Stand: Januar 2019 / Last updated: January 2019

Modulhandbuch / Module Manual
Wahlfächer / Compulsory Elective Modules
Masterstudiengänge / Master's Programmes

Module	**Study programme**					
	SET		**IWI**			**ME**
Schwerpunkte / Focus:	**EUT**	**UPT**	**EUT**	**UPT**	**PUI**	
Combustion Science and Technology						**X**
Turbulent Flows						**X**
Innovative Product Development					**X**	**X**
Control Theory	**X**	**X**	**X**	**X**	**X**	**X**
Thermoelektrik und Energierückgewinnung (Thermoelectrics and Energy Recovery)	**X**		**X**		**X**	**X** **(d)**
Virtual Reality für die Anlagentechnik (Virtual Reality for Process Plant Technology)		**X**				
Low-Noise Design	**X**	**X**	**X**	**X**	**X**	**X**
Intercultural Competence	**X**	**X**	**X**	**X**	**X**	**X**
Polymer Technology	**X**	**X**	**X**	**X**		**X**
Two-Phase Flows						**X**
Advanced Business English	**X**	**X**	**X**	**X**	**X**	**X**
Non-Metallic Materials	**X**	**X**	**X**	**X**	**X**	**X**
Automation with Microcontrollers	**X**	**X**	**X**	**X**	**X**	**X**
Prozessführung und Prozessautomation (Process Control and Process Automation)	**X**	**X**	**X**	**X**	**X**	**X** **(d)**
Pollutant Sensors in Ambient Air Control and Automobiles (Schadstoff-Sensoren in der Luftreinhaltung und bei Automobilen)	**X**	**X**	**X**	**X**	**X**	**X**
Energie- und umwelttechnische Prozessoptimierung (Energy and Environmental Process Optimisation) (Modulhandbuch Master SET / Module Manual Master SET)	**X**					
Finite Element Method (FEM) (Module Manual Master ME)	**X**	**X**	**X**	**X**	**X**	
Engineering Mathematics (Module Manual Masters SET/ME)	**X***	**X***	**X**	**X**	**X**	
Innovation and Technology Management (Module Manual Master IWI)	**X**	**X**				**X**
Computer-Based Measurement Technology (Module Manual Masters SET/ME)	**X***	**X***	**X**	**X**	**X**	
Computational Fluid Dynamics (Module Manual Masters SET/ME)	**X***	**X***	**X**	**X**	**X**	
Versuchsplanung und -auswertung (Test Planning and Evaluation) (Modulhandbuch Master SET / Module Manual Master SET)	**X***	**X***	**X**	**X**	**X**	**X** **(d)**
Life Cycle and Services Management (Module Manual Master IWI)	**X**	**X**				**X**
International Technical Sales Management (Module Manual Master IWI)	**X**	**X**				**X**

Methoden des Qualitätsmanagement (Quality Management Methods) (Modulhandbuch Master IWI / Module Manual Master IWI)	**X**	**X**				**X (d)**
Optimierung und Simulation (Optimisation and Simulation) (Module Manual SET)	**X***	**X***	**X**	**X**	**X**	**X (d)**
Simulation of Mechanical Systems (Module Manual Master ME)	**X**	**X**	**X**	**X**	**X**	
Energy Storage and Flexibility Options	**X**	**X**	**X**	**X**		**X**
Industrial Services Marketing & Business Development	**X**	**X**	**X**	**X**	**X**	**X**
Advanced Computational Methods	**X**	**X**	**X**	**X**	**X**	**X**
Software Lab	**X**	**X**	**X**	**X**	**X**	**X**
Heterogene Katalyse	**X**	**X**	**X**	**X**		

Agenda / Abbreviations:

Studiengänge / Study programmes:
SET = Simulations- und Experimentaltechnik / Simulation and Experimental Engineering,
IWI = Internationales Wirtschaftingenieurwesen / International Industrial Engineering,
ME = Mechanical Engineering
Schwerpunkte / Focus:
EUT = Energie- und Umwelttechnik / Energy and Environmental Technology,
UPT = Umwelt- und Prozesstechnik / Environmental and Process Technology,
PUI = Produktion und Innovation / Production and Innovation
Sprache / Language of instruction:
X (d) = German
Sonstiges / Other:
sem. = semester
SS = summer semester; WS = winter semester
SWS = credit hours per week
ECTS = credits according to the European Credit Transfer System

*Im Masterstudiengang SET müssen im Block der Methodenfächer 4 aus 5 Fächern ausgewählt werden. Das nicht gewählte 5. Fach kann als Wahlpflichtfach belegt werden. Die Modulbeschreibungen aller 5 Methodenfächer enthält das Modulhandbuch für die Pflichtfächer.

