AME 460 Aerodynamic Theory

University of Southern California – Spring 2023

Course Syllabus

Term	Spring 2023 (January 9 – May 10 , 2023)
Lectures	Tuesdays & Thursdays, 9:30 – 10:50am, in VHE 214
Instructor	Alejandra URANGA ▪ Email: `auranga@usc.edu` ▪ Office: OHE 500P Office Hours: Tuesdays 11:00am – 12:30pm Wednesdays 9:30 – 11:00am

The most effective way to communicate with the instructor is via Piazza (see below). If you reach out via email, please use your USC email account and allow 2–3 days to receive a reply.

Course Description

The goal of the course is to teach the fundamental concepts and techniques used in aerodynamics—the study of the flow of air about a body—as applied to subsonic, transonic, and supersonic regimes. Topics covered include conservation principles, incompressible flows, potential flows, thin airfoil and lifting line theories, quasi-one-dimensional compressible flows and shocks, small disturbance approximation, and an introduction to viscous flows and boundary layer theory.

Learning Outcomes

Upon completion of this course, students will be able to:

a) Understand how the aerodynamic forces that a fluid exerts on a body are produced, and relate them to pressure and viscous stresses on the body's surface; Define lift and drag, and understand the importance of the lift-to-drag ratio in aerodynamics; Define and use lift, drag, moment, and pressure coefficients;

b) Understand and decide when the flow may be considered inviscid, and/or incompressible, and when the use of potential flow analysis is appropriate; understand and explain the major differences between: incompressible and compressible flow; viscous and inviscid flow; rotational and irrotational flow;

c) Understand and apply the conservation laws (continuity, momentum, and energy) in differential form, and understand flow kinematics; Explain the relation between streamline curvature, pressure gradient, and lift generation;

d) Relate lift to circulation, and be able to apply Thin Airfoil Theory and lumped vortex methods to 2D airfoils and problems in incompressible potential flow;

e) Understand and use loading distributions to determine the performance of wings, including through the use of lifting line theory concepts; Understand the source of induced drag and how to predict it;

f) Determine changes in flow properties due to changes in flow direction in compressible supersonic flow using shock-expansion theory, and understand the source of wave drag;

g) Understand and apply linearized potential flow to compressible subsonic and supersonic flows to determine forces over bodies;

h) Determine an airfoil's critical Mach number, and understand the particularities of transonic flow, including the detrimental effects of the drag divergence and how they can be mitigated.

Textbook

John D. Anderson Jr., *Fundamentals of Aerodynamics*, 6th edition, 2016, McGraw-Hill (*Note: an older edition can also be used*)

Required Preparation

- AME 309 Dynamics of Fluids, or equivalent course in fluid mechanics
- Basic physics, vector calculus, and differential equations, at a level common to 1st year college

Grading

- Homework: 50% of final grade (two lowest grades dropped)
- Midterm exam: 30% of final grade (in-class and take-home parts)
- Final exam: 20% of final grade (in-class)

References

We will be following Anderson's textbook closely, but there are a number of other good books on aerodynamics. The following references are good complements for those students who want to get another perspective or go in more depth on the material.

Fundamentals:

- J. Katz and A. Plotkin *Low-Speed Aerodynamics*, Cambridge University Press
- J.D. McLean, *Understanding Aerodynamics*, Wiley

Advanced Topics:

- M. Drela, *Flight Vehicle Aerodynamics*, MIT Press
- F.M. White, *Viscous Fluid Flow*, McGraw-Hill
- H. Schlichting, *Boundary Layer Theory*, Springer

Resources

Desire2Learn (D2L, DEN@Viterbi Course's Page) https://courses.uscden.net

DEN@Viterbi's D2L online course management platform will be used used to distribute all course material, including assignments, and to send announcements. Make sure you are able to log in and see the course, then familiarize yourself with the platform. Also check your preferences so you don't miss course notifications. **Note: We use D2L instead of Blackboard.**

Piazza Discussion Forum https://https://piazza.com/usc/spring2023/20231ame460

You are strongly encouraged to use the **Piazza discussion forum** to ask questions, make comments, and answer questions from your peers. Piazza is great for asking technical questions, since you can enter mathematical formulae, and insert images and attachments. When discussing homework assignments, *do not give out the answers to questions!* That would be a violation of the Collaboration Policy. Public posts related to graded assignments should only be for clarification purposes. *No posts are allowed while a take-home exam is out.*

If you are unsure whether you are revealing too much, you can use a private post that only the instruction team can see (under "Post to" select "Individual Student(s) / Instructor(s)" and then type "Instructors" in the corresponding field).

Gradescope for Homework and Exam Submission https://gradescope.com

We will use **gradescope** for homework and exams. You are responsible for uploading your work electronically on time, and you will see your grade and comments once they are graded.

You can access the gradescope class page from the top menu bar in D2L, or once you have registered directly at gradescope.com.

Zoom https://usc.zoom.us

If we must move to online teach, we will use Zoom to conduct live lectures and office hours. You will receive a notification in advance if a lecture will be delivered online.

Course Policies

My goal is to make this class an exciting and challenging learning experience for all of you! But it is a team effort, and **you will get the most out of this class by being active.**

These course policies are designed to help students learn the material effectively, and the course assessment system is designed to best test students on what they really know, and can effectively use, in a real-world context. To ensure fairness, the rules will be strictly enforced.

Attendance and Participation

- You are expected to attend the lectures in person, so lectures will not be recorded. If you get sick or are unable to attend lectures, let the instructor know.
- You will get the most out of this class if you are active and participate. Do not hesitate to ask questions, whether in class, on Piazza, or during office hours.
- Solutions to homework and exam assignments will not be posted online, but hard copies will be distributed in class — another reason to come to class.

