EPFL

ME-467

Turbulence

Schneider Tobias

Cursus	Sem.	Type
Computational science and Engineering	MA2, MA4	Opt.
Computational science and engineering minor	E	Opt.
Mechanical engineering minor	E	Opt.
Mechanical engineering	MA2, MA4	Opt.
Mechanics		Opt.

Language of teaching	English
Credits	5
Withdrawal	Unauthorized
Session	Summer
Semester	Spring
Exam	During the semester
Workload	150h
Weeks	14
Hours	**5 weekly**
Courses	3 weekly
Exercises	2 weekly
Number of positions	

It is not allowed to withdraw from this subject after the registration deadline.

Summary

This course provides an introduction to the physical phenomenon of turbulence, its probabilistic description and modeling approaches including RANS and LES. Students are equipped with the basic knowledge to tackle complex flow problems in science and engineering practice.

Content

Turbulence is a ubiquitous physical phenomenon observed when fluids - liquids or gases - flow at high speeds. The fluctuating chaotic non-equilibrium phenomenon modifies the lift and drag of airfoils and affects the efficiency of mixing and combustion. It also is the driving force creating our weather and influences timescales on which stars and galaxies form in the universe.
This course provides an introduction to the physical phenomenon of turbulence, its probabilistic description and modeling approaches. Thereby students will be equipped with the fundamental understanding of turbulence that allows to tackle specific flow problems in science and engineering practice.

Specific topics covered include:

- Based on the Navier-Stokes equations together with symmetry assumptions, a probabilistic description of turbulence will be developed.
- The results of classical Kolmogorov theory for turbulence in an incompressible Newtonian flow will be interpreted in terms of a phenomenological description of physical processes in turbulence. Specific concepts include energy cascades and the quantitative estimation of relevant length- and timescales of the turbulent dynamics.
- The need for modeling turbulent flows will be motivated and common turbulence models as well as associated simulation strategies will be discussed.
- Finally, current research topics including intermittency corrections of the classical Kolmogorov results, transition to fully developed turbulence and turbulence decay will be covered.

Keywords

turbulence, non-equilibrium statistical physics

Learning Prerequisites

Required courses

Basic BA-level Fluid Mechanic course (e.g. ME-280, ME-344 or equivalent)

Important concepts to start the course

basics of statistics
variance and mean
Fourier analysis
Navier-Stokes equations

Learning Outcomes

By the end of the course, the student must be able to:

- Describe the physical differences between laminar and turbulent flows, AH4
- Estimate relevant length- and timescales of turbulent flows based on Kolmogorov theory, AH28
- Link flow behaviour with non-dimensional parameters (e.g. Reynolds and Mach numbers), AH2
- Describe the physical behavior of a flow in scientific terms, AH1
- Integrate deterministic chaotic flow dynamics with a probabilistic description of turbulence, AH29
- Assess / Evaluate turbulence simulation concepts including DNS, RANS and LES. Describe their advantages and limitations, AH30

Transversal skills

- Use a work methodology appropriate to the task.
- Use both general and domain specific IT resources and tools
- Write a scientific or technical report.

Teaching methods

Lectures and homework

Assessment methods

Graded project exercise

Resources

Bibliography

U. Frisch, Turbulence: the legacy of A. N. Kolmogorov
S. B. Pope, Turbulent flows

Ressources en bibliothèque

- Turbulent flows / S. B. Pope
- Turbulence: the legacy of A. N. Kolmogorov / U. Frisch

Moodle Link

- https://go.epfl.ch/ME-467