Master-Focus-Field Fluid Mechanics

Responsibility: **Prof. Dr.-Ing. Bettina Frohnapfel**

Date: 17.03.2026

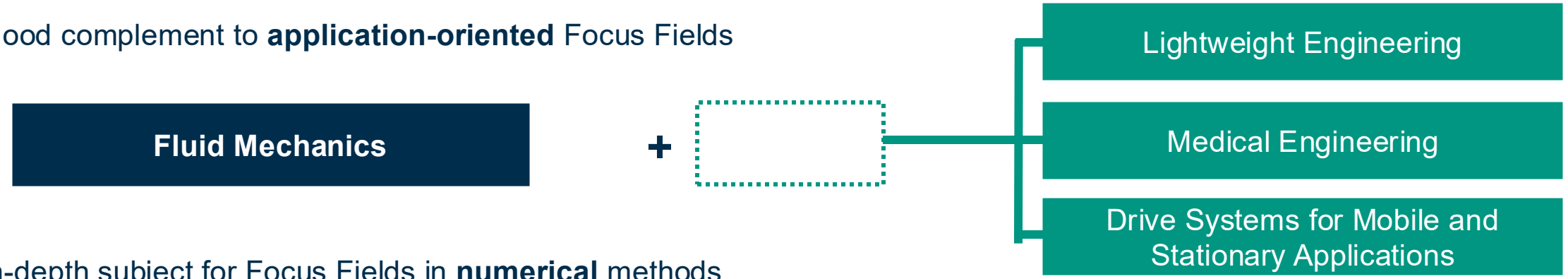
Institut für Strömungsmechanik

Focus Field: Fluid Mechanics

- can be chosen within the **Master**'s program in **Mechanical Engineering**
- can be studied in German (D) or English (E)
- Recommendation for the **Module Mathematical Methods**:
  Mathematische Methoden der Strömungslehre (D) OR
  Mathematical Methods in Fluid Mechanics (E)
- Recommendation for the **Module Laboratory Course**:
  Strömungsmesstechnik (D) OR
  Flow Measurement Techniques (E)

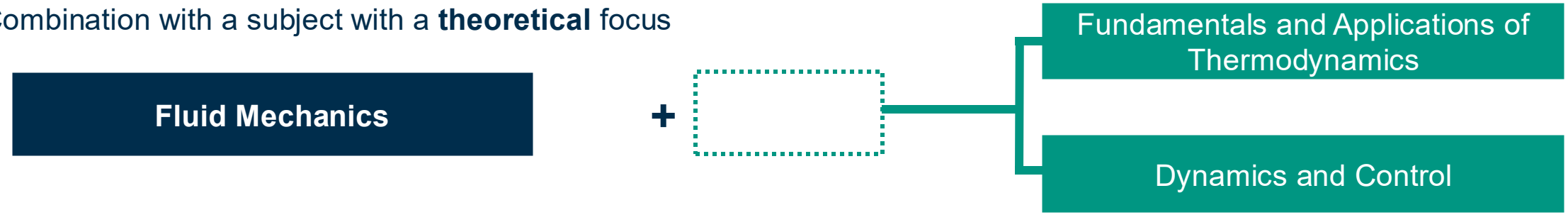
Focus Field: Fluid Mechanics

- Good complement to **application-oriented** Focus Fields



- In-depth subject for Focus Fields in **numerical** methods

- Combination with a subject with a **theoretical** focus



Overview: Fluid Mechanics Focus Field

Core area (minimum 8CP)

Identifier	Title	Lecturer	Institute	SWS	LP	Semester
T-MACH-114023	Experimental Fluid Mechanics with Research Seminar	Kriegseis,Frohnapfel	ISTM	2	4	SS
T-MACH-114021	Research Seminar Experimental Fluid Mechanics	Kriegseis, Frohnapfel	ISTM	2	4	SS
T-MACH-114022	Numerische Strömungsmechanik mit Forschungsseminar	Gatti, Frohnapfel	ISTM	4	4	WS
T-MACH-114024	Forschungsseminar Numerische Strömungsmechanik	Gatti, Frohnapfel	ISTM	2	4	WS
T-MACH-114025	Experimentelle und Numerische Strömungsmechanik	Gatti, Kriegseis	ISTM	6	8	SS+WS
T-MACH-114026	Angewandte Strömungsmechanik: Skalierungsgesetze, Stabilität, nichtlineare Dynamik	Class, Bühler	ITES	4	8	SS

Clarification regarding the choice of core subject

at least one core subject must be chosen

Within the **core area** of the **Fluid Mechanics** Focus Field, **students may enrol in a research seminar:**

Experimental Fluid Mechanics with Research Seminar	=	**Experimental Fluid Mechanics**	+	**Research Seminar Experimental Fluid Mechanics**
Numerical Fluid Mechanics mit Forschungsseminar	=	**Numerical Fluid Mechanics**	+	**Research Seminar Numerical Fluid Mechanics**

Note: The relevant **research seminar** must be completed **before the exam**.

