1 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~~
	for now ONLINE ONLY! (cf. below)	
Start date:	April 21, 2020	April 27, 2020

2 Contact

	M. Uhlmann	**H. Herlina**
Consultation:	by appointment	by appointment
Location:	~~Room 122, Bldg. 10.81~~	~~Room 124, Bldg. 10.81~~
	for now Email only!	
Phone:	0721-608 47245	0721-608 46668
Email:	`uhlmann@kit.edu`	`herlina@kit.edu`

3 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

4 Supporting material

Please register with the E-learning system ILIAS under the following URL:
`https://ilias.studium.kit.edu/goto_produktiv_crs_1105100.html`
There you will find the slides as well as the lecture notes and accompanying exercises for download.

Non-presential teaching during summer term 2020

The presential lecture will be replaced by recorded videos from a previous edition as well as the detailed lecture notes, available via ILIAS.
The presential problem session will be replaced by self study on the basis of the provided problem sheets (which contain a detailed solution); help with solving the problems is provided by the two instructors by the following means:

- Please ask salient question through use of the forum functionality of ILIAS; use of descriptive subject lines makes the threads more valuable for everyone.
- Videochat with the instructors using the application "MS Teams" (cf. technical information by SCC under this URL); you can join the team for this course with the following key:
  http://connect.studium.kit.edu/teams/join/iwsLr2aReq
  The chat will take place during the regular hours of the problem session (cf. times listed above and the calendar on page 3). It will also feature a short recap of the lecture material where appropriate.

5 Prerequisites

- Advanced fluid mechanics (Navier-Stokes equations)
- Mathematics (PDEs, statistics, Fourier analysis)
- Numerical methods & programming skills (e.g. Matlab)

6 Exam

Oral exam, 45 minutes. Next exam date: **August 3, 2020**.
Please register before the end of the lecture period (by **July 24, 2020**). If not possible online, this must mandatorily be done on paper (presenting the relevant authorization forms) with A. Fels (Bldg. 10.81, room 123, mornings 9-13h).

~~In case you desire an attendance certificate (without exam), please notify the instructor at the start of the lecture; attendance will then be checked.~~ No attendance certificates this year.

7 Contents & planning

7.1 Lecture

Chapter 1 (21.4./28.4.): 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 (5.5./12.5.): The basic flow equations
Derivation of the conservation equations – mass, momentum, energy, vorticity, enstrophy – transformation properties

Chapter 3 (19.5./26.5.): 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 (9.6./16.6.): 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 (23.6./30.6.): The scales of turbulent flow
The turbulent energy cascade of Richardson – Kolmogorov hypotheses – energy balance in wavenumber space

Chapter 6 (7.7./14.7.): 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, recap (21.7.)

7.2 Problem sessions

date	exercise	topic	chapter
20.4.	–		
27.4.	–		
04.5.	E1	Chaos in low-dimensional systems	C1
11.5.	E2	Working with the energy equation	C2
18.5.	E3	Vortex stretching & straining	C3
25.5.	E4	Temporal auto-correlation coefficient	C3
08.6.	E5	Reynolds stress & realizability	C3
15.6.	E6	More on realizability	C4
22.6.	E7	Round jet flow similarity	C4
29.6.	E8	Homogeneous shear flow	C4
06.7.	E9	Homogeneous-isotropic turbulence	C5
13.7.	E10	Plane channel flow wall asymptotics	C6
20.7.	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] 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.