EPFL

ME-467

# Turbulence

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| Cursus | Sem. | Type |
|---|---|---|
| Computational science and Engineering | MA2, MA4 | Opt. |
| Energy Management and Sustainability | MA2, MA4 | Opt. |
| Mechanical engineering minor | E | Opt. |
| Mechanical engineering | MA2, MA4 | Opt. |
| Mechanics | | Opt. |

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|---|---|
| Language of teaching | English |
| Credits | 4 |
| Withdrawal | Unauthorized |
| Session | Summer |
| Semester | Spring |
| Exam | During the semester |
| Workload | 120h |
| Weeks | 14 |
| **Hours** | **4 weekly** |
| Courses | 3 weekly |
| Exercises | 1 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

Incompressible fluid mechanics

### 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 behaviour of a flow in scientific terms, AH1
- Choose the appropriate turbulence model for a given turbulent flow, AH27
- 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
- Make an oral presentation.

## Teaching methods

Lectures and homework

## Assessment methods

- Graded project exercise

## Resources

### Bibliography

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

### Ressources en bibliothèque

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

### Moodle Link

- http://moodle.epfl.ch/course/view.php?id=14488