The other two core subjects do not include a research seminar, but consist of two combined lectures:

Experimental and Numerical Fluid Mechanics	=	**Experimental Fluid Mechanics**	+	**Numerical Fluid Mechanics**
Applied Fluid Mechanics: Scaling Laws, Stability, Nonlinear Dynamics	=	**Skalierungsgesetze der Strömungsmechanik (English)**	+	**Hydrodynamische Stabilität: Von der Ordnung zum Chaos (German)**

The courses **'Experimental Fluid Mechanics'** and **'Numerical Fluid Mechanics'** can be taken as part of the **supplementary component (E) of the Fluid Mechanics Focus Field** and as part of the **elective module** within the interdisciplinary elective area, respectively, **without** the need to attend a **research seminar**.

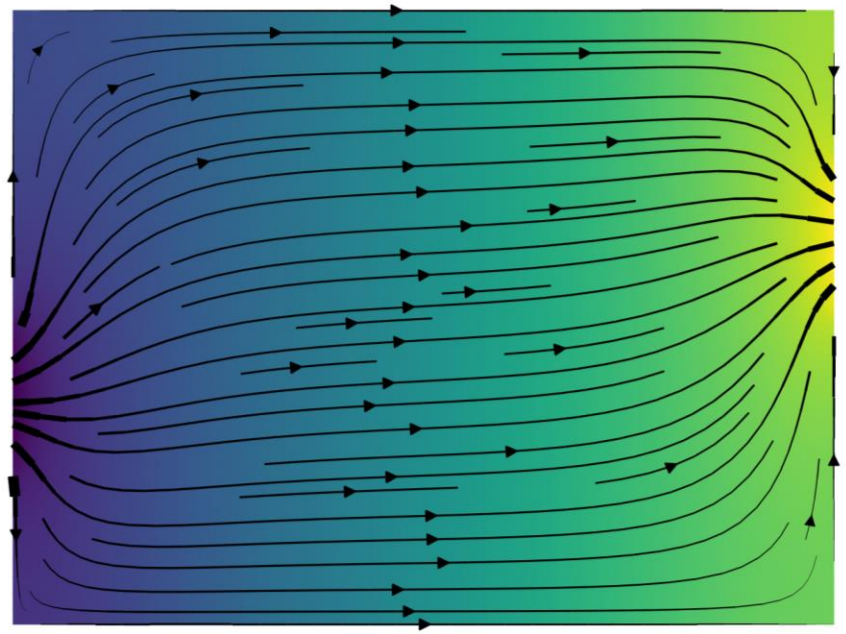
Numerical Fluid Mechanics

Lecturer: Dr.-Ing. Davide Gatti

Language: German

Topics:

- Fundamental equations of computational fluid dynamics
- Most important discretization methods for fluid mechanics problems, with a focus on finite differences and finite volumes
- Boundary and initial conditions
- Mesh generation and mesh handling
- Solution algorithms for linear and nonlinear systems of equations
- Solution strategies for the incompressible Navier–Stokes equations
- Introduction to the solution of the compressible Navier–Stokes equations
- Practical examples of numerical simulation



In the core area (K), can be chosen either in combination with the corresponding research seminar or in combination with Experimental Fluid Mechanics
In the supplementary area (E), can be taken as a standalone course if not selected in the core area

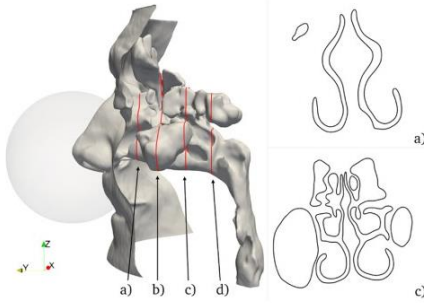
Research Seminar Numerical Fluid Mechanics

