As a pre-eminent and inclusive student-focused research institution, Syracuse University considers academic integrity at the forefront of learning, serving as a core value and guiding pillar of education. Syracuse University's Academic Integrity Policy provides students with the necessary guidelines to complete academic work with integrity throughout their studies. Students are required to uphold both course-specific and university-wide academic integrity expectations such as crediting your sources, doing your own work, communicating honestly, and supporting academic integrity. The full Syracuse University Academic Integrity Policy can be found by visiting class.syr/edu, selecting, "Academic Integrity," and "Expectations and Policy."

Upholding Academic Integrity includes the protection of faculty's intellectual property. Students should not upload, distribute, or share instructors' course materials, including presentations, assignments, exams, or other evaluative materials without permission. Using websites that charge fees or require uploading of course material (e.g., Chegg, Course Hero) to obtain exam solutions or assignments completed by others, which are then presented as your own violates academic integrity expectations in this course and may be classified as a Level 3 violation. All academic integrity expectations that apply to in-person assignments, quizzes, and exams also apply online.

Students found in violation of the policy are subject to grade sanctions determined by the course instructor and non-grade sanctions determined by the School or College where the course is offered. Students may not drop or withdraw from courses in which they face a suspected violation. Any established violation in this course may result in course failure regardless of violation level.

All generative-AI tools are prohibited in this course because their use inhibits achievement of the course learning objectives. This policy applies to all stages of project and writing processes including researching, brainstorming, outlining, organizing, and polishing. Do not use Generative-AI tools to create any content (i.e., images and video, audio, text, code, etc.). If you have any questions about a feature and whether it is considered Generative-AI, ask your instructor.

Disability-related accommodations

If you believe that you need accommodations for a disability, please contact the Office of Disability Services (ODS), http://disabilityservices.syr.edu, located in Room 309 of 804 University Avenue, or call (315) 443-4498, TDD: (315) 443-1371 for an appointment to discuss your needs and the process for requesting accommodations. ODS is responsible for coordinating disability-related accommodations and will issue students with documented "Disabilities Accommodation Authorization Letters", as appropriate. Since accommodations may require

early planning and generally are not provided retroactively, please contact ODS as soon as possible.

Religious observances policy

SU religious observances notification and policy, found at http://hendricks.syr.edu/spiritual-life/index.html, recognizes the diversity of faiths represented among the campus community and protects the rights of students, faculty, and staff to observe religious holidays according to their tradition. Under the policy, students are provided an opportunity to make up any exam, study, or work requirements that may be missed due to a religious observance provided they notify their instructors before the end of the second week of classes for regular session classes and by the submission deadline for flexibly formatted classes.

For fall and spring semesters, an online notification process is available for students in MySlice / StudentServices / Enrollment / MyReligiousObservances / Add a Notification. Instructors may access a list of their students who have submitted a notification in My Slice Faculty Center.

Equal opportunity, inclusion and resolution services

The Code of Ethical Conduct is a statement of principles guiding the activities of all faculty, staff, and students. It provides, in part, that we: Respect the rights and dignity of all persons and recognize that discrimination or harassment in any form undermines the fundamental principles of the University; and Support a respectful environment through our own actions, encourage respectful behavior in others, and speak out against hatred and bias. Additional information can be found at www.syr.edu/hcd/equal-opportunity.html. If you have any concerns about these matters, write to the Office of Equal Opportunity, Inclusion and Resolution Services at titleix@syr.edu.

We want to hear your feedback! You are an important part of our community, and we value your opinion; if you have any comments, concerns, or suggestions that you would like to relay anonymously, we have an anonymous survey you can find by using the QR codes in the dept.