*In the master's programme SET, within the block of methodology modules (*Methodenfächer*), students must select 4 out of 5 modules. The module they did not select (module 5) can be chosen as an elective module. The module descriptions of all 5 methodology modules are in the module manual for compulsory modules.

Die Gültigkeit von Wahlfächern ist generell auf zwei Studienjahre beschränkt. Der Fachbereichsrat kann eine Modulbeschreibung für ein Wahlfach, für das laufende Studienjahr oder für das jeweils nächste Studienjahr beschließen bzw. deren Gültigkeit verlängern.

The validity of the elective modules is generally limited to two academic years. The Faculty Council can determine the description of an elective module for the current academic year or extend its validity for the following academic year.

Combustion Science and Technology						
Modulnummer (Module number)	**Workload**	**Präsenzzeit (Attendance)**	**Selbststudium (Self-study)**	**Studiensemester (Semester)**	**Angebot im (Offered in)**	**Dauer (Duration)**
40011	180 h	60 h	120 h	Sem. 1 or 2	SS/WS	1 sem.
Lehrveranstaltungen (Courses)		**Credits**	**Zuordnung zu den Curricula (Allocation to study programmes)**			
Seminar: 4 SWS		6 ECTS	Master ME			

1 **Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**

- The attendees have acquired a scientific understanding of and scientific insight into the combustion phenomena, at graduate level. The course includes combustion of gaseous, liquid and solid fuels, as well as gasification – which goes far beyond the basic combustion course normally taught at bachelor's level.
- They have also gained in-depth knowledge of a very broad range of all important engineering applications in combustion technology in detail. These competences are the ideal prerequisites for an employment in research or development in the industry in the area of combustion technology.

2 **Inhalte (Contents)**

- Chemical thermodynamics
- Chemical kinetics
- Oxidation mechanisms of fuels
- Transport phenomena
- Conservation equations
- Laminar non-premixed flames and laminar premixed flames
- Limit phenomena
- Asymptotic structure of flames
- Aerodynamics of laminar flames
- Combustion in turbulent flows
- Combustion in boundary layer flows
- Combustion in two-phase flows
- Combustion in supersonic flows
- Basic combustor aerodynamics (non-swirling and swirling jets)
- Atomisation techniques for spray combustion
- Internal combustion engines
- Gas turbine combustion
- Coal pulverisation

	• Pulverised solid combustion • Fluidised bed combustion • Grate combustion • Biomass combustion systems • Gasification techniques • Waste incineration • Fires
3	**Lehrformen (Forms of teaching)** • Lecture • Seminar • Discussion • Independent elaboration (in oral or written form)
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • Bachelor's degree in mechanical engineering (or in another relevant discipline) • Mathematics • Differential equations • Fluid dynamics • Computational Fluid Dynamics (CFD) • Heat transfer • Chemistry • English
5	**Prüfungsformen (Types of examination)** • Written multiple-choice examination (duration: 90 min.)
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Passed examination (100 %)
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr.-Ing. Ali Cemal Benim
8	**Sprache (Language of instruction)** • English
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • Kuo, "Principles of Combustion", 2nd edn, Wiley, 2005

Turbulent Flows						
Modulnummer (Module number) 40021	**Workload** 180 h	**Präsenzzeit (Attendance)** 60 h	**Selbststudium (Self-study)** 120 h	**Studiensemester (Semester)** Sem. 2	**Angebot im (Offered in)** SS/WS	**Dauer (Duration)** 1 sem.
Lehrveranstaltungen (Courses) Seminar: 4 SWS		**Credits** 6	**Zuordnung zu den Curricula (Allocation to study programmes)** Master ME			

1 **Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**

- The attendees have acquired a fundamental understanding of the physics and mathematical description of turbulent flows encountered in nature and engineering applications. They have gained detailed insights into different philosophies of turbulence modelling and in-depth knowledge of a broad range of applied turbulence models. Thus, they are able to analyse and interpret turbulent flow data maturely. They are competent to apply turbulence models to analyse turbulent flows and design technical devices.

