

Turbulence / Turbulent Flows (MCEN7221/ASEN6037): Syllabus

Course Purpose: To establish a fundamental understanding of turbulent fluid flows.

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Lectures: T/TH 9:35 – 10:50 AM via Zoom; all lectures will be recorded and uploaded to Canvas

Zoom Info: Not available for public view.

Office Hours: T 11:00 AM – 1:00 PM; W 10:00 AM – 12:00 PM
All office hours will use the same Zoom info as above

Web Page: All relevant notes, slides, schedules, and supplemental documents will be posted to the course webpage at canvas.colorado.edu throughout the semester. Please check the website to see what has been posted.

Text: The required textbook for the course can be downloaded from the course website.

Recommended Texts: *Turbulence*, by P.A. Davidson, Oxford University Press, 2004.
Turbulent Flows, by S.B. Pope, Cambridge University Press, 2000.
A First Course in Turbulence, by H. Tennekes and J.L. Lumley, MIT Press, 1972.

Asynchronicity: This course can be taken fully asynchronously. Lectures will be recorded and uploaded to Canvas, and all lecture notes will also be uploaded. Homework solutions can be uploaded electronically at the students' convenience.

Grading: Your final grade is determined according to the following percentage breakdown:
Homeworks..... 70%
Project..... 30%

Homeworks: There will be 12 homeworks assigned throughout the semester, and students will be able to keep their 10 highest homework grades (i.e., one homework can be skipped without penalty). Homework responses should be uploaded electronically using Canvas (more details will be provided with homework assignments).

Project: There will be one project in the course. This will involve an in-depth analysis of turbulent flow data, with an emphasis on calculating turbulence statistics and other quantities discussed in the course. A detailed description and grading rubric for the project will be distributed in the first several weeks of the semester. All projects should be uploaded to a dropbox on learn.colorado.edu and will be checked for plagiarism.

Topic outline: The material to be covered includes (i) the foundations of high Reynolds number flows and their implications for universal structure in turbulence, (ii) the motivations behind a statistical description of turbulent flows, (iii) statistical concepts relevant to turbulent flows, focusing on probability density functions,

characteristic functions, and correlations, (iv) a description of the structure and dynamics of homogeneous, isotropic turbulence, focusing on multi-point statistics, energy-transfer concepts, and their application to the classical problems of turbulence decay and return to isotropy, (v) a description of contemporary approaches to turbulence modeling for practical engineering problems, focusing on two-equation models of the type widely used in practice, (vi) an introduction to large-scale organized structure in turbulent flows, including boundary layers and free-shear flows such as jets, wakes, and mixing layers (vii) an overview of turbulence modeling and simulation approaches, and (viii) turbulence in complex real world situations.

Prerequisites: This class requires prior experience with fluid dynamics. It approaches the subject at a graduate mathematics level with extensive use of indicial notation, vector calculus, and statistics. Students with some prior experience with these topics will find the course easier to follow, since only a brief review of background material will be given.

Assignment	Thursday 1/21:	Homework 1 assigned	
Schedule:	Thursday 1/28:	Homework 2 assigned	Homework 1 due
	Thursday 2/4:	Homework 3 assigned	Homework 2 due
	Thursday 2/11:	Homework 4 assigned	Homework 3 due
	Thursday 2/18:	Homework 5 assigned	Homework 4 due
	Thursday 2/25:	Homework 6 assigned	Homework 5 due
	Thursday 3/4:	Homework 7 assigned	Homework 6 due
	Thursday 3/11:	Homework 8 assigned	Homework 7 due
	Thursday 3/18:	No homework assigned	Homework 8 due
	Thursday 3/25:	Homework 9 assigned;	No class
	Thursday 4/1:	Homework 10 assigned	Homework 9 due
	Thursday 4/18:	Homework 11 assigned	Homework 10 due
	Thursday 4/15:	Homework 12 assigned	Homework 11 due
	Thursday 4/22:		Homework 12 due
	Thursday 4/29:		Project due

This schedule is subject to change depending on the interests and progress of the class.

1. Course Notes and Policies

1.1 Homework: Collaboration is permitted on homework. This means you may discuss the means and methods for solving problems and even compare answers, but you are not free to copy someone's assignment. The work that you turn in must be your own—copying is not allowed for any assignments.

1.2 Homework Format: It is your responsibility to make your solutions clear and legible. The graders have the discretion to deduct points (up to and including full credit) for solutions that are hard to read or unprofessional in appearance. Unless the problem requires a written response or short answer, the following format is *required*. This will facilitate grading and will assist you to approach problems in a consistent, organized way that will lead to the correct solution. Problems may be written by hand and subsequently scanned and converted to an electronic format. No hard copies, only electronic submission will be accepted.

1. Schematic/sketch (unless it is obviously not needed). List relevant information on the figure.
2. List of assumptions.
3. Governing equations. Label the equations.
4. List of known values, with units, including properties obtained from a table. Indicate the source, if applicable.
5. List of unknowns. Make sure they correspond to a sketch if applicable.
6. Solution: Present the answer with a box around it.
7. Verification. Check the answer against what common sense tells you. Do the units make sense? Do the results compare reasonably to a related known quantity?

1.3 Grading Scale: This will be the final grading scale used for the course. *There is no curve.* You are not competing against your classmates, so help them out if you can! I reserve the right to lower the scale (i.e., make it easier), but I will not raise it.

