AE 311 – Incompressible Flow

Spring 2024

General Information

Instructor:
Laura Villafañe Roca

Office Hours & Location
Monday 3-4 pm @ TBD

Teaching Assistants
Matthew Lauer, Farhad Hasanli

Office Hours & Location
TBD

Course Assistants
To be confirmed: NL, LH, PP

Lectures
MWF 1:00-1:50 pm, 3025 Campus Instructional Facility. From January 17th to May 1st 2024.

Office Hours

Start date: Monday January 22nd. *No office hours during Spring break,*

You may walk-in to any office hour session that suits you. Please bring to office hours any question you might have about the course material. You can also use office hours to ask clarifications about homework, to get help with specific parts of a problem that you have doubts on how to approach, etc. If requested by a group of people, we can dedicate some office hours time to revisit specific parts of course materials.

Online Course Platforms

We will use two online platforms that will be monitored by course staff, Canvas and Gradescope. In addition we have created a Discord server for you to communicate with your peers and that will not be monitor by the instructor, TAs or CAs.

- We use **Canvas** as our course website.
  - All course content including handouts, problem sets and their solutions, quiz links, and any other supplemental material will be posted as the course evolves in Canvas in section *Modules* (see Course Structure and Course Components/Lectures below).
  - We will also use Canvas for all written communications outside of lecture times. Individual or group exchanges between the instructor/TAs/CAs and students will use *Canvas mail application*, including any private or personal matter (DRES, justified absence, etc). Emails outside of Canvas platform will not be answered by the instructor. Public announcements (in addition to those made in class if needed), and open discussions regarding course material or homework will also be hosted in Canvas, in sections *Announcements* and *Discussions*, respectively You are encouraged to make public questions about concepts, homework or any other related topic you think might be interesting for all (post course related cool applications or news, etc). You are also encouraged to answer questions from your peers. For those that find this scary you can post anonymously. The instructor and TAs will act as moderators, indicating when answers provided by classmates are correct or not, and adding further clarification when needed. Note that you are encouraged to post questions regarding homework as long as you do not violate the HW guidelines (see corresponding section in Syllabus). In short: no, you cannot post HW solutions; yes, you are encouraged to ask clarifying questions. If you have lengthy or complex questions about HW or class material, please bring those to office hours.

You are automatically enrolled to Canvas if you are registered for this course.

Turnaround times: expect responses to Canvas questions within 24-48 hours Monday through Friday. Responses will generally be faster than that, but it is not a norm.

- We have created a Discord server for you to communicate with your peers which you can join through this link **AE311 Spring 2024-Discord.** The link for joining is set to expire in 30 days.
- We use **Gradescope** for **all submissions** (homework, quizzes and projects). Links to shared folders will be shared if needed to upload group project deliverables.

  Those of you enrolled in the course by January 12 2024 will be added to Gradescope. If you enrolled after that date please reach out to the instructor via Canvas.

Course Description and Goals:

AE 311. The Class. Welcome to the world of fluid dynamics! As aerospace engineers, an evident motivation to learn fluid dynamics is to understand how "air flows" around bodies with important engineering goals like predicting lift and drag on wings and designing aerodynamic bodies for a wide range of applications. Fluid dynamics extends beyond aerodynamic applications to help us understand and model all natural flows we interact with (atmospheric phenomena, river flows, etc) and those foundational to many engineering devices. We are surrounded by moving fluids! To truly master fluid dynamics, and more specifically aerodynamics, we need to grasp the fundamentals of how fluids move: What defines a fluid? What are the equations that govern the motion of a fluid, and how amenable are these equations to analytical solutions? What assumptions can we make in different contexts and how do those simplifications facilitate meaningful progress towards approximating the flow behavior? We will answer these questions in the incompressible regime, where the Mach number is sufficiently small, so that the flow is moving slow relative to the speed of sound (AE 312 covers the other side of the limit).

Learning Goals: The goals of this course can be summarized in three fundamental questions:

What are incompressible flows?
Why do we need incompressible flow?
How do we solve incompressible flow problems?