2 **Inhalte (Contents)**

- Governing equations of fluid flow with initial and boundary conditions
- Introduction to turbulence phenomenon
- Turbulent flows in nature and engineering with their important characteristics
- Vortex stretching
- Energy cascade
- Turbulence eddies
- Turbulence mechanisms
- Characterisation of turbulence
- Averaging procedures
- Reynolds averaging
- The Schwarz inequality
- The probability density function
- Statistically steady and unsteady flows
- Favre averaging
- Morkovin hypothesis
- Ensemble averaging
- Phase averaging
- Short time averaging
- Filtering
- Root mean square values
- Turbulence kinetic energy
- Turbulence intensity
- Homogeneous turbulence
- Isotropic turbulence
- Dissipation rate and length scale
- Two-point correlation functions
- Integral scales of turbulence
- Spectral density, turbulence energy spectrum
- Near-wall turbulent flow

	• Direct numerical simulation • Reynolds averaged equations • Turbulent viscosity models • Zero-equation models • One-equation models • Two-equation models • Boundary conditions • Advanced eddy viscosity models • Algebraic and differential Reynolds stress models • Large eddy simulations • Hybrid models
3	**Lehrformen (Forms of teaching)** • Lecture • Seminar • Discussion • Independent elaboration (in oral or written form)
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • Bachelor's degree in mechanical engineering (or in another relevant discipline) • Mathematics • Differential equations • Fluid dynamics • Computational Fluid Dynamics (CFD) • English
5	**Prüfungsformen (Types of examination)** • Written multiple-choice examination (duration: 90 min.)
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Passed examination (100 %)
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr.-Ing. Ali Cemal Benim
8	**Sprache (Language of instruction)** • English
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • S. B. Pope, "Turbulent Flows", Cambridge University Press, 2011.

Innovative Product Development						
Modulnummer (Module number)	**Workload**	**Präsenzzeit (Attendance)**	**Selbststudium (Self-study)**	**Studiensemester (Semester)**	**Angebot im (Offered in)**	**Dauer (Duration)**
40031	180 h	60 h	120 h	Sem. 2	SS/WS	1 sem.
Lehrveranstaltungen (Courses)		**Credits**	**Zuordnung zu den Curricula (Allocation to study programmes)**			
Seminar: 4 SWS		6	Master ME, Master IWI			

1	**Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)** The students know • the theoretical and practical foundations of product development. They can • communicate with clients and suppliers systematically and in a structured way about costs, time schedules, and controlling. • work scientifically in this area.
2	**Inhalte (Contents)** • Development of a specific industrial product, typically in cooperation with a ‘contracting’ company
3	**Lehrformen (Forms of teaching)** • Consulting and guiding students in project work and in project groups
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • Knowledge of technical design and production technology as well as project management
5	**Prüfungsformen (Types of examination)** • Maximum of two intermediate presentations according to planned milestones and one final presentation in front of the cooperation partners. Examination (duration: 30 min.). Details to be announced at the beginning of the module.
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Passed examination (100 %)
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr.-Ing. Andreas Jahr (lecturer)
8	**Sprache (Language of instruction)** • English

9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • All documents on Moodle References (latest edition): • Pahl/Betz/Feldhusen: Konstruktionslehre, Springer 2007 • VDI 2221: Methodik zum Entwickeln und Konstruieren • VDI 2206: Entwicklungsmethodik für mechatronische Systeme • Brown, T. (2008). Design thinking. Harvard Business Review, 86(6), 84. • Tathagat Varma: Agile Product Development, Apress 2015 • Weitere Literatur wird zur konkreten Aufgabenstellung angegeben *(Further literature depending on the task will be recommended)*

Control Theory						
Modulnummer (Module number)	**Workload**	**Präsenzzeit (Attendance)**	**Selbststudium (Self-study)**	**Studiensemester (Semester)**	**Angebot im (Offered in)**	**Dauer (Duration)**
40041	180 h	60 h	120 h	Sem. 1	SS	1 sem.
Lehrveranstaltungen (Courses)		**Credits**	**Zuordnung zu den Curricula (Allocation to study programmes)**			
Seminar: 4 SWS		6	Master SET, Master IWI, Master ME			

