

## Time and location

	<b>Lecture</b>	<b>Problem session</b>
Time:	Tuesday 9:45–11:15 h	Monday 14–15:30 h
Location:	HS 59, Bldg. 10.81	HS 62, Bldg. 10.81
Start date:	April 16, 2024	April 29, 2024

## Contact (by appointment)

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## Aim and scope of the course

- Introduction to turbulent flow physics and consequences for engineers
- The governing equations
- Introduction to statistical analysis of turbulent flow data
- The scales of turbulent flows
- Basic building blocks: free shear flows, wall-bounded flows

## Supporting material

Please register with the online learning system ILIAS under the following URL:

[https://ilias.studium.kit.edu/goto.php?target=crs\\_2366354](https://ilias.studium.kit.edu/goto.php?target=crs_2366354)

There you will find the slides as well as the lecture notes and accompanying exercises for download.

Zoom-link (just in case):

<https://kit-lecture.zoom.us/j/68019655194?pwd=SnNVeU9uZFFmTX1FbzJyZmZXSXhXUT09>

## Prerequisites

- Advanced fluid mechanics (Navier-Stokes equations)
- Mathematics (PDEs, statistics, Fourier analysis)
- To some degree: numerical methods & programming skills (e.g. Matlab)

## Exam

Oral exam, 45 minutes. Next exam date(s): **August 5, 2024**.

Please register before the end of the lecture period (by **July 26, 2024**). If not possible online, this must be done by contacting the secretariate [A. Fels](#).

## Contents & planning

### Lecture

#### Chapter 1 (16.4./23.4.): General introduction to turbulent flows

Motivation – what is turbulence – characteristics of turbulent flows – consequences for the engineer – possible strategies for computational analysis of turbulent flows: DNS, LES, RANS

#### Chapter 2 (30.4./7.5.): The basic flow equations

Derivation of the conservation equations – mass, momentum, energy, vorticity, enstrophy – transformation properties

#### Chapter 3 (14.5./28.5.): Statistical description of turbulent flows

Statistical tools for analyzing random variables – random processes – random fields – derivation of the averaged flow equations – the closure problem

#### Chapter 4 (4.6./11.6.): Free shear flows

Description of the flow in a round jet – turbulent boundary layer approximation – energy budget – a simple eddy-viscosity closure – formation of small scales/scaling of dissipation

#### Chapter 5 (18.6./25.6.): The scales of turbulent flow

The turbulent energy cascade of Richardson – Kolmogorov hypotheses – energy balance in wavenumber space

#### Chapter 6 (2.7./9.7.): Wall-bounded turbulent flows

Pipe flow, channel flow, boundary layer – structure of turbulence in the vicinity of a solid wall – coherent structures in the boundary layer – the effect of wall roughness

#### Buffer dates, recap (16.7./23.7.)

### Problem sessions

date	exercise	topic	chapter
15.4.	–		
22.4.	–		
29.4.	E1	Chaos in low-dimensional systems	C1
06.5.	E2	Working with the energy equation	C2
13.5.	E3	Vortex stretching & straining	C2
20.5.	–		
27.5.	E4	Temporal auto-correlation coefficient	C3
03.6.	E5	Reynolds stress & realizability	C3
10.6.	E6	More on realizability	C4
17.6.	E7	Round jet flow similarity	C4
24.6.	E8	Homogeneous shear flow	C4
01.7.	E9	Homogeneous-isotropic turbulence	C5
08.7.	E10	Plane channel flow wall asymptotics	C6
15.7.	E11	Plane channel flow: TKE & dissipation	C6
22.7.		(buffer date)	

### References

- [1] S.B. Pope. *Turbulent flows*. Cambridge University Press, 2000.
- [2] P.A. Davidson. *Turbulence: an introduction for scientists and engineers*. Oxford University Press, 2004.
- [3] M. Van Dyke. *An album of fluid motion*. Parabolic Press, 1982.

- [4] J. Matthieu and J. Scott. *An introduction to turbulent flow*. Cambridge University Press, 2000.
- [5] U. Frisch. *Turbulence: The legacy of A.N. Kolmogorov*. Cambridge U. Press, 1995.
- [6] H. Tennekes and J.L. Lumley. *First Course in Turbulence*. The MIT Press, 1972.
- [7] H. Schlichting and K. Gersten. *Grenzschicht-Theorie*. Springer, tenth edition, 2006.
- [8] P.K. Kundu and I.M. Cohen. *Fluid mechanics*. Academic Press, 2nd edition, 2002.
- [9] R. Aris. *Vectors, Tensors, and the Basic Equations of Fluid Mechanics*. Dover Science and Maths, 1962.
- [10] A.H. Shapiro. National committee for fluid mechanics films, 1972.  
<http://web.mit.edu/hml/ncfmf.html>.