At the end of the course you will be able to:

- Describe and understand fluid motion both qualitatively and quantitatively
- Reduce many common fluid problems present in our daily life to a set of assumptions, unknown variables and equations that provide a closed solution.
- Differentiate between exact solutions and assumptions and understand the implications of each assumption
- Make use of different problem-solving skills to a wide variety of engineering problems: approach complex or novel problems, iterative solving strategies, using self-reflection to find alternative paths.
- Explain the origin of the fluid equations of motion and discriminate when to use integral and differential formulations
- Explain the origin of aerodynamic forces in bodies immersed in a moving fluid and be able to calculate their value
- Estimate the aerodynamic performance of two-dimensional and three-dimensional bodies and explain the role of viscous effects and the reach of inviscid theories.
- Discuss what modifications you would incorporate in an airfoil or wing to obtain a desired aerodynamic performance.
- Describe the role of viscosity in fluid dynamics and provide estimates for friction forces.

Course Structure, Materials, Prerequisites and Expectations:

Structure and content: This is a **3 credit hour** course. The course is divided in six modules.

Modules	Reference Text's section
1. Introduction	1.1 - 1.4, 1.9 - 1.11, 2.2
2. Governing Equations	2.3 - 2.6, 2.9 - 2.12, 3.2 - 3.5
3. Potential Flow Theory	2.13 – 2.16, 3.7 – 3.18, 1.5 - 1.6
4. Inviscid Incompressible Flow Over Airfoils	4.1 – 4.10
5. Inviscid Incompressible Flow Over Finite Wings	5.1 - 5.3
6. Viscous Flow	15.2 – 15.4, 16.2 – 16.3, 17.1 – 17.4, 18.2, 19.1 – 19.3

Reference Text: (Recommended but not required)

Certain sections of the reference text will be made available in PDF via Canvas. Hard copies are available at the University Engineering Library

→Fundamentals of Aerodynamics, 5th or 6th Edition, John D. Anderson, Jr., McGraw-Hill,2011/2016.

Note: the reference text should be considered as recommended reading material. It does not substitute the course lectures. The order and context in which different concepts are presented is not always equivalent.

Other useful textbooks:

1. Foundations of Aerodynamics, 5th edition, A.M. Kuethe and C.-Y. Chow, Wiley, 1998.
2. Aerodynamics, Aeronautics and Flight Mechanics, 2nd edition, B.W. McCormick, Wiley, 1995.
3. Aerodynamics for Engineers, 6th edition, J.J. Bertin and R.M. Cummings, Pearson, 2014.
4. Theoretical Aerodynamics, E. Rathakrishnan, Wiley, 2013.
5. Introduction to Fluid Mechanics, 8th ed., R.W. Fox, P.J. Pritchard, and A.T. McDonald, Wiley, 2011.
6. Viscous Fluid Flow, 3rd edition, F.M. White, McGraw Hill, 2006.
7. Boundary Layer Theory, 8th edition, H. Schlichting and K. Gersten, Springer, 2000.
8. An Album of Fluid Motion, M. Van Dyke, Parabolic Press, 1982.

Video Channels:

1. NSF Fluid Mechanics Series https://www.youtube.com/playlist?list=PL0EC6527BE871ABA3
2. F Yeah Fluid Mechanics https://www.youtube.com/user/fyfluiddynamics
3. Gallery of Fluid Motion https://gfm.aps.org/
4. National Committee for Fluid Mechanics Films, NCFMF http://web.mit.edu/hml/ncfmf.html

We will use some of these sources during the lectures. The NCFMF is a great source of knowledge by Ascher Shapiro. Videos are old in style but remain one of the best lecture series in Fluid Mechanics. Highly recommended.

Course Prerequisites: AE202, MATH 241

Expectations:

Student Expectations

- Please be active and participate in class
- Listen and respect others
- Be comfortable taking risks
- Complete all assignments
- Turn off/keep away & in silence your cell phones (unless announced otherwise for in-class activities)
- Be punctual for classes
- Discuss class concerns with TAs or instructor

Instructor/ TAs Expectations

- Be active and enthusiastic to facilitate student learning
- Listen and respect students' views
- Respond effectively to student concerns
- Grade objectively, consistently and in a timely manner
- Be prepared for class
- Accommodate differences in students' learning

Course Components and Assessment

Lectures (3/week)

The lectures will be fairly traditional, with in-person sessions that will use slide-based lectures and supplemental board/tablet work for example problems or as driven by student questions (please ask questions!). Lecture slides and related supplemental materials will be posted to Canvas in the corresponding module. In some instances, and always with prior announcement, assigned readings might be posted prior to the lecture time.