1	**Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)** • Students are able to solve rather complex control-technique tasks. • Therefore, the SISO system is extended to multiple-state systems and different control strategies are possible. • Different techniques to evaluate the stability of a system.
2	**Inhalte (Contents)** • Multiple-input-multiple-output systems • Adaptive control • Optimal control • Controllability and observability • Lyapunov stability • State-space representation • Digital control
3	**Lehrformen (Forms of teaching)** • Lecture (PC with projector, overhead slides, blackboard) • Exercises
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • Control techniques • Mathematics
5	**Prüfungsformen (Types of examination)** • Oral examination (duration: 30 min.) or written examination (duration: 120 min.) (to be announced at the beginning of the course)
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Passed examination (feedback talk) (100 %)
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr.-Ing. Jürgen Kiel
8	**Sprache (Language of instruction)** • English or German
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • Lecture notes

Stand: Januar 2019 / Last updated: January 2019

Thermoelektrik und Energierückgewinnung (Thermoelectrics and Energy Recovery)

Modulnummer (Module number)	Workload	Präsenzzeit (Attendance)	Selbststudium (Self-study)	Studiensemester (Semester)	Angebot im (Offered in)	Dauer (Duration)
40051	180 h	60 h	120 h	Sem. 2	WS	1 sem.

Lehrveranstaltungen (Courses)	Credits	Zuordnung zu den Curricula (Allocation to study programmes)
Seminar: 4 SWS	6	Master SET, Master IWI (nur Schwerpunkt EUT / only in focus EUT), Master ME

1 **Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**

Nach erfolgreicher Absolvierung des Moduls haben die Studierenden

- Verständnis für die verwendeten Materialien entwickelt,
- den Aufbau und die Optimierung von Bauelementen kennengelernt,
- Methoden zur Systemintegration kennengelernt,
- die notwendigen Fähigkeiten und Kenntnisse, thermoelektrische Systeme zu analysieren, zu entwerfen und zu optimieren.

(After successful completion of the module, the students

- *understand the materials used,*
- *know the structure and optimisation of components,*
- *know methods of system integration,*
- *have the necessary abilities and expertise to analyse, design and optimise thermoelectric systems.)*

2 **Inhalte (Contents)**

Was ist Thermoelektrik, welche Größen bestimmen die Thermoelektrik?

- Grundlagen Aufbau der Materie,
- Seebeckkoeffizient,
- Peltiereffekt,
- Elektrischer Transport,
- Wärmeleitung,
- Charakterisierungsverfahren,
- Bauelemente,
- Anwendungen:
  - Prinzip Kühlschrank, Elektronik-Kühlung,
  - Low power TEG (energieautarke Sensorik),
  - High Power TEG (z.B. Energierückgewinnung im Auto)

(Defining thermoelectrics: Which aspects define thermoelectrics?

- *Fundamentals,*
- *Seebeck coefficient,*
- *Peltier effect,*
- *Electricity transmission,*
- *Heat conduction,*

	• *Characterisation procedures,*
	• *Components,*
	• *Application:*
	  • *Refridgerator method, electronic cooling,*
	  • *Low-power TEG (energy-self-efficient sensor technology)*
	  • *High-power TEG (e.g. automotive energy recovery))*

3	**Lehrformen (Forms of teaching)** • Seminaristischer Unterricht und Übungen *(Seminar with exercises)*
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • Keine Vorkenntnisse *(None)*
5	**Prüfungsformen (Types of examination)** • Je nach Teilnehmerzahl Klausur (120 min) oder Projektarbeit mit Vortrag (30 min) *(Depending on the number of students: either written examination (duration: 120 min.) or project work incl. presentation (duration: 30 min.))*
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Bestandende Modulprüfung (100 %) *(Passed module examination (100 %))*
7	**Modulverantwortliche(r) (Person responsible for the module)** • Dr. Dirk Ebling
8	**Sprache (Language of instruction)** • Englisch/Deutsch *(German and English)*
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • pdf-Dateien der Vorlesungsfolien für das Fach *(pdf documents of the lecture slides)* Empfohlene Literatur (jeweils neueste Auflage) (Recommended literature (latest edition): • [1] D.M. Rowe, “Thermoelectrics Handbook - macro to nano”; Taylor and Francis 2006, Kapitel 2 und Kapitel 14 • [2] K. Seeger, „Semiconductor Physics“; (1985) Springer Verlag • [3] C. Herring, “ Theory of thermoelectric power of semiconductors”, Phys. Rev. 96 (1954) 1163 • [4] R.P. Hübener; “Thermoelectricty in metals and alloys”; Solid State Physics 27 (1972) 63 • [5] U. Birkholz, „Thermoelektrische Bauelemente“, (1984), in „Amorphe und polykristalline Halbleiter“, W. Heywang (Hrsgb.) Serie „Halbleiter-Elektronik“, Springer Verlag • [6] N.W. Ashcroft, et al., „Solid State Physics“; (1976), Saunders College • [7] Ch. Kittel, H. Krömer; „Thermodynamik“, (2001), Oldenburg Verlag