Collaboration

- Collaboration of any sort on all matters that are not graded is strongly encouraged.
- Students may discuss the homework problems with one another, but no written or digital material can be part of such exchanges. *If it's not in your head, it isn't yours.* The corollary is that *you must develop and write your own solutions*.
- *Absolutely no collaboration is allowed on take-home exams*: these are individual efforts, and you are not allowed to discuss them with anyone else than the instructor.
- We will be very strict about academic integrity violations and report them as appropriate.

Homework Assignments

- Weekly homework will be assigned on Thursdays and due the following Thursday most weeks (except before exams). It is due *before* class begins on the due date. To be fair to everyone, late submissions will incur a 20% penalty after the due *time* (9:30am) and for each 24h delay.
- Homework must be submitted via **gradescope**.
- Your solutions must be clear and your handwriting legible (you may handwrite or type your solutions
- The two lowest homework grades will be dropped when computing the homework portion of the final grade. These can of course include homeworks that you do not submit.
- In order to receive full credit, solutions must be presented in a clear manner, and show evidence of work, including all steps: magical one-line answers do not make the cut. The reasoning is as important as the solution. *This also applies to the exams*.
- If you have questions or concerns about the grading of your assignments, you must submit a regrade request on gradescope within two weeks of receiving the grade for the corresponding assignment.

Office Hours

- Office hours are held by the instructor (see first page for days and times).
- If you cannot make any of the office hour times, contact the instructor to request a meeting a t a different time. You are also strongly encouraged to **post your questions** on Piazza at any time, and to answer other student's questions.
- Office hours provide a good opportunity for you to get clarifications and better understand the course material. This time is best utilized when you come with *clear questions* and at least *an attempt at a solution.* The goal is for us to help you clarify the concepts and guide you through your thought process. *It is not meant as a way for you to effortlessly obtain the solutions.* So come often but come prepared.

Topics and Tentative Schedule

*You are responsible for reading the chapter(s) in the textbook **before** the corresponding lecture.*

Week	Date	Topics	Reading
1	JAN 10, 12	**I.** Introduction . Forces and moments . Flow similarity . Aerodynamic performance	Ch. 1
2 3	JAN 17, 19 JAN 24, 26	**II.** Conservation laws . Conservation of mass, conservation of momentum . Intrinsic coordinates, streamlines, stream function	Ch. 2
4 5 6 7 8	JAN 31, FEB 2 FEB 7, 9 FEB 14, 16 FEB 21, 23 FEB 28, MAR 2	**III.** Incompressible potential flows . Equations, flow modeling . Non-lifting flow models . Lifting flow models . 2D aero modeling . 3D aero modeling	 Ch. 3, 6 Ch. 4 Ch. 5
9 10	MAR 7, 9 MAR 14, 16	**IV.** Shock-expansion theory . Gas dynamics, energy equation . Normal shocks *No class (Spring recess)*	 Ch. 7 Ch. 8
11	MAR 21 MAR 23	Midterm review **Midterm exam, in-class part**	
12	MAR 28 MAR 30	**IV.** Shock-expansion theory (cont.) . Oblique shocks, expansion waves . Quasi 1D flows and applications **Midterm exam, take-home part: due Thursday March 30**	 Ch. 9 Ch. 10
13 14	APR 4, 6 APR 11, 13	**V.** Inviscid compressible aerodynamics . Full potential flow . Small disturbances, perturbation potential . Linearized compressible potential flow . Subsonic linearized potential flow, Prandtl-Glauert . Supersonic linearized potential flow . Transonic flows and design considerations	Ch. 11, 12
15 16	APR 18, 20 APR 25, 27	**VI.** Viscous flows and boundary layer theory . Viscous flows fundamentals . Boundary layer equations and integral parameters . Laminar boundary layers . Turbulent boundary layers . Stability, transition, and other viscous flow considerations	 Ch. 15 Ch. 17 Ch. 18 Ch. 19
	MAY 9	**Final exam Tuesday May 9, 8 – 10am**	

Statement on Academic Conduct and Support Systems

Academic Conduct

Plagiarism — presenting someone else's ideas as your own, either verbatim or recast in your own words — is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, "Behavior Violating University Standards" https://policy.usc.edu/scampus-part-b/. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Support Systems

Student Counseling Services (SCS) – (213) 740-7711 – 24/7 on call
https://engemannshc.usc.edu/counseling/
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline – 1-800-273-8255 – 24/7 on call
http://www.suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship & Sexual Violence Prevention Services (RSVP) – (213) 740-4900 – 24/7 on call
https://engemannshc.usc.edu/rsvp/
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED) | Title IX – (213) 740-5086
https://equity.usc.edu, http://titleix.usc.edu
Information about how to get help or help a survivor of harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants. The university prohibits discrimination or harassment based on the following protected characteristics: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations.

Bias Assessment Response and Support – (213) 740-2421
https://studentaffairs.usc.edu/bias-assessment-response-support
Avenue to report incidents of bias, hate crimes, and microaggressions for appropriate investigation and response.

The Office of Disability Services and Programs – (213) 740-0776
http://dsp.usc.edu
Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Support and Advocacy – (213) 821-4710
https://studentaffairs.usc.edu/ssa
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC – (213) 740-2101
https://diversity.usc.edu Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency – UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
http://dps.usc.edu, https://emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety – UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
http://dps.usc.edu
Non-emergency assistance or information.