AME 530a Dynamics of Incompressible Fluids

Units: 4.0

Fall 2021—Tue, Thu—Time: 11:00-12:50pm

IMPORTANT:

Location: OHE 120

Instructor: Carlos Pantano

Office: OHE

Office Hours: by appointment (COVID restrictions may apply)

Contact Info: pantanor@usc.edu

- Allow 24 hours for email responses during weekdays.
- Please use your USC email account for all communication.

Teaching Assistant: TBD

Office: TBD

Office Hours: TBD

Contact Info: TBD

IT Help: https://viterbigrad.usc.edu/technical-support/

Contact Info: dentsc@usc.edu; (213) 740-2881

Course Description

This course provides a graduate-level introduction to the dynamics of incompressible fluids. Topics covered will include:

1. Basics
    a. Continuum description of fluids
    b. Fluid statics
    c. Similarity and dimensional analysis
    d. Tensor notation
    e. Flow kinematics
2. Governing equations
    a. Convective Derivative
    b. Velocity Gradient and Stress Tensors
    c. Conservation laws and control volume analyses
    d. Differential form of the governing equations
    e. Navier-Stokes equations
    f. Reynolds number
3. Laminar flows
    a. Exact steady solutions
    b. Lubrication theory
    c. Stokes flow
4. Ideal flows
    a. Potential flow theory
    b. Kutta-Jouwkowski theorem
    c. Surface waves
5. Vorticity Dynamics
    a. Vorticity and Angular Momentum
    b. Classical 'Inviscid' Models
    c. Viscous Effects
6. Boundary Layers and Related Topics
    a. Steady Boundary Layers (Blasius, Falkner-Skan solutions)
    b. Unsteady Boundary Layers (Stokes' 1^{st} and 2^{nd} problems)
    c. Perturbation Analyses
7. Turbulence
    a. Introduction to Turbulence
    b. Origins of Turbulence in Shear Flows
        i. Instability
        ii. Transient Growth
        iii. Other Pathways
    c. Reynolds Averaging and the Closure Problem
    d. Spectral Description

Learning Objectives and Outcomes

- Employ analysis techniques of varying complexity for fluid flows (dimensional analysis, integral or control volume analysis, differential analysis).
- Understand and explain the range of applicability of various approximations to the full governing equations for incompressible fluid flows.
- Solve idealized problems of engineering and scientific interest using appropriate approximations and analytical tools.

Prerequisite(s): NA
Co-Requisite(s): NA
Concurrent Enrollment: NA

Recommended Preparation: Undergraduate courses in fluid mechanics, vector and tensor calculus, and partial differential equations.

Course Notes

This course will make extensive use of the Desire2Learn (D2L) USC Viterbi course management platform. All lecture notes and videos will be made available online through this website. The system will also be used to manage the homework submission process. Each homework assignment will have its own Dropbox to which the students can upload solutions. The D2L system will also be set up with a discussion forum for the homework assignments. Students are encouraged to use this for peer-to-peer discussions. The instructor and TA will monitor these discussion forums.

Please familiarize yourself with the D2L system as soon as possible.
https://courses.uscden.net/d2l/home

Technological Proficiency and Hardware/Software Required

Basic use of mathematical and plotting software (e.g., Matlab, Mathematica) will be required for some homework assignments.

Textbook and Other Resources

There is no required text for this class, but ***Incompressible Flow by R.L. Panton (Wiley)*** is recommended. Readings will be suggested from this book to complement the material covered in class.