Stand: Januar 2019 / Last updated: January 2019

Virtual Reality für die Anlagentechnik (Virtual Reality for Process Plant Technology)

Modulnummer (Module number)	Workload	Präsenzzeit (Attendance)	Selbststudium (Self-study)	Studiensemester (Semester)	Angebot im (Offered in)	Dauer (Duration)
40061	180 h	60 h	120 h	Sem. 2	WS	1 sem.

Lehrveranstaltungen (Courses)	Credits	Zuordnung zu den Curricula (Allocation to study programmes)
Seminar: 4 SWS	6	Master SET (nur Schwerpunkt UPT / only in focus UPT)

1 **Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**

Die Studierenden

- kennen die Einsatzfelder von Virtual Reality (VR) – Anwendungen in der Prozess- und Anlagentechnik
- sind in der Lage, VR-Szenarien zur konzipieren
- haben Methoden der VR-Anwendungsprogrammierung kennengelernt
- besitzen die notwendigen Fähigkeiten, an aktuellen Forschungs- und Entwicklungsarbeiten im Bereich Virtual Reality mitzuwirken

(The students

- *know the fields of application of Virtual Reality (VR) – application in process engineering and process plant technology,*
- *are able to design VR scenarios,*
- *know methods of applied VR programming,*
- *are able to contribute to current research and development work in the field of VR.)*

2 **Inhalte (Contents)**

- Grundlagen der VR-Szenenentwicklung
- Daten-Preprocessing für effektiven VR-Einsatz
- Hard- und Softwaresysteme für die Realisierung von VR-Projekten im Anlagenbau
- Programmierung und Bedienung von Demonstrations-VR-Anlagen

- *(Fundamentals of VR design*
- *Data preprocessing for efficient VR use*
- *Hardware and software systems for implementing VR projects in process plant design*
- *Programming and operation of VR demonstration in process plant design)*

3 **Lehrformen (Forms of teaching)**

- Seminar mit Praktikumsanteil unter Nutzung des Virtual Reality-Pools
  (Seminar incl. practical training using the VR pool)

4 **Empfohlene Voraussetzungen (Recommended prerequisites)**

- Rechnergestützte Prozess- und Anlagenplanung (Schwerpunkt Umwelt- und Prozesstechnik)
  (Computer-aided process and process plant design (focus Environmental and Process Technology (UPT)))

5	**Prüfungsformen (Types of examination)** • mündliche Prüfung (30 min) zu den oben genannten Inhalten. Die Prüfungsform wird zu Beginn der Lehrveranstaltung festgelegt *(Oral examination (duration: 30 min.) about the contents mentioned above. Type of examination to be announced at the beginning of the course.)*
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Bestandende Modulprüfung (100 %) *(Passed module examination (100 %)*
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr.- Ing. Martin Nachtrodt
8	**Sprache (Language of instruction)** • Deutsch *(German)*
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • notwendige Unterlagen zur Aufgabenstellung unter Moodle *(Relevant documents for the assignment on Moodle)* Empfohlene Literatur (Recommended literature): • TAUER, H: Stereo 3D, Schiele & Schön • DÖRNER, R.: Virtual und Augmented Reality (VR/AR), Springer Verlag • Sherman, William R.; Craig, Alan. Understanding Virtual Reality: Interface, Application and Design, Morgan Kaufman Publishers, San Francisco, 2003

Stand: Januar 2019 / Last updated: January 2019

Low-Noise Design						
Modulnummer (Module number)	**Workload**	**Präsenzzeit (Attendance)**	**Selbststudium (Self-study)**	**Studiensemester (Semester)**	**Angebot im (Offered in)**	**Dauer (Duration)**
40071	180 h	60 h	120 h	Sem. 2	WS	1 sem.
Lehrveranstaltungen (Courses)		**Credits**	**Zuordnung zu den Curricula (Allocation to study programmes)**			
Seminar: 4 SWS		6	Master SET, Master ME, Master IWI			

1	**Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**
	• The students have fundamental knowledge of low-noise design with applications for
	  • industrial machinery,
	  • HVAC,
	  • automotive industry,
	  • aviation industry.
	• The participants can evaluate noise and noise sources with experimental and numerical methods.

