

THE UNIVERSITY OF COLORADO BOULDER

**ASEN 6037 / MCEN 7221: Turbulent Flows / Turbulence
Spring 2020**

SYLLABUS

Instructor: Assistant Professor John Evans
Office: AERO 361
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Office Hours: Monday/Wednesday/Thursday, 12:00 pm – 1:00 pm

Time: Monday/Wednesday, 2:30 pm – 3:45 pm

Location: AERO 232

Web Page: Canvas (canvas.colorado.edu)

Course Objective:

To establish a fundamental understanding of the mathematics and physics of turbulent flows and to introduce the concepts and analytical tools needed in developing turbulence models and turbulence simulation methods.

Prerequisites:

This class requires a graduate course in fluid mechanics such as ASEN 5051 / MCEN 5021. Topics covered should include kinematics of fluid flows, conservation laws, vorticity dynamics, theory and application of irrotational flows, dynamic similarity, viscous flows, and boundary layers. A working knowledge of vector calculus, Cartesian tensors, and Fourier transforms is also required.

Required Textbook:

Turbulent Flows, Pope, Cambridge University Press, 2000.

Reference and Supplemental Textbooks:

Fluid Mechanics, Kundu, Cohen, and Dowling, Academic Press, Sixth Edition, 2016.

Turbulence: An Introduction for Scientists and Engineers, Davidson, Oxford Press, Second Edition, 2015.

Statistical Theory and Modeling for Turbulent Flows, Durbin and Pettersson Reif, Wiley, Third Edition, 2001.

A First Course in Turbulence, Tennekes and Lumley, MIT Press, 1972.

Turbulence: The Legacy of A.N. Kolmogorov, Frisch, Cambridge Press, 1995.

Topics:

1. Turbulence Theory

- a. Statistical Description of Turbulence
- b. Mean Flow Equations
- c. Free Shear Flows
- d. Wall-Bounded Flows
- e. The Scales of Turbulent Motion

2. Turbulence Modeling and Simulation

- a. Direct Numerical Simulation (DNS)
- b. Reynolds Averaged Navier-Stokes (RANS) Models
 - i. Turbulent Viscosity Models
 - ii. Reynolds Stress Transport Models
- c. Large Eddy Simulation (LES)

Class Format:

The class meets twice a week for an hour and fifteen minutes of formal lecture and discussion.

Grading:

40% Homework Assignments
20% Midterm Exam
15% Literature Review Project
25% Final Project

Grades will be posted to the class website on Canvas.

Reading Assignments:

Reading assignments are assigned frequently through the course website and are to be completed before lecture. The lecture should help to clarify and supplement what students have read. If a student has any questions on the reading material, the student should contact the instructor by e-mail who will address the question during lecture.

Homework Policy:

There will be six homework assignments throughout the semester. Students should make an effort to turn in assignments that are organized, professional looking, and legible. Students must staple their work (no paperclips or dog-ears). Very messy work will be returned to a student ungraded and a score of zero will be recorded. Final answers should be indicated with an arrow, underline, or box. Multiple answers (when only one is required) will be counted as incorrect.

Homework is due at the start of class on the due date. Late assignments will not be accepted, though there will be a ten-minute grace period. If a student will be unable to attend class, the student may submit his or her homework early by slipping it under the instructor's door.

Collaboration is permitted on homework. This means students may discuss the means and methods for solving problems and even compare answers, but students are not free to copy someone's assignment. The work that a student turns in must be his or her own – copying is not allowed for any assignment and will not be tolerated. Students who are caught copying (or providing his or her assignment to another) will receive an “F” for the course and reported to the Dean's office for further punitive action.

Examination Policy:

The midterm examination will cover all “Turbulence Theory” material in the course including lecture, discussions, and homework. The midterm examination will be take-home and open-book.

Collaboration on the midterm examination will not be tolerated. Students who are caught in these activities will receive an “F” for the course and reported to the Dean's office for further punitive action. Students are free to ask the instructor any clarification questions.

Literature Review Project:

A literature review project will be assigned during the fourth week of the semester. For this project, students will review a highly-cited journal article on either turbulence theory or turbulence modeling and simulation. The deliverable of the project will consist of a review paper which summarizes the main results of the article, reflects on the impact of the article, and identifies what new questions the article raises.

Final Project:

A final project will be assigned before the spring break. For this project, students will either (i) conduct a statistical analysis of turbulence simulation data, (ii) conduct a statistical analysis of turbulence experimental data, (iii) conduct a comparison of turbulence modeling approaches using a standard turbulent benchmark problem, (iv) examine the efficacy of a turbulence modeling approach for several turbulent benchmark problems, or (v) pursue their own topic with the instructor's permission. The deliverable of the project will consist of a journal-style paper, the details of which will be discussed when the project is assigned.

Accommodation for Disabilities:

If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the [Disability Services website](#). Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition or injury, see [Temporary Medical Conditions](#)

under the Students tab on the Disability Services website.

Classroom Behavior:

Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the policies on [classroom behavior](#) and the [Student Code of Conduct](#).

Preferred Student Names and Pronouns:

CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

Honor Code:

All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the policy may include: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to the Honor Code (honor@colorado.edu; 303-492-5550). Students found responsible for violating the academic integrity policy will be subject to nonacademic sanctions from the Honor Code as well as academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found at the [Honor Code Office website](#).

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation:

The University of Colorado Boulder (CU Boulder) is committed to fostering a positive and welcoming learning, working, and living environment. CU Boulder will not tolerate acts of sexual misconduct, intimate partner abuse (including dating or domestic violence), stalking, or protected-class discrimination or harassment by members of our community. Individuals who believe they have been subject to misconduct or retaliatory actions for reporting a concern should contact the Office of Institutional Equity and Compliance (OIEC) at 303-492-2127 or cureport@colorado.edu. Information about the OIEC, university policies, [anonymous reporting](#), and the campus resources can be found on the [OIEC website](#).

Please know that faculty and instructors have a responsibility to inform OIEC when made aware of incidents of sexual misconduct, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

Religious Holidays:

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, you must let the instructors know of any such conflicts within the first two weeks of the semester so that we can work with you to make arrangements. See the [campus policy regarding religious observances](#) for full details.

Prepared by: John Evans

Date: December 30, 2019