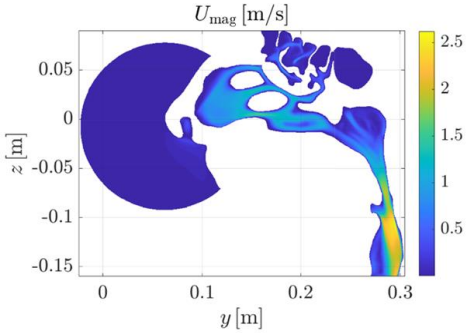
Lecturers: Dr.-Ing. Davide Gatti, Prof. Dr.-Ing. Bettina Frohnapfel and scientific staff

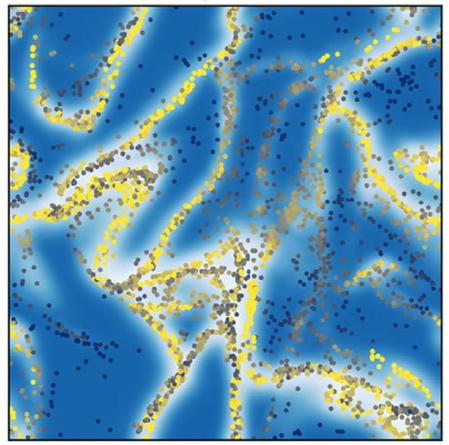
Language: English / German (the literature is available in English only)

Objective: Students critically engage with scientific articles from the following exemplary and changing topic areas:

- Immersed boundary methods
- Efficient solution of the Navier–Stokes equations in simple geometries for turbulent flows
- Discretization of differential operators
- Aerodynamic flows and boundary layers
- Particle-laden flows and multiphase flows







Available exclusively as a prerequisite for the core area (K) ‘Numerical Fluid Mechanics with Research Seminar’

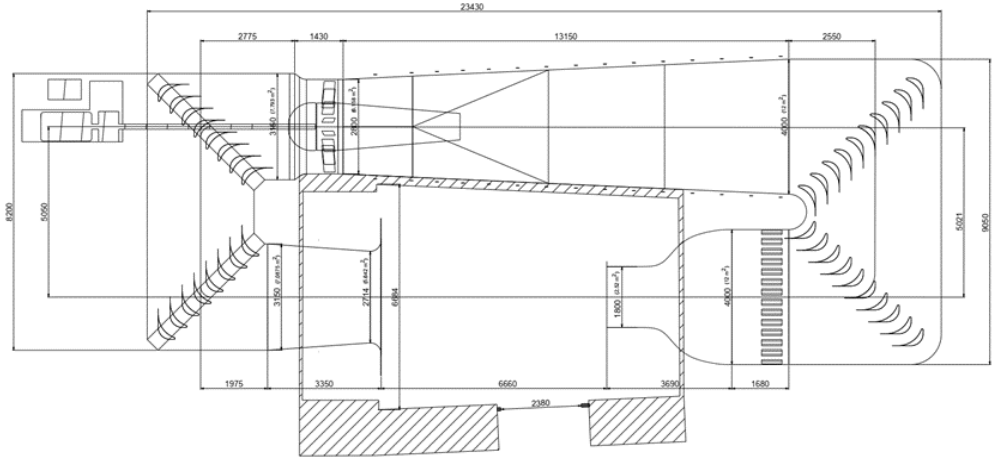
Experimental Fluid Mechanics

Lecturers: Dr. Jochen Kriegseis and scientific staff

Language: English

Topics:

- Measurement methods and measurable quantities in fluid mechanics
- Measurements in turbulent flows
- Pressure measurements
- Hot-wire measurements
- Optical measurement techniques
- Error estimation and error analysis
- Scaling laws
- Signal and data analysis