2	**Inhalte (Contents)** • Noise and vibration generation, theoretical approaches, prediction of noise levels, noise and vibration measurement technique
3	**Lehrformen (Forms of teaching)** • Consulting and guiding students in project work and project groups
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • Computer-based measurement technology
5	**Prüfungsform (Types of examination)** • Written assignment and presentation (duration: 30 min.)
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Passed examination (feedback talk)
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr.-Ing. Frank Kameier
8	**Sprache (Language of instruction)** • English
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • Smith, M.J.T. Aircraft Noise, 1989 • Fletcher, Rossing, The Physics of Musical Instruments, 2008 • Nguyen-Schäfer, Hung, Aero and Vibroacoustics of Automotive Turbochargers, 2013 • Bendat, Julius S., Piersol, Allan G.: Engineering applications of correlation and spectral analysis, New York, 1980 • Lucas et al.: Handbook of the Acoustic Characteristics of Turbomachinery Cavities, 1997. • Blauert, Jens, Xiang, Ning, Acoustics for Engineers, 2009

Intercultural Competence						
Modulnummer (Module number)	**Workload**	**Präsenzzeit (Attendance)**	**Selbststudium (Self-study)**	**Studiensemester (Semester)**	**Angebot im (Offered in)**	**Dauer (Duration)**
	180 h	60 h	120 h	Sem. 1	SS	1 sem.
Lehrveranstaltung (Courses)		**Credits**	**Zuordnung zu den Curricula (Allocation to study programmes)**			
Seminar: 4 SWS		6	Master SET, Master IWI, Master ME			

1	**Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)** • The students have good knowledge of theories of culture types and cultural values. • They understand the basic principles of intercultural communication and have gained cultural awareness. • They have insight into the diversity in global business. • They are able to handle communication issues and can strive for solutions in a business environment.
2	**Inhalte (Contents)** • Intercultural competence is one of the crucial soft skills anyone should have who would like to be successful in a leading position in the globalised business world – independent of his/her job-specific skills. • In particular students who would like to be part of an international team – in Germany or abroad – need additional skills in order to communicate successfully with members of different cultures. • What is culture? Different types of cultures are studied with regard to power distance; individualism, collectivism; uncertainty avoidance; orientations to time etc. These are issues the students want to study. Especially by focusing on selected examples, the students will be enabled to deal with different corporate cultures.
3	**Lehrformen (Forms of teaching)** • Presentations • Case studies • Lecture • Videos
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • Good knowledge of English
5	**Prüfungsformen (Types of examination)** • Presentations (duration: 30 min.) and/or written examination (duration: 120 min.) and/or oral examination (duration: 30 min.). To be announced at the beginning of the seminar.
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Passed examination • Regular participation required (min. 80 %)
7	**Modulverantwortliche(r) (Person responsible for the module)** • Britta Zupfer MA
8	**Sprache (Language of instruction)** • English

9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • None

Polymer Technology

Modulnummer (Module number)	Workload	Präsenzzeit (Attendance)	Selbststudium (Self-study)	Studiensemester (Semester)	Angebot im (Offered in)	Dauer (Duration)
40091	180 h	60 h	120 h	Sem. 1 or 2	WS	1 sem.

Lehrveranstaltungen (Courses)	Credits	Zuordnung zu den Curricula (Allocation to study prgramme)
Seminar: 4 SWS	6	Master SET, Master ME, Master IWI (UPT/EUT)

1 **Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**

- This seminar has provided the students with basic knowledge of polymer properties, synthesis processes, polymer processing and main technologies in this field. It has enabled them to design fundamental polymer processes, considering the impact of the specific properties of polymers on the processes.
  During the seminar, the students have learned to correlate the structure of polymers with their corresponding properties. They know the essential methods to determine chemical and physical polymer properties and get an insight into polymer blends. Concerning polymer processing, the students have learned the essential dimensionless numbers and how to use them to design extrusion processes. Besides, they know how to calculate pressure losses of flowing polymers. Finally, the students are aware of the main characteristics of the most important polymer processing technologies (injection moulding, blow moulding etc.).
  After this course, the students have the necessary fundamental knowledge of polymer technology – and are well prepared to start working in the polymer industry.

2 **Inhalte (Contents)**

- Chemical structure of polymers
- Physical and chemical properties of polymers
- Rheological behaviour of polymers
- Relationship of structure and properties of polymers
- Chemistry of polymer synthesis
- Processes for polymer synthesis
- Polymer compounds
- Extrusion of polymers
- Main polymer processing technologies (injection moulding, blow moulding etc.)