In person lectures will not be recorded. Students who miss lectures should timely check Canvas for posted notes and material covered, use the reference book, reach out to course peers if needed, and complete post-lecture quizzes to remain up to date with the course evolution.

Materials will be posted in Canvas organized by modules (see course structure and content above). For each module information on the detailed outline, learning goals, and class progress will be shared. Students have reported finding this information very useful to keep up with the course progress, to summarize learnings and review materials. (Further improvements/suggestions are welcomed!)

Students are referred to the course reference text and books indicated in other resources if further interested in the topics covered in class. Please reach out to the instructor or TAs during office hours for further knowledge or clarifications.

Post-lecture quizzes:

Short post-lecture quizzes will be posted in Gradescope following (almost or every) lecture. They are meant to reinforce lecture concepts and help you stay up to date with the material. They also serve to identify unclear concepts so that I can address them in following lectures. They will be posted by 4pm the day of the lecture at the latest (generally will be available right after the lecture) and submission will close by default at the end of the day of the following class. No late submission or exception will be granted but up to 3 missed post-lecture quizzes are allowed, this is, they will not be considered for grading.

Example: for a class on Monday, submission will close Wednesday at 23:59, for a class on Friday submission will close on Monday at 23:59. They will consist of multiple choice, true-false questions or at times short problems.

Homework:

Assigned: Homework will be assigned on Fridays and will be made first available in Canvas (in the corresponding Module in chronological order when posted). About 5-6 homework are to be expected depending on projects and class evolution. This is, there will not be homework assigned every week but we will have some of the assignments on consecutive weeks. When posted a notification will be made during the lecture. It will also automatically show in your Canvas Calendar and under "Course Summary" in the Syllabus section in Canvas. It is important that you pay close attention to assignments and due dates, especially if you miss a lecture.

Due: before the end of the day (11:59 pm) one week after assignment is posted.

Drop policy: At the end of the semester, the (one) homework with the least credit will not be used for the calculation of your grade. This can potentially include a non-submitted homework. Note that you are still responsible for learning that material.

Late policy: Late homework submission will be accepted up to 48 hours after the due date/time with a 25% penalty on the maximum grade within 24 hours after the deadline, and 50% penalty after 24 hours but within 48 hours. The 48-hour deadline after the due date/time is a hard deadline.

Solutions: Homework solutions will be posted 48 hours after the due date to Canvas. Solutions will be provided with great detail and are meant as additional course material.

Submission guidelines. Homework must be submitted in Gradescope by the due date/time as a **single PDF file**. You can find guidelines on scanning and submitting your homework on Gradescope Student Center. Gradescope will allow unlimited submission attempts until the deadline +48 hours (incurring penalty), and no submission thereafter.

Homework and project guidelines. Submissions must include all derivations, explanations, figures, data and any code that you have used to produce your solution. Detailed guidelines, quality requirements and tips for full credit are described in the separate document "Homework Guidelines", available in Canvas in Syllabus section. Make sure you check it as many times as needed and certainly prior to the fist HW assignment, and ensure your submission complies for full credit. You will not get full points for an assignment that does not provide sufficient information on how the solution was obtained, that cannot be understood or that lacks the code used to generate the results, even if the final answer is correct.

Each assignment turned in must be your own individual work. You are encouraged to discuss your problem sets, but each student should prepare and submit their own work, code, and plots. *Submitting the work of another (person or machine) as one's own, or facilitating such a submission: 1) goes again your best interest and is a lost opportunity for you to learn, 2) is considered an infraction of academic integrity as outlined the Student Code of the University of Illinois at Urbana-Champaign and may be reported via the FAIR system, in addition to not given any credit.*

Mini-Projects

Instead of exams, we will have two projects for AE311. Each project will have two deliverables, one will be individual work and the second one will be group work. You are encouraged to start choosing your team members, groups will be of 4-5 people. Each project is expected to take more effort and critical thinking than a homework. Projects will have a component that is open-ended by design and will offer you an opportunity to dive in and extend your knowledge beyond the course material.