Other useful books:

- G.K. Batchelor, An Introduction to Fluid Mechanics, Cambridge University Press
- F.M. White, Fluid Mechanics, McGraw-Hill Education
- M. Van Dyke, An Album of Fluid Motion, Parabolic Press*

Finally, there is a series of 39 videos developed by the National Committee for Fluid Mechanics Films (NCFMF) that I would highly recommend for anyone interested in the subject:
http://web.mit.edu/hml/ncfmf.html

Grading Breakdown

Assignment	**% of Grade**
Homework (7 total)	35
Midterm Exam	30
Final Exam	35
TOTAL	

The 7 homework assignments will each involve 3-5 problems related to topics covered in class. A week-by-week breakdown of the topics covered in class is provided below. Consistent with this breakdown, the homework assignments will cover:

- HW1: Vector Calculus Review, Dimensional Analysis, Fluid Statics
- HW2: Conservation of mass momentum and energy (Integral form)
- HW3: Laminar and viscous flows
- HW4: Ideal Flows
- HW5: Boundary Layers
- HW6: Instabilities and Transition to Turbulence
- HW7: Turbulent flows

Assignment Submission Policy

- You can discuss homework problems with each other, but your solutions must be your own.
- Please indicate on your homework assignment if you have worked with another student.
- Assignments that are late will be penalized 25% for each day after the due date (see weekly schedule).
- All exams will be open-notes.
- Please notify the instructor at least 1 week ahead of time if you are unable to attend an examination or meet a homework deadline.

Grading Timeline

Graded assignments will be returned to students one week after submission.

Gallery of Fluid Motion

We will be running a Gallery of Fluid Motion competition!

Students are encouraged to capture images of fluid flow as they go about their day-to-day activities and post them in the designated Dropbox on the D2L website, together with a brief description. You may also submit results from numerical simulations. All submissions must be in the form of a single (10" x 7.5") powerpoint slide. The students who provide the top 5 entries (as judged by your peers) will receive 5% towards their grade and their lowest-scoring homework assignment will be discarded.

Course Schedule: A Weekly Breakdown

	Topics/Daily Activities	**Deliverable/ Due Dates**
Week 1	Preliminaries, Continuum Description, Fluid Statics Similarity and Dimensional Analysis	T: HW1 out Th:
Week 2	Vector Calculus Review Flow Kinematics, Eulerian vs. Lagrangian Descriptions	T: Th: HW1 due
Week 3	Conservation of Mass, Momentum and Energy (Integral Form)	T: HW2 out Th:
Week 4	Conservation of Mass, Momentum and Energy (Differential Form)	T: Th: HW2 due
Week 5	Boundary Conditions, Exact Laminar Solutions Reynolds Number and Asymptotic Limits	T: HW3 out Th:
Week 6	Viscous Flows: Stokes' 1st and 2nd Problems Viscous Flows: Lubrication Theory	T: Th: HW3 due
Week 7	Stokes Flow and Fundamental Solutions Ideal Flows: Potential Flow Theory	T: HW 4 out Th:
Week 8	Ideal Flows: Blasius and Kutta-Joukowsky Theorems Ideal Flows: Surface Waves	T: Th: HW4 due
Week 9	Vorticity and Circulation Vorticity Equation and Vortex Dynamics	**T: Mid-term out (take home)** **Th: Mid-term due at 5pm**
Week 10	Boundary Layer Theory Steady Laminar Boundary Layers	T: HW5 out Th:
Week 11	Unsteady Wave Boundary Layer Perturbation Expansion and Streaming	T: Th: HW5 due
Week 12	Transition to Turbulence Instability, Transient Growth, Other Pathways	T: HW6 out Th:
Week 13	Introduction to Turbulence Reynolds Decomposition	T: Th: HW6 due
Week 14	Scaling and Kolmogorov's Hypothesis Wall-Bounded Turbulent Flows	T: HW7 out Th:

Week 15	Wall-Bounded Turbulent Flows Boundary-Free Turbulent Flows	T: Th: HW7 due
FINAL	**TBD**	Date: For the date and time of the final for this class, consult the USC *Schedule of Classes* at classes.usc.edu/.

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" 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, policy.usc.edu/scientific-misconduct.

Support Systems:

Student Health Counseling Services - (213) 740-7711 – 24/7 on call
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
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-4900 – 24/7 on call
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
equity.usc.edu, 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
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
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
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
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
dps.usc.edu, 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
dps.usc.edu
Non-emergency assistance or information.