3 **Lehrformen (Forms of teaching)**

- Seminar
- Discussions
- Excursion

4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • Fluid mechanics • Chemistry • Physics • Mathematics
5	**Prüfungsformen (Types of examination)** • Combined examination: Short written assignment with presentation (duration: 15 min.) (= 40 %) and written examination (duration: 60 min.) (= 60 %)
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Passed examination, written assignment or oral presentation
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr.-Ing. Maren Heinemann
8	**Sprache (Language of instruction)** • English or German (depending on participants)
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • Material science of polymers for engineers, Tim A. Osswald, Georg Menges, ISBN 978-1-56990-514-2 • Understanding polymer processing: processes and governing equations, Tim A. Osswald, ISBN 978-1- 56990-472-5 • International plastics handbook: the resource for plastics engineers, Tim A. Osswald, ISBN 978-3- 446-22905-1 • Kunststoffchemie für Ingenieure: Von der Synthese bis zur Anwendung, Wolfgang Kaiser, ISBN 978-3446446380 • Kunststofftechnik: Einführung und Grundlagen, Christian Bonten, ISBN 978-3446440937 • Menges Werkstoffkunde Kunststoffe, Georg Menges, Edmund Haberstroh, Walter Michaeli, Ernst Schmachtenberg, ISBN 978-3446427624 • Polymer-Werkstoffe: Struktur - Eigenschaften – Anwendung, Gottfried Wilhelm Ehrenstein, ISBN 978-3446422834

Stand: Januar 2019 / Last updated: January 2019

Two-Phase Flows						
Modulnummer (Module number)	**Workload**	**Präsenzzeit (Attendance)**	**Selbststudium (Self-Study)**	**Studiensemester (Semester)**	**Angebot im (Offered in)**	**Dauer (Duration)**
	180 h	60 h	120 h	Sem. 2	WS/SS	1 sem.
Lehrveranstaltungen (Courses)		**Credits**	**Zuordnung zu den Curricula (Allocation to study programmes)**			
Seminar: 4 SWS		6	Master ME			

1 **Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**

- The attendees have acquired an understanding of and insight into fluid dynamics and heat transfer of two-phase flows – which goes beyond the introductory information provided at bachelor's level. They can apply the fundamental principles to a variety of homogeneous mixture as well as separated liquid-liquid, gas-solid, liquid-solid and gas-liquid flow problems. They can read and understand publications on two-phase flows and apply the knowledge in their own research and development work. They can apply these skills in a wide range of industrial applications involving two-phase flows – including areas such as power generation, combustion technology, heat exchanger technology, fluidised beds, separation technology, hydrology, environmental problems, food processing, media transport.

2 **Inhalte (Contents)**

- Review of important topics in single-phase flow, heat and mass transfer
- Introduction to two-phase flows
- Gas-liquid interfacial phenomena
- Some basic definitions in two-phase flows
- Two-phase flow patterns and flow maps
- Homogeneous flow
- Separated flow
- The concept of drift flux
- Flooding in two-phase flow
- Introduction to boiling, pool boiling
- Critical heat flux in boiling
- Condensation
- Gas-solid two-phase flows
- Gas-liquid dispersed two-phase flows (sprays)
- Multi-dimensional field equations for describing two-phase flows in different regimes with phase coupling
- Special topics and applications

3 **Lehrformen (Forms of teaching)**

- Lecture
- Seminar
- Discussion
- Independent elaboration (in oral or written form)

4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • Bachelor's degree in mechanical engineering (or in another relevant discipline) • Mathematics • Differential equations • Fluid dynamics • Heat transfer • English
5	**Prüfungsformen (Types of examination)** • Written multiple-choice examination (duration: 90 min.) or oral examination (duration: 30 min.) and presentation. To be announced at the beginning of the course.
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Passed examination (100 %)
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr.-Ing. Ali Cemal Benim
8	**Sprache (Language of instruction)** • English
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • S. M. Ghiaasiaan, "Two Phase Flow, Boiling and Condensation", Cambridge University Press, 2007.

Stand: Januar 2019 / Last updated: January 2019

Advanced Business English

Modulnummer (Module number)	Workload	Präsenzzeit (Attendance)	Selbststudium (Self study)	Studiensemester (Semester)	Angebot im (Offered in)	Dauer (Duration)
	180 h	60 h	120 h		SS	1 sem.