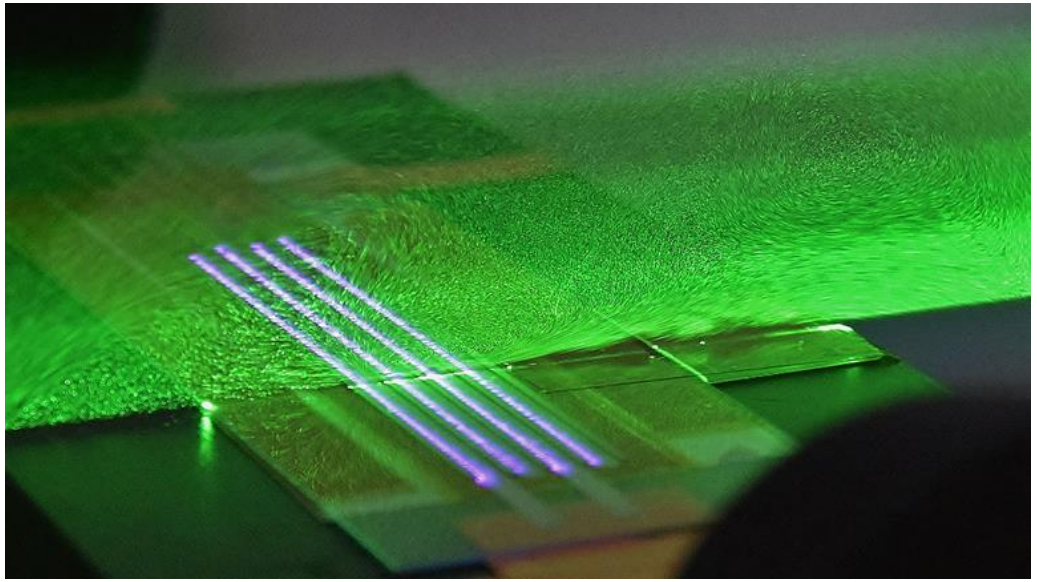
In the core area (K), this can be taken in combination with the corresponding research seminar or in combination with Computational Fluid Dynamics
Can be taken as a standalone module in the supplementary area (E) if not taken in the core area

Research Seminar Experimental Fluid Mechanics

Lecturers: Dr. Jochen Kriegseis, Prof. Dr.-Ing. Bettina Frohnapfel and scientific staff

Language: English

Topic: Students critically analyse scientific articles on experimental fluid mechanics.



Available exclusively as a prerequisite for the core area ‘Experimental Fluid Mechanics with Research Seminar’

Applied Fluid Mechanics: Scaling Laws, Stability, Nonlinear Dynamics

Lecturers: apl. Prof. Dr.-Ing. Andreas Class and apl. Prof. Dr.-Ing. Leo Bühler
Institute for Thermal Energy Technology and Safety (ITES)
Language: German and English

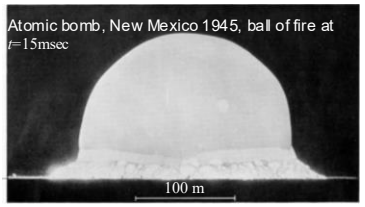
A combination of two courses

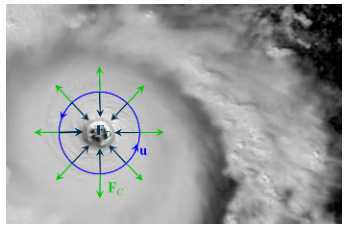
Scaling laws in fluid mechanics

Lecturer: Prof. Dr.-Ing. Leo Bühler
Language: German

Topics:

- Buckingham Pi-Theorem
  - Dimensionless Numbers
- Model Experiments and Real-World Applications
  - Reduction of Measurement Effort
- Examples:
  - Von Kármán Vortex Street, Thermal Convection
  - Spherically Symmetric Explosion, Hydrodynamic Journal Bearings
- Physically Meaningful Simplifications (Modeling)
  - Boundary Layer Flows
  - Self-Similar Solutions
  - Rotating Flows, Geostrophic Flows, Taylor Vortices



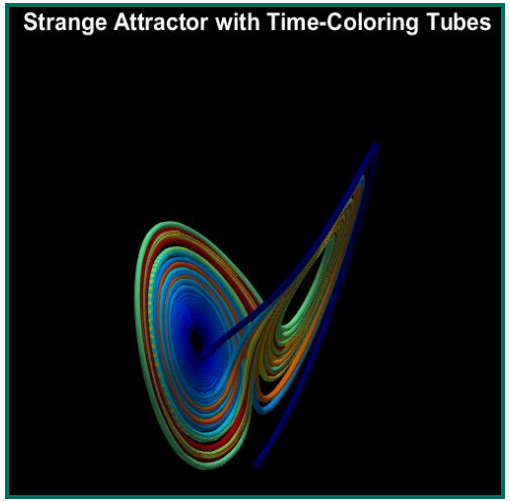


Hydrodynamic Stability: From order to chaos

Lecturer: Prof. Dr.-Ing. Andreas Class
Language: English (German)

Topics:

- Overview of Hydrodynamic Phenomena
- Linear Stability Analysis: Determination of the stability limits a flow configuration
- Low-Mode Approximation: Reduced-order models describing nonlinear dynamics
- Lorenz Equations: A generic system exhibiting chaotic behavior



Recommendations for planning the Focus Field Fluid Mechanics

The supplementary area (E) (max 16 credits, or 18 credits if combined with a 6-credit subject) offers a wide range of options. Possible combinations with the core subjects are listed here by way of example. Note that not all these courses are taught in English.

