AEROSP-525 Turbulent Flows

3 Credits, Winter 2023, Mon/Wed 9:00-10:20pm

Instructor:

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Office hours:

GSI:

Office hours:

Required Background:

This course requires a strong background in the following topics:

1. *Fluid mechanics:* Conservation equations, Stress-strain relationships, (Laminar) Boundary layer theory.
2. *Probability and Statistics:* Probability axioms, Joint and conditional probabilities, random variables and probability density functions, multi-variate distributions
3. *Mathematics:* Tensor notations, Discrete and continuous Fourier transforms
4. *Programming:* The homeworks and projects will involve data analysis and writing computational codes to implement simple turbulence models.

Note: This is a strong pre-requisite, we are happy to help you cover the background over the first week. Please take advantage of material posted on Canvas (and use office hours) in the first week to not risk falling behind. Homework has already been assigned of these topics and will be due on the day of Lecture 2, so please look through the background material (Chapters 1 & 2) before lectures start and take advantage of office hours in the first week of classes.

Delivery Style:

Lectures will be delivered in-person. **Attendance is required for the live lecture**, though accommodations will be made if the student cannot attend specific lectures for valid reasons.

5% of the grade is reserved for class participation (in-class discussion, forums, etc.)

Resources:

Lecture notes available through Canvas. Recommended reading (available online for free through the UM library)

Turbulent Flows, Pope, Cambridge.

Turbulence: An introduction for Scientists & Engineers, Davidson, Oxford.

CANVAS forums is a great place to interact with the class and instructors.

Grading:

Homeworks & Projects: 60 %

Class participation : 5 %

Mid Term : 20 %

Final Exam : 15 %

Topics (Lectures):

1. Introduction (0.5)
   - What is turbulence?
   - What are its implications?
   - How do we describe it?
   - How do we model it?
2. Mathematical Background (1.5)
   - Probability axioms, Conditional probability
   - Random variables and probability distributions
   - Sampling
   - Fourier transforms
3. Coarse-graining the Navier–Stokes equations (1)
   - Coarse-graining operations
   - Single-point moments
   - Two-point moments
   - RANS & LES
4. Probability & Statistics for Turbulence (2)
   - Central limit theorem
   - Statistics of fields, correlation and auto-correlation
   - The Energy spectrum tensor
5. The Nature of turbulence (4)
   - Non-linearity, Chaos & Ergodicity
   - Phenomenology & K41 theory
   - Freely decaying turbulence & Karman-Howarth equation
6. Wall bounded Turbulence (4)
   - Law of the wall
   - Coherent Structures
   - Attached Eddy hypothesis
7. Homogeneous Turbulence & Modeling (8)
   - Description
   - Rapid Distortion Theory
   - PDF-based models

8. Engineering Turbulence Modeling & Simulations (5)

   RANS modeling

   LES & DNS

   — Final Exam —

Homework Policy:

1. Allowable collaboration for homework is restricted to discussion of relevant concepts (See honor policy below)
2. Make sure submitted work is tidy.
3. Late homework will not be accepted unless there is a clear extenuating circumstance.

Honor Code and Collaboration Policy

• Collaboration on homework is permitted. Any collaboration must be explicitly acknowledged.

• Collaboration should be at the conceptual level; each student should work through and write up each assignment without looking at the work of other students.

• Examples of acceptable collaboration: Discussing the general approach to a problem, including relevant equations–Comparing intermediate and final answers after finishing a problem.

• Examples of unacceptable collaboration: Copying down a solution; Turning in a photocopy or an identical printout of code/plots

• Of course, collaboration in an exam is not permitted.

Culture

It is my hope that every student in this course is also excited to learn the material and learn the most they can. I am committed to a class culture that welcomes and serves students of all ages, ethnicities, genders, gender identities and expressions, national origins, religious affiliations, sexual orientations, and socioeconomic backgrounds - and other visible and nonvisible differences. I will work to foster a respectful, welcoming, and inclusive environment, and will expect each student to contribute as well. Your suggestions are encouraged and appreciated.

It is common for students to experience any of a number of things that can be a barrier to learning. The department and university are committed to advancingthe mental health and well-being of our students. If you or someone you know is feeling over-whelmed, depressed, and/or in need of support, services are available. You can learn more about the range of confidential services available at caps.umich.edu/mitalk.