Lehrveranstaltungen (Courses)	Credits	Zuordnung zu den Curricula (Allocation to study programmes)
Seminar: 4 SWS	6	Master SET, Master ME, Master IWI

1 **Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**

The students

- are able to communicate in English in a wide range of business situations,
- have gained confidence in using the language of international business,
- know important business words and phrases relevant for engineers,
- have good knowledge of important grammar topics,
- are able to write business e-mails,
- have improved their listening skills,
- are able to read and understand authentic business articles.

2 **Inhalte (Contents)**

- Authentic articles on a variety of current business topics
- Listening comprehension exercises and interviews
- Grammar exercises
- Business correspondence

3 **Lehrformen (Forms of teaching)**

- Seminar
- Lecture
- Group work
- Discussion
- Videos

4 **Empfohlene Voraussetzungen (Recommended prerequisites)**

- Good knowledge of English

5 **Prüfungsformen (Types of examination)**

- Written examination or multiple-choice examination (duration: 120 min.).
- Details to be announced at the beginning of the seminar.

6 **Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)**

- Passed examination (100 %)

7 **Modulverantwortliche(r) (Person responsible for the module)**

- Britta Zupfer MA

8	**Sprache (Language of instruction)** • English
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • *Market Leader.* Business English Course Book. 3rd edition. FT Publishing. Pearson Education Limited 2014. • Basis for Business. Cornelsen Professional. Berlin 2012. • Business Spotlight • The Local

Stand: Januar 2019 / Last updated: January 2019

Non-Metallic Materials: Ceramics and Glasses, Polymers and Composite Materials						
Modulnummer (Module number)	**Workload**	**Präsenzzeit (Attendance)**	**Selbststudium (Self-study)**	**Studiensemester (Semester)**	**Angebot im (Offered in)**	**Dauer (Duration)**
	180 h	60 h	120 h	Sem. 1 or 2	WS	1 sem.
Lehrveranstaltungen (Courses)		**Credits**	**Zuordnung zu den Curricula (Allocation to study programmes)**			
Seminar: 2 SWS Lecture: 2 SWS		6	Master ME, Master SET, Master IWI			

1	**Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)** • At the end of the module, students know the applications of ceramics, glasses, polymers and composite materials – as well as the respective materials' composition(s). They understand how the microscopic structure of the materials determines or influences the macroscopic properties of the materials. They can explain various preparation techniques and possibilities to modify or optimise given materials according to individual needs.
2	**Inhalte (Contents)** • Fundamentals of atomic interactions (chemical bond, metals and non-metals), chemical structures, phase transitions • Ceramics: composition and structures, applications and characteristic properties, processing and manufacturing, varying types of ceramics • Glasses: composition and structures, applications and characteristic properties, the glass transition temperature, production and modification, glass ceramics, piezo ceramics • Polymers: composition and structures, properties and applications, production and introduction to processing and preparation, properties and application • Composite materials: characteristics and (anisotropic) properties, failure types, applications • Selected topics: manufacturing of synthetic diamonds, ceramic joining, ceramic coating
3	**Lehrformen (Forms of teaching)** • Lecture and seminar with students' presentations and discussion
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • Fundamentals of chemistry (e.g. 'Chemistry I – General Chemistry' from the bachelor's programme)
5	**Prüfungsformen (Types of examination)** • Presentation (duration incl. discussion: 30 min.).
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Successful presentation (100 %)
7	**Modulverantwortliche(r) (Person responsible for the module)** • Dean and Dr. Ulf Ritgen
8	**Sprache (Language of instruction)** • English

9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)**
	• M.F. Ashby, D.R.H. Jones, Engineering materials:
	  • 1 – An introduction to properties, application and design, 4th ed., 2012
	  • 2 – An introduction to microstructures and processing, 4th ed., 2013
	• (In German: Werkstoffe 1: Eigenschaften, Mechanismen und Anwendungen, 3. Aufl., 2013; Werkstoffe 2: Metalle, Keramiken und Gläser, Kunststoffe und Verbundwerkstoffe, 3. Aufl., 2012)

Automation with Microcontrollers

Modulnummer (Module number)	Workload	Präsenzzeit (Attendance)	Selbststudium (Self-study)	Studiensemester (Semester)	Angebot im (Offered in)	Dauer (Duration)
	180 h	60 h	120 h	Sem. 2	WS	1 sem.

Lehrveranstaltungen (