The language of the course title on the following slides corresponds to the language of the lecture!

	Research Focus	Numerical Focus	Practical Focus
K	Experimental Fluid Mechanics with Research Seminar (8LP)	Numerical Fluid Mechanics with Research Seminar (8LP)	Applied Fluid Mechanics: Scaling Laws, Stability, Nonlinear Dynamics (8LP)
E	Vortex Dynamics (4LP)	Fluid Mechanics of Turbulent Flows (6LP)	Thermal Turbomachines I (8LP)
E	Aerodynamics (4LP)	Numerical Fluid Mechanics with PYTHON (4LP)	Advanced CFD with OpenFOAM (4LP)
E	Microscale Fluid Mechanics (4LP)	Modeling of Turbulent Flows – RANS and LES (6LP)	Modeling of Polymer and Suspension Flows for Industrial Manufacturing Processes (4LP)
E	Magnetohydrodynamics (4LP)	-	-

To discuss your individual specialisation, please feel free to book an appointment during Prof. Frohnapfel's consultation hours by emailing sekretariat@istm.kit.edu

Overview Fluid Mechanics Focus Field*

Supplementary module I (maximum 16CP)

Identifier	Title	Lecturer	Institute	SWS	LP	Semester
T-MACH-114098	Advanced CFD with OpenFOAM	Stroh, Gatti	ISTM	2	4	WS
T-MACH-112029	Aerodynamik	Gatti, Kriegseis	ISTM	3	4	WS
T-MACH-114020	Experimental Fluid Mechanics	Kriegseis	ISTM	2	4	WS
T-BGU-110841	Fluid Mechanics of Turbulent Flows	Uhlmann	IFH	4	6	SS
T-MACH-111507	Fluid-Struktur-Interaktion mit Python	Mühlhausen	ISTM	2	4	SS
T-MACH-105426	Magnetohydrodynamics	Bühler	ITES	2	4	WS
T-MACH-113956	Mathematische Methoden der Strömungslehre	Frohnapfel, Gatti	ISTM	4	6	WS
T-MACH-113955	Mathematical Methods in Fluid Mechanics	Frohnapfel, Gatti	ISTM	4	6	WS
T-MACH-113144	Microscale Fluid Mechanics	Marthaler	ITES	2	4	SS
T-MACH-114949	Modeling of Polymer and Suspension Flows for Industrial Manufacturing Processes	Wittemann	FAST	2	4	SS
T-MACH-113367	Modellierung von Polymer- und Suspensionsströmungen für industrielle Fertigungsprozesse	Wittemann	FAST	2	4	SS

Overview Fluid Mechanics Focus Field*

Supplementary module II (maximum 16CP)

Identifier	Title	Lecturer	Institute	SWS	LP	Semester
T-BGU-110842	Modeling of Turbulent Flows – RANS and LES	Uhlmann	IFH	4	6	WS
T-MACH-105338	Numerische Strömungsmechanik	Frohnapfel, Gatti	ISTM	4	4	WS
T-MACH-105422	Strömungen mit chemischen Reaktionen	Class	ITES	2	4	WS
T-MACH-114052	Thermal Turbomachines I	Bauer	ITS	6	8	WS
T-MACH-106372	Thermofluiddynamik	Ruck	IATF	2	4	WS
T-MACH-105784	Wirbeldynamik	Kriegseis	ISTM	3	4	WS

* The language of the course title reflects the language in which the course is taught

Institute of Fluid Mechanics (ISTM)