Each group will only upload one submission per group (as opposed to having each student submit individually). Note that it need not be the case that all group members earn the same grade for the group portion of the project. In situations where it is clear that a group member (members) is (are) not contributing adequately, their grade for the group portion of the project may be less than the nominal group grade. Make sure that you are prompt in responding to meeting requests, contributing to the technical evolution and writeup/presentation of the project, etc., to ensure that you and your team all receive the same grade on the group portion of the project.
The total project grade will be assigned from a 50/50 split of the individual and group grades. For example, for Project 1 your grade worth 22% of your total course grade will be computed as 0.5x your grade on the individual portion +0.5x your grade for the group portion.

Project expected timelines:
The dates indicated below are informative and might be subject to change depending on the class evolution. The date change will not be by more than a week maximum. Any change will be announced in class, Canvas and Gradescope on a timeline manner.

-**Project 1** individual component is expected to be released on February 16 with due date Monday Feb. 26. P1 group component will be released on the same date with due date March 8th.
Group members P1: You should enter the names and surnames of your group in this online spreadsheet by **February 16**. Past that date, we will randomly assign students to groups. Information will be visible on the same spreadsheet. Note that if you created a group with 3-4 people it is possible that we assign 2-1 members to your group to ensure all groups have 4-5 participants.

-**Project 2** individual component is expected to be released on April 12 with due date on Monday April 22. Project 2 group component will be released on April 12 with due date on May 1st.
Group members P2: You should enter the names and surnames of your group in this online spreadsheet (tab2) by **April 12**. Past that date, we will randomly assign students to groups. Information will be visible on the same spreadsheet. Note that if you created a group with 3-4 people it is possible that we assign 2-1 members to your group to ensure all groups have 4-5 participants.

Grading Policies

a) Grading Scheme:

Homework	40 %
Post-lecture quizzes	8 %
Project 1	22 %
Project 2	30 %

All assignments will be graded on a scale 0-100. While each individual assignment might have assigned a different number of points (and each problem within a homework does not necessarily need to count the same number of points), the final score of a given assignment will be considered in percent of the total points. (Example: HW X has a total of 85 points. A student gets 80/85 points. The student will be getting a score of 94.1/100 points.) This way each HW counts equally towards the final HW grade.

Grades of 90, 80, 70, and 60 guarantee at least an A-, B-, C- and D-. The cutoffs might be lowered to account for challenging assignments, but they will not be raised.

Participation: Please contribute to the class environment by asking questions and participating in discussions! Your interaction (in class and/or Canvas) will be considered when assigning borderline grades, as it will improving performance throughout the course of the semester.

b) **Grading assignments**: Most questions on homework and project assignments will be graded for correctness of approach and final answer, with significant partial credit given for explaining your reasoning and your problem-solving process. Some open-ended questions will be graded on effort rather than on complete correctness. To get full credit review the HW guidelines document. Neatness and clarity of presentation will affect the credit; confusing or illegible content will be considered wrong.

c) Regrading Policy: Regrade of homework or exam will follow this process:

- You must wait 24 hours after receiving your returned item before requesting a regrade. During this time, review the posted solutions and carefully consider what the dispute is and why you believe an error has been made. While we all are humans and make errors, unjustified regrade requests might result in lower scores after scrutiny.
- Requests should be made in Gradescope, with rationale, and within one week of returned items. After one week no dispute will be considered.
- If you and the TAs/CAs do not reach agreement, we will meet and resolve the matter.

Justified absences

Events do happen that lead to justified class absences. Read the separate document "AE 311 absences and exceptions", available in Canvas in Syllabus section with guidelines of what to do to stay up to date with the course materials.

Important notes and statements

Anti-Racism, diversity, and Inclusivity Statement

The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community.