A	90+
A-	87-89
B+	85-86
B	83-84
B-	80-82
C+	77-79
C	74-76
C-	70-73
D+	68-69
D	63-67
D-	60-62
F	59 or below

1.4 Academic Integrity: You will be asked to complete individual homework assignments in this course. Though you may work in groups to discuss and solve problems, it is expected that you will abide by the University of Colorado at Boulder honor code at all times. Therefore, you may not plagiarize a problem set or allow another student to plagiarize your answers to a problem set. Examples of plagiarism include: copying from a solution manual, copying from Internet sites, copying from previous academic year homework sets, and copying directly from classmates. If you have any doubt that you are using sanctioned materials to assist with your homework solution, please ask your current instructor/professor. On assignments that require you to use supplemental materials, it is also essential that you properly document the sources of information you use.

Any instances of dishonesty on homework or tests will result in a minimum sanction for your first violation of the honor code of a zero score and an entry in your departmental file. Additional sanctions will be imposed for subsequent violations. You may contest any accusation according to the campus honor code.

1.5 Policy on Privacy of Graded Work: Federal law requires that your grades be communicated to you privately. Grades will be posted on Canvas and can only be viewed by individual students, the instructor, and the grader.

2. Departmental Notes and Policies

2.1 Overview: A primary objective of the Mechanical Engineering Department is to prepare each of our students for careers in the engineering profession. As professionals, engineers must meet high standards of technical competence and ethical behavior. According to the Accreditation Board of Engineering and Technology (ABET) code of ethics, engineers uphold and advance the integrity, honor and dignity of the engineering profession by:

1. Using their knowledge and skill for the enhancement of human welfare;
2. Being honest and impartial, and serving with fidelity the public, their employers and clients;
3. Striving to increase the competence and prestige of the engineering profession.

The Department of Mechanical Engineering (ME) believes that it is essential for each of you to learn the professional behavior that will prepare you for your career after college. Therefore, in each mechanical engineering course you will be required to practice the professional behavior that will be expected by your future employers. This syllabus clearly outlines the ME policy regarding academic integrity and academic climate. These policies will be upheld in each of your courses throughout the mechanical engineering curriculum. However, we also expect that this culture of professionalism will pervade all of your University of Colorado experiences.

2.2 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 [classroom behavior](#) policies and the [Student Code of Conduct](#).

2.3 Problematic Language, Behavior, and Discrimination: The ME department holds students, faculty, and staff accountable for racist, sexist, ableist, classist, heterosexist, ageist and other types of prejudiced comments and behavior, whether intentional or unintentional. We expect members of our community to recognize and speak up when witnessing comments and actions that may be discriminatory to others. The ME community strives to actively eliminate language and behaviors that perpetuate inequities and bias towards marginalized populations. More information and resources are available at [An Antiracist CU](#) and the [campus IDEA Plan](#).

2.4 Discrimination and Harassment: Discriminatory and harassing behavior will not be tolerated in the Department of Mechanical Engineering. A safe and inclusive environment will be created and maintained by the students, teaching assistants, and instructing faculty members. Students with concerns about discrimination or harassment actions should immediately contact the instructor, the Department Chair, their academic advisor, or the [Office of Institutional Equity and Compliance](#). Examples that may be considered harassment:

- A teaching assistant or instructor asking a student for a date.
- Displaying sexually explicit material in an academic setting (including laptop wallpaper).
- Persisting in asking a classmate for a date after being turned down.
- Using degrading terminology in referring to others, including peers.
- Making identity-based jokes or comments that create a hostile environment.

2.5 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 public health orders in place to reduce the risk of spreading infectious disease. Required safety measures at CU Boulder relevant to the classroom setting include:

- Maintain 6-foot distancing when possible,
- Wear a face covering in public indoor spaces and outdoors while on campus consistent with state and county health orders,
- Clean local work area,
- Practice hand hygiene,
- Follow public health orders, and
- If sick and you live off campus, do not come onto campus (unless instructed by a CU Healthcare professional), or if you live on-campus, please alert [CU Boulder Medical Services](#).

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 policies on [COVID-19 Health and Safety](#) and [classroom behavior](#) and the [Student Code of Conduct](#). If you require accommodation because a disability prevents you from fulfilling these safety measures, please see the “Accommodation for Disabilities” statement on this syllabus.

Before returning to campus, all students must complete the [COVID-19 Student Health and Expectations Course](#). Before coming on to campus each day, all students are required to complete a [Daily Health Form](#). Students who have tested positive for COVID-19, have symptoms of COVID-19, or have had close contact with someone who has tested positive for or had symptoms of COVID-19 must stay home and complete the [Health Questionnaire and Illness Reporting Form](#) remotely. In this class, if you are sick or quarantined, please contact Prof. Hamlington as soon as possible.

2.6 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.

2.7 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.

2.8 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](#).

2.9 Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation: The University of Colorado Boulder (CU Boulder) is committed to fostering an inclusive and welcoming learning, working, and living environment. CU Boulder 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 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, dating and domestic violence, stalking, discrimination, harassment and/or related retaliation, to ensure that individuals impacted receive information about options for reporting and support resources.

2.10 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, please contact Prof. Hamlington if you require accommodation for a religious holiday.

See the [campus policy regarding religious observances](#) for full details.