Below you will find further information on the supplementary subjects offered by ISTM

three-pillar model in education

Mathematical Methods in Fluid Mechanics

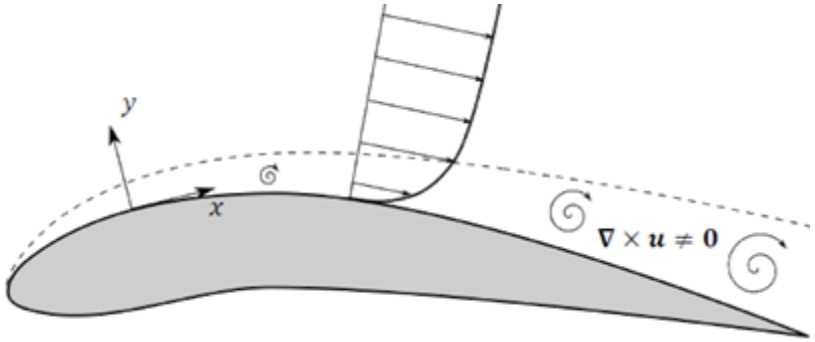
Lecturers: Prof. Dr.-Ing. Bettina Frohnapfel and Dr.-Ing. Davide Gatti

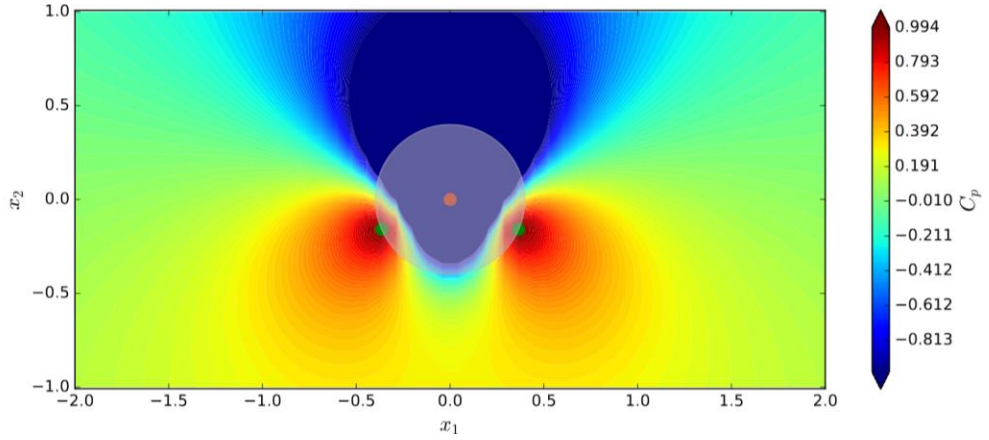
Course content: Lectures, tutorials and practical Python sessions

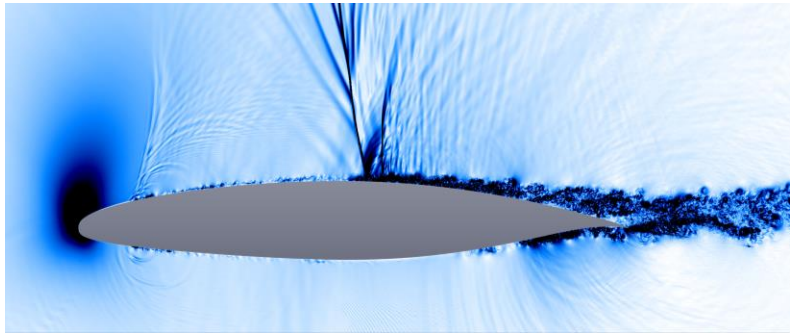
Language: The course is taught in both German and English

Topics:

- Stokes flows
- Lubrication theory
- Potential theory
- Boundary layer theory
- Turbulent flows







This module can be chosen as part of the Mathematical Methods module or, alternatively, as part of the supplementary area (E) of the Fluid Mechanics specialisation

Numerical Fluid Mechanics with Python

Summer semester, practical course (ungraded)

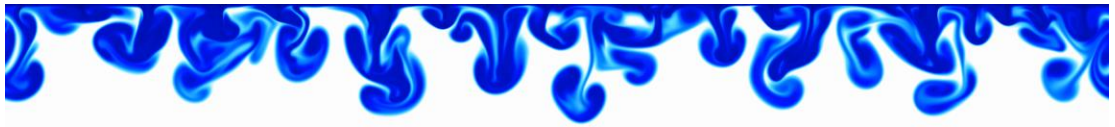
Intensive course (1 week) at the start of the summer break

Lecturers: Dr.-Ing. Davide Gatti and scientific staff

Language: German / English

Topics:

- Introduction to Numerical Methods and Python
- Discretised Navier-Stokes equations
- Finite differences methods
- Finite volumes methods
- Explicit and implicit time schemes
- Pressure correction method



Related to: Numerical Fluid Mechanics

Advanced CFD with OpenFOAM

Lecturers: Dr.-Ing. Alexander Stroh, Dr.-Ing. Davide Gatti and scientific staff

Language: English

Topics:

- Fundamentals of OpenFOAM ® mathematics (tensor operations, discretisation)
- Advanced adaptation of boundary conditions and pre-/post-processing using third-party tools (swak4Foam: groovyBC, funkySetField, funkyDoCalc)
- Introduction to C++
- Advanced model customisation in OpenFOAM ® using codeStream
- Customisation of solvers or development of new solvers in OpenFOAM ®
- Git for code development

Related to: Numerical Fluid Mechanics
prior knowledge of OpenFOAM is required

Fluid-Structure-Interaction with Python

Intensive course (1 week) at the start of the summer semester break

Lecturer: Dr.-Ing. Mark-Patrick Mühlhausen (Lecturer)

Language: German

Topics:

- Brief introduction to Python and Ansys Fluent
- Fundamental equations of continuum mechanics
- Smoothing and remeshing algorithms for mesh deformation
- Finite volume and finite element methods
- Methods of fluid-structure interaction
- Coupling conditions
- Monolithic and partitioned coupling methods
- Coupling algorithms for partitioned methods
- Stability and convergence of coupled systems”

Related to: Numerical Fluid Mechanics

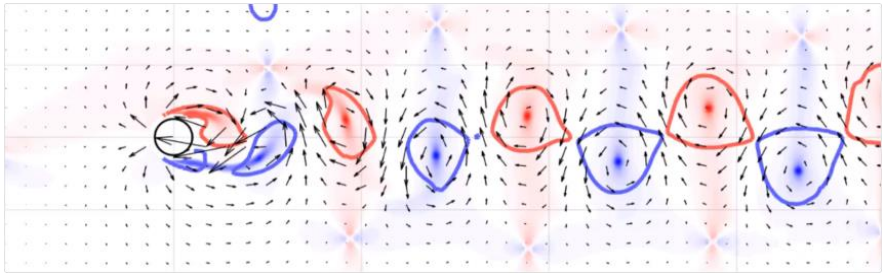
Vortex Dynamics

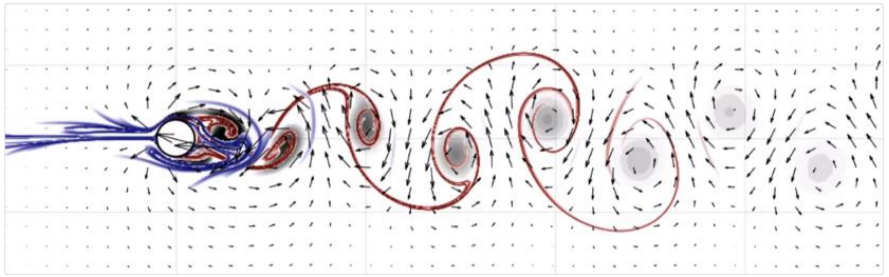
Lecturers: Dr.-Ing. Jochen Kriegseis and scientific staff

Language: German

Topics:

- Definition of a vortex
- Theoretical foundations of vortex flow
- Stationary and time-dependent solutions of vortex flows
- Helmholtz vortex sets
- Vortex transport equation
- Properties of various special vortex shapes
- Introduction to various vortex identification techniques





Related to: Experimental Fluid Mechanics and Aerodynamics

Aerodynamics

Lecturers: Dr.-Ing. Jochen Kriegseis and Dr.-Ing. Davide Gatti

in collaboration with students of Akaflieg

Language: German

Akademische Fliegergruppe
am Karlsruher Institut für Technologie e.V.

Topics:

- Fundamental equations of incompressible aerodynamics
- Airfoil theory and wing theory
- Fundamentals of experimental and numerical methods
- Fundamentals of unsteady aerodynamics
- Fundamentals of flight mechanics

Weather permitting, students will have the opportunity to experience and consolidate the fundamentals of aircraft aerodynamics and flight mechanics for themselves in a glider.

