جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

Course Syllabus: Turbulence - ME 307

Division	Physical Science and Engineering Division
Course Number	ME 307
Course Title	Turbulence
Academic Semester	Spring
Academic Year	2017/2018
Semester Start Date	01/28/2018
Semester End Date	05/24/2018
Class Schedule (Days & Time)	02:30 PM - 04:00 PM | Mon Thu

Instructor(s)

Name	Email	Phone	Office Location	Office Hours
Sigurdur T Thoroddsen	Sigurdur.Thoroddsen@kaust.edu.sa	+966128082160		To be determined.

Teaching Assistant(s)

Name	Email
None	N/A

Course Information

Comprehensive Course Description	This course describes the basic principles of fluid Turbulence. We start by describing what characterizes turbulent flows and why they are important both in nature and industrial applications. Numerous examples will be given where turbulence is used to enhance industrial processes, such as mixing, or to enhance heat transfer or even reduce drag on objects. The theoretical treatment will start with the Reynolds Averaged Navier-Stokes Equations. We will introduce the statistical tools necessary to develop these equations. The various statistical properties will be described, such as rms, skewness and flatness, as well as correlations used to evaluate transport of momentum and heat. The spectral properties will also be studied, with focus on the energy spectrum in three dimensions. We then characterize the various length and time-scales of turbulent flows, with respect to the energy cascade and the Kolmogorov theory. We formulate the averaged equations for homogenous as well as isotropic turbulence, followed by the canonical free shear flows of mixing layers, jets and wakes. The treatment is then applied to wall-bounded flows, like the boundary layer on a flat plate, deriving the log-law, viscous sublayer. Other flows include those in a Taylor-Couette device and in Rayleigh-Bernard convection. The numerical simulations of turbulent flow, using Direct Numerical Simulations (DNS) and Large Eddy Simulations (LES) will be discussed. The experimental methods used to study turbulence will be briefly reviewed, including hot-wires and Particle Image Velocimetry (PIV) in two-dimensional sheets, or Tomo-PIV in a volume. The vortical structure underlying the energy transport in the cascade will be discussed. Coherent structures will be described and how they affect and evolve in the mixing layers as well as the role hairpins in the boundary layer turbulence. Scalar spectra will be described for different ranges of the Schmidt numbers. Finally, two-dimensional turbulence will be described along with the inverse energy cascade.
Course Description from Program Guide	Introduction to turbulence. Fundamental equations of turbulent flow. Statistical description of turbulence. Experimental methods for turbulence. Reynolds equations. Kolmogorovs theory. Scales of turbulence. Homogeneous turbulence. Free-shear flows. Bounded flows. Boundary layers. Simulating turbulent flows. Reynolds Average Navier- Stokes approach. Introduction to Large Eddy
Goals and Objectives	To understand the basic properties of turbulence. How to estimate the structure of canonical turbulent flows, like boundary layers, mixing layers, jets and wakes. Understand the length- and time-scales and spectral properties characterizing these flows. Understand how to simulate numerically or investigate experimentally these flows, including a feeling of the limitations of these approaches. Know how to apply this knowledge to specific industrial applications.

Required Knowledge	Basic course in Fluids Mechanics, where the Navier-Stokes equations have been derived. Understanding of basic statistical techniques.
Reference Texts	Main Text: Turbulent Flows by Stephen B. Pope, Cambridge University Press (2000). Supplementary Texts: A first course in Turbulence, by Tennekes & Lumley, MIT Press (1972).
Method of evaluation	**30.00**% - Final exam **25.00**% - Midterm exam **20.00**% - Homework /Assignments **25.00**% - Course Project(s)
Nature of the assignments	Bi-weekly homework assignments will focus on the statistical aspect of the averaged equations, the self-similar treatment of the canonical flows, the spectral description and calculations of turbulent data.
Course Policies	Lecture attendence is mandatory. Project will consist of a small-group Laboratory experiment, with a joint report and presentation in class, where each student presents a part.
Additional Information	

Tentative Course Schedule *(Time, topic/emphasis & resources)*		
Week	**Lectures**	**Topic**
1	Mon 01/29/2018	**Basics: What is turbulence; Reynolds experiment**
1	Thu 02/01/2018	**Fundamental Equations of Turbulent Flows; index notation; Reynolds decomposition**
2	Mon 02/05/2018	**Statistical description of turbulence; averages, probability density functions, Correlation tensor**
2	Thu 02/08/2018	**Reynolds averaged equations; Dissipation, Closure problem**
3	Mon 02/12/2018	**Spectral description, energy spectrum**
3	Thu 02/15/2018	**Length and time-scales of turbulence**
4	Mon 02/19/2018	**Homogeneous vs Isotropic turbulence**
4	Thu 02/22/2018	**Kolmogorov's energy cascade theory**
5	Mon 02/26/2018	**Homogeneous shear flow and grid turbulence; Taylor's hypothesis**
5	Thu 03/01/2018	**Intermittency and velocity gradient skewness**
6	Mon 03/05/2018	**Coherent structures**
6	Thu 03/08/2018	**Free-shear flows; eddy viscosity, Reynolds stresses**
7	Mon 03/12/2018	**Turbulent jets, self-similar profiles**
7	Thu 03/15/2018	**In class Midterm exam, closed book and closed notes**
8	Mon 03/19/2018	**Turbulent wakes**
8	Thu 03/22/2018	**Mixing Layers**
9	Mon 03/26/2018	**Wall-bounded flows. Boundary layers**
9	Thu 03/29/2018	**Viscous sublayer; log-law**
10	Mon 04/02/2018	**Hairpin vortex dynamics**
10	Thu 04/05/2018	**Constrained turbulence: Stratification and Rotation**
11	Mon 04/09/2018	**Turbulence in a Taylor-Couette device**
11	Thu 04/12/2018	**Turbulence in a Rayleigh-Bernard convection**
12	Mon 04/16/2018	**Two-dimensional turbulence, inverse cascade**
12	Thu 04/19/2018	**Turbulent scalar fields**
13	Mon 04/23/2018	**Experimental Techniques: Hot wires, LDV, Laser Induced Fluorescence (LIF)**
13	Thu 04/26/2018	**Laboratory Experiment 1**
14	Mon 04/30/2018	**Laboratory Experiment 2**
14	Thu 05/03/2018	**Experimental Techniques: Particle Image Velocimetry (PIV), Tomo-PIV**
15	Mon 05/07/2018	**Simulating turbulent flows; DNS; k-? models**
15	Thu 05/10/2018	**Introduction to Large Eddy Simulations**
16	Mon 05/14/2018	**DNS techniques**
16	Thu 05/17/2018	**20 minutes in Class presentations per student**
17	Mon 05/21/2018	**20 minutes in Class presentations per student**
17	Thu 05/24/2018	**Final Exam Period. Exam will be closed book and closed notes**

Note

The instructor reserves the right to make changes to this syllabus as necessary.