AE 6012 Turbulent Flow Spring 2023

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Course objectives:

This is an introductory course to turbulence, the most common state of fluid motion in nature and engineering, and a very challenging physical problem. We begin by introducing fundamental concepts in the description of the mean flow and of the turbulent fluctuations, using Cartesian tensor formulations and with coverage of necessary concepts from probability and statistics. Turbulent shear flows with both free and wall boundaries are considered. We also discuss some of the more common approaches in turbulence modeling, and turbulence research in general.

Numbers in square brackets below denote the approximate number of *weeks* of class to be devoted to each topic.

Course Outline

1. Introduction and the study of turbulence [2]
   (a) Basic concepts, length scales and time scales
   (b) Review of Navier-Stokes equations in tensor form
   (c) Reynolds averaging and the closure problem
   (d) Turbulence research: experiments, theory, modeling
   (e) Turbulence research: the role of advanced computation
2. Energy and scale relations [2]
   (a) Kinetic energy equation and energy budget
   (b) Concepts of homogeneity and isotropy
   (c) Interscale energy transfer, small-scale universality
3. Probability and statistics [1.5]
   (a) Discrete and continuous random variables
   (b) Characteristics of one random variable
   (c) Characteristics of two random variables
   (d) Random processes
   (e) Statistical sampling
4. Statistical and spectral description [1.5]

   (a) Correlation and structure functions
   (b) Spectra in wavenumber space
   (c) Kolmogorov's similarity hypotheses

5. Free shear flows [1.5]
   (a) Momentum equations for almost parallel flows
   (b) Self-preserving wakes
   (c) Plane jets and mixing layers

6. Wall-bounded shear flows [1.5]
   (a) Mean velocity profile in a turbulent boundary layer
   (b) Inner and outer scalings, logarithmic region
   (c) Turbulent bursts and flow structures

7. Turbulence Simulation and Modeling [2.5]
   (a) Overview of various approaches
   (b) Turbulent (eddy) viscosity models
   (c) Second-order Reynolds stress modeling

8. Selected topics in current turbulence research [1.5]
   (a) Mixing of passive scalars
   (b) Lagrangian viewpoint and turbulent dispersion
   (c) Compressible turbulence

Disclaimer: Although I will make an effort to cover every topic listed above, in the event of a lack of time discussion of certain topics may be abbreviated.

Textbook and references

You should have (both) *A First Course in Turbulence* by H. Tennekes & J.L. Lumley (1972) and *Turbulent Flows* by S.B. Pope (2000).