Related to: Experimental Fluid Mechanics

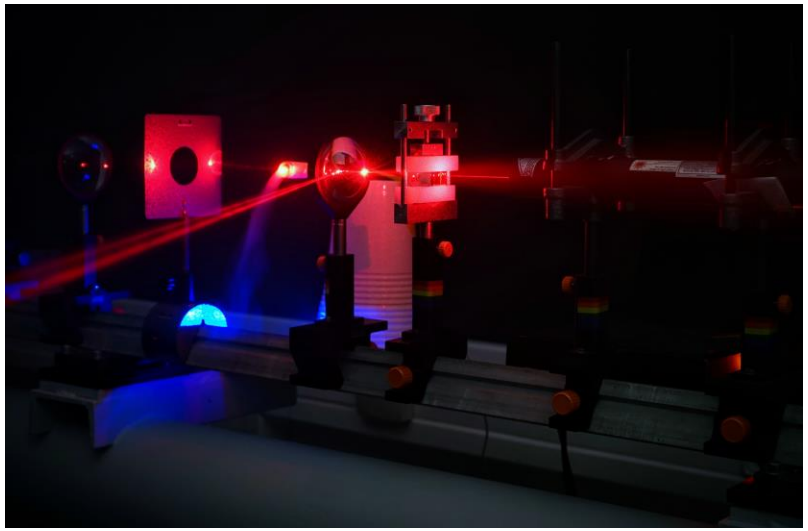
Flow Measurement Techniques

Practical course, offered in German and English

Lecturers: Dr.-Ing. Jochen Kriegseis and scientific staff

Topics:

- Wind tunnel technology and determination of turbulence levels
- Hot-wire calibration and measurement
- Pressure measurement in air (flow around a body)
- Pressure measurement in water (Nikuradse diagram)
- Schlieren method
- Mach-Zehnder interferometry
- Laser Doppler anemometry
- Particle image velocimetry
- Error propagation analysis



Can only be selected as part of the Laboratory Practical module, not as part of the Fluid Mechanics semester module
Recommended in combination with the Experimental Fluid Mechanics lecture

Career opportunities for fluid mechanics engineers

Qualifications:
A basic understanding of
the behaviour of fluid flows

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Estimation
Prediction (Calculation)
Control

Automotive industry

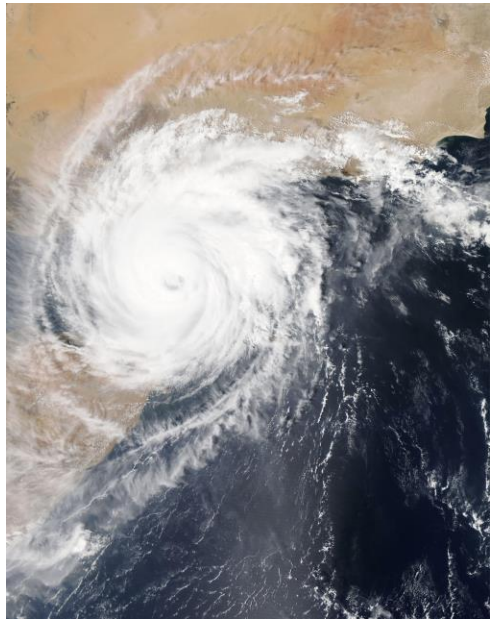
Process engineering

Shipbuilding industry

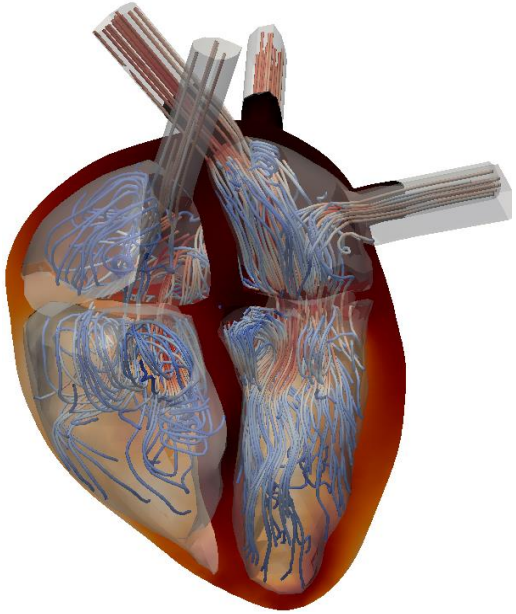
Transport sector

Aerospace industry

Career opportunities for fluid mechanics engineers



Meteorology & Climatology



Health technology

We look forward to seeing you!