

Turbulence / Turbulent Flows (MCEN7221/ASEN5037): Syllabus

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

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Lectures: T/TH 11:00 AM – 12:15 PM in ECCR 110

Office Hours: T 1:00 – 3:00 PM in ECME 222
W 1:00 – 2:00 PM in ECME 222

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.

Exams: There will be take-home final exam during finals week.

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.

Grading: Your final grade is determined according to the following percentage breakdown:

Homeworks.....20%
Project 1.....20%
Project 2.....30%
Final Exam.....30%

1. Course Notes and Policies

1.1 Reading assignments: Reading assignments are to be completed *before* the lecture/discussion. The lecture/discussions should help to clarify and supplement what you have read.

1.2 Homework: Homework assignments are due on Thursdays by 11am in class. Late assignments are not accepted. Problems may be written by hand or typed, but must be submitted in hard copy. Email/electronic submittals will not be accepted.

Collaboration is permitted and encouraged 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. It is your responsibility to make your homework solutions clear and legible. The graders have the discretion to deduct points for solutions that are hard to read or unprofessional in appearance.

1.3 Projects: There will be two projects in the course. In project 1 you will write a review paper on a topic area of your choosing that is relevant to turbulence. Project 2 will involve an in-depth analysis of turbulent flow data, with an emphasis on calculating turbulence statistics discussed in the course. Detailed descriptions and grading rubrics for all projects will be distributed in advance of the project due dates. All projects should be uploaded to a dropbox on learn.colorado.edu and will be checked for plagiarism.

1.4 Exams: There will be one exam in the course during finals week. Collaboration on the exam, using another student's work as your own, or allowing another student to use your work as their own is academic misconduct and is not tolerated.

1.5 Grading Scale: This will be the final grading scale used for the course. 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.

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| 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 |

1.6 Policy on Privacy of Graded Work: Federal law requires that your grades be communicated to you privately. You will be assigned a unique, private ID number for this purpose. Put this number on all work that you hand in, instead of or in addition to your name. You can pick up your graded work filed under this number. Grades will be posted on CULearn as well, where the ID number will also be available. Graded assignments will be placed in the ME common filing cabinet.

1.7 Accommodation of Disabilities or Religious Commitments: If you qualify for accommodations because of a disability, please submit to your professor a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your

needs can be addressed. Disability Services determines accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by e-mail at dsinfo@colorado.edu.

If you have a temporary medical condition or injury, see Temporary Injuries under Quick Links at Disability Services website (<http://disabilityservices.colorado.edu/>) and discuss your needs with your professor.

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 provide at least two weeks notice of occasions that conflict with course due dates, so that other arrangements can be made.

See full details at http://www.colorado.edu/policies/fac_relig.html

2. Departmental Notes and Policies

2.1 Overview: A primary objective of the Department of Mechanical Engineering is to prepare 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:

- i.* Using their knowledge and skill for the enhancement of human welfare;
- ii.* Being honest and impartial, and serving with fidelity the public, their employers and clients;
- iii.* 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 course you will be required to practice the professional behavior that will be expected by your future employers. This syllabus clearly outlines the departmental 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 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 system.

2.3 Academic Climate – In-Class Expectations: It is our expectation that each of you will be respectful to your fellow classmates and instructors at all times. In an effort to create a professional atmosphere within the classroom, it is requested that you:

- Arrive to class on time
- Turn off your cell phone
- Limit use of your laptop computer to class purposes
- Put away newspapers and magazines
- Refrain from having disruptive conversations during class
- Remain for the whole class, or if you must leave early do so without disrupting others
- Display professional courtesy and respect in all interactions related to this class

Compliance with these expectations will assist us with the creation of a learning community and a high quality educational experience. The University of Colorado Classroom behavior policy will compliment the outlined classroom expectations. The University of Colorado Classroom Behavior policy is stated below.

2.4 Academic Climate – Out of Class Expectations: Though many of the above stated policies address academic climate within the classroom, these policies should also be upheld outside of the classroom. As a member of the CU community you are expected to consistently demonstrate integrity and honor through your everyday actions. Furthermore, faculty and staff members are very willing to assist with your academic and personal needs. However, multiple professional obligations make it necessary for us to schedule our availability. Suggestions specific to interactions with faculty and staff include:

- Respect posted office hours. Plan your weekly schedule to align with scheduled office hours
- Avoid disrupting ongoing meetings within faculty and staff offices. Please wait until the meeting concludes before seeking assistance. Respect faculty and staff policies regarding use of email and note that staff and faculty are not expected to respond to email outside of business hours. Send emails to faculty and staff using a professional format. Tips for a professional email include:
 - Always fill in the subject line with a topic that indicates the reason for your email to your reader.
 - Respectfully address the individual to whom you are sending the email (e.g., Dear Professor Smith).
 - Avoid email, chat room or text message abbreviations.
 - Be brief and polite.
 - Add a signature block with appropriate contact information.
 - Reply to emails with the previously sent message. This will allow your reader to quickly recall the questions and previous conversation.

2.5 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 and instructing faculty member. Students with concerns about discrimination or harassment actions should immediately contact the instructor, the Department Chair or their academic advisor, or contact the Office of Discrimination and Harassment (below).

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.

The University of Colorado Discrimination and Harassment policy is stated below.

3. University Notes and Policies

3.1 University of Colorado at Boulder Honor Code Policy: All students of the University of Colorado at Boulder are responsible for knowing and adhering to the academic integrity policy of this institution. Violations of this policy may include: cheating, plagiarism, aid of academic dishonesty, fabrication, lying, bribery, and threatening behavior. All incidents of academic misconduct shall be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found to be in violation of the academic integrity policy will be subject to both academic sanctions from the faculty member and non-academic sanctions (including but not limited to university probation, suspension, or expulsion). Other information on the Honor Code can be found at <http://www.colorado.edu/policies/honor.html> and at <http://honorcode.colorado.edu>

3.2 University of Colorado Classroom Behavior Policy: 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 differences of race, color, culture, religion, creed, politics, veteran's status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. See policies at

<http://www.colorado.edu/policies/classbehavior.html> and at
http://www.colorado.edu/studentaffairs/judicialaffairs/code.html#student_code

3.3 University of Colorado Discrimination and Harassment Policy: The University of Colorado Boulder (CU-Boulder) is committed to maintaining a positive learning, working, and living environment. The University of Colorado does not discriminate on the basis of race, color, national origin, sex, age, disability, creed, religion, sexual orientation, or veteran status in admission and access to, and treatment and employment in, its educational programs and activities. (Regent Law, Article 10, amended 11/8/2001). CU-Boulder will not tolerate acts of discrimination or harassment based upon Protected Classes or related retaliation against or by any employee or student. For purposes of this CU-Boulder policy, "Protected Classes" refers to race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, or veteran status. Individuals who believe they have been discriminated against should contact the Office of Discrimination and Harassment (ODH) at 303-492-2127 or the Office of Student Conduct (OSC) at 303-492-5550. Information about the ODH, the above referenced policies, and the campus resources available to assist individuals regarding discrimination or harassment can be obtained at <http://hr.colorado.edu/dh/>