THE UNIVERSITY OF COLORADO BOULDER

ASEN 6037 / MCEN 7221: Turbulent Flows / Turbulence
Spring 2022

SYLLABUS

Instructor: Assistant Professor John Evans
E-Mail Address: john.a.evans@colorado.edu
Office Hours Location: Zoom
Office Hours Times: Tuesday/Thursday, 1:00 pm – 2:00 pm

Time: Tuesday/Thursday, 11:30 am – 12:45 pm

Location: AERO N240

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:

30% Homework Assignments
30% 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 Slack or e-mail who will address the question during lecture.

Homework Policy:

There will be six homework assignments throughout the semester. Homework assignments are to be turned in through the course website by the start of class on their due date. Students should make an effort to turn in assignments that are organized, professional looking, and legible.

Each homework assignment will consist of a number of problems and be worth 100 points, of which 50 points will be assigned for "completeness" and 50 points will be assigned for "correctness". All problems associated with an assignment will count toward the "completeness" score. Only one

problem associated with an assignment will count toward the "correctness" score. Homework solutions will be made available for each assignment so students can "self-grade" their performance on problems only graded on the basis of "completion".

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.

Slack:

A Slack channel has been created to foster communication. Students will receive an e-mail invitation to join this channel. Students can use Slack to ask questions regarding lecture material, homework assignments, the midterm exam, the literature review project, and the final project. Slack is the instructor's preferred means of communication, and he will make every effort to respond to Slack messages within 24 hours.

Late Submission Policy:

Generally speaking, late submissions will not be accepted. That being said, we are living in unusual times, so please contact the instructor if you are unable to submit any of the homework assignments, the midterm exam, the literature review project, or the final project due to illness, technical issues, or other challenging extenuating circumstances. Reasonable accommodations will be made where appropriate provided you contact the instructor before the submission due date.

Requirements for COVID-19:

As a matter of public health and safety due to the pandemic, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. Students who fail to adhere to these requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policy on classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus.

CU Boulder currently requires masks in classrooms and laboratories regardless of vaccination status. This requirement is a precaution to supplement CU Boulder's COVID-19 vaccine requirement. Exemptions include individuals who cannot medically tolerate a face covering, as well as those who are hearing-impaired or otherwise disabled or who are communicating with someone who is hearing-impaired or otherwise disabled and where the ability to see the mouth is essential to communication. If you qualify for a mask-related accommodation, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus. In addition, vaccinated instructional faculty who are engaged in an indoor instructional activity and are separated by at least 6 feet from the nearest person are exempt from wearing masks if they so choose.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the Public Health Office(contacttracing@colorado.edu). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the Public Health Office (contacttracing@colorado.edu).

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, see Temporary Medical Conditions on the Disability Services website.

Classroom Behavior:

Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. 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 Conduct & Conflict Resolution policies.

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 academic integrity policy. Violations of the Honor Code may include, but are not limited to: 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 on the Honor Code website.

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

CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. The university will not tolerate acts of sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, or protected-class discrimination or harassment by or against 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 email cureport@colorado.edu. Information about university policies, reporting options, and the support resources can be found on the OIEC website.

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of incidents of sexual misconduct, dating and domestic violence, stalking, discrimination, harassment, and/or related retaliation, to ensure that individuals impacted receive information about their rights, support resources, and reporting options. To learn more about reporting and support options for a variety of concerns, visit Don't Ignore It.

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.

See the campus policy regarding religious observances for full details.

Prepared by: John Evans Date: January 5, 2022