Time and location

	Lecture	**Problem session**
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 22, 2025	May 5, 2025

Contact (by appointment)

	M. Uhlmann	**H. Herlina**
Location:	Room 122, Bldg. 10.81	Room 124, Bldg. 10.81
Phone:	0721-608 47245	0721-608 46668
Email:	`uhlmann@kit.edu`	`herlina@kit.edu`

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_2645000`
There you will find the slides as well as the lecture notes and accompanying exercises for download.

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 11, 2025**.
Please register before the end of the lecture period (by **August 1, 2025**). If not possible online, this must be done by contacting the secretariate (A. Fels).

Contents & planning

Lecture

Chapter 1 (22.4./29.4.): 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 (6.5./~~13.5.~~/20.5.): The basic flow equations
Derivation of the conservation equations – mass, momentum, energy, vorticity, enstrophy – transformation properties

Chapter 3 (27.5./3.6.): 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 (17.6./24.6.): 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 (1.7./8.7.): The scales of turbulent flow
The turbulent energy cascade of Richardson – Kolmogorov hypotheses – energy balance in wavenumber space

Chapter 6 (15.7./22.7.): 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 date(s), recap (29.7.)

Problem sessions

date	exercise	topic	chapter
28.4.	–		
05.5.	E1	Chaos in low-dimensional systems	C1
12.5.	(buffer date)		C2
19.5.	E2	Transformation props/energy equation	C2
26.5.	E3	Vortex stretching & straining	C3
02.6.	E4	Temporal auto-correlation coefficient	C3
09.6.	–	(lecture-free week)	
16.6.	E5	Reynolds stress & realizability	C4
23.6.	E6	More on realizability	C4
30.6.	E7	Round jet flow similarity	C4
07.7.	E8	Homogeneous shear flow	C5
14.7.	E9	Homogeneous-isotropic turbulence	C6
21.7.	E10	Plane channel flow wall asymptotics	C6
28.7.	E11	Plane channel flow: TKE & dissipation	C6

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] J. Matthieu and J. Scott. *An introduction to turbulent flow.* Cambridge University Press, 2000.
[4] U. Frisch. *Turbulence: The legacy of A.N. Kolmogorov.* Cambridge U. Press, 1995.

[5] H. Tennekes and J.L. Lumley. *First Course in Turbulence.* The MIT Press, 1972.

[6] H. Schlichting and K. Gersten. *Grenzschicht–Theorie.* Springer, tenth edition, 2006.

[7] M. Van Dyke. *An album of fluid motion.* Parabolic Press, 1982.

[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.