The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can report these behaviors to the Bias Assessment and Response Team (BART). Based on your report, BART members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported

behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action. Read the separate document "Guidelines for classroom interactions", available in Canvas in Syllabus section with expectations for our class/

It is the instructor's intent that students from all diverse backgrounds and perspectives be well served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength, and benefit. It is the instructor's intent to present materials that are respectful of diversity: gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture. Your suggestions are encouraged and appreciated. Please let the instructor know of ways to improve the effectiveness of the course for you personally or for other students.

Academic Integrity

The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: http://studentcode.illinois.edu/
Academic dishonesty may result in a failing grade. Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt.

Religious Observances

Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your religious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at https://odos.illinois.edu/community-of-care/resources/students/religious-observances/ to request appropriate accommodations. This should be done in the first two weeks of classes.

Disability-Related Accommodations:

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities **must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible**. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603, e-mail disability@illinois.edu or go to https://www.disability.illinois.edu. If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnosis a previously undiagnosed disability. You may access these by visiting the DRES website and selecting "Request an Academic Screening" at the bottom of the page.

Family Educational Rights and Privacy Act (FERPA):

Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See https://registrar.illinois.edu/academic-records/ferpa/ for more information on FERPA.

Extra Resources to Succeed

Counseling Center

Counseling Center services are designed to help students address many of the academic, relational, social, and emotional concerns they face. The Counseling Center provides a same-day appointment

system. To schedule a same-day, confidential appointment please call 217-333-3704 any time after 7:50 a.m., Monday through Friday or go to the Counseling Center website.

Health Center

The McKinley Health Center provides medical services to students University of Illinois at Urbana-Champaign. The Health Service Fee, which is paid as part of your enrollment, provides the funds to prepay many of your health care needs. To schedule appointments please call 217-333-2700, Monday through Friday, 8 a.m. to 5 p.m. or go to the McKinley website. For ambulance or emergency situations dial: 911 (from a campus phone: 9-911).

Office of the Dean of Students

The Office of the Dean of Students implements a variety of programs and services to assist and support students in achieving academic and personal success. The Office provides important educational and developmental opportunities, serves as student advocates, empowers students to be successful, and promotes students' rights and responsibilities. For more information, please visit the Office of the Dean of Students website.

Center for Academic Resources in Engineering

The Center for Academic Resources in Engineering (CARE) enhances the learning experience for all undergraduate engineering students through academic support, enhancing collaborative learning opportunities, and providing positive influence through peer mentoring. For more information, please visit the CARE website.

Run > Hide > Fight

Emergencies can happen anywhere and at any time. It is important that we take a minute to prepare for a situation in which our safety or even our lives could depend on our ability to react quickly. When we're faced with any kind of emergency – like fire, severe weather or if someone is trying to hurt you – we have three options: Run, hide or fight.

Run

Leaving the area quickly is the best option if it is safe to do so.

- Take time now to learn the different ways to leave your building.
- Leave personal items behind.
- Assist those who need help, but consider whether doing so puts yourself at risk.
- Alert authorities of the emergency when it is safe to do so.

Hide

When you can't or don't want to run, take shelter indoors.

- Take time now to learn different ways to seek shelter in your building.
- If severe weather is imminent, go to the nearest indoor storm refuge area.
- If someone is trying to hurt you and you can't evacuate, get to a place where you can't be seen, lock or barricade your area, silence your phone, don't make any noise and don't come out until you receive an Illini-Alert indicating it is safe to do so.

Fight

As a last resort, you may need to fight to increase your chances of survival.

- Think about what kind of common items are in your area which you can use to defend yourself.
- Team up with others to fight if the situation allows.
- Mentally prepare yourself – you may be in a fight for your life.

Please be aware of persons with disabilities who may need additional assistance in emergency situations.

Other resources

- **police.illinois.edu/safe** for more information on how to prepare for emergencies, including how to run, hide or fight and building floor plans that can show you safe areas.
- **emergency.illinois.edu** to sign up for Illini-Alert text messages.
- **Follow the University of Illinois Police Department** on Twitter and Facebook to get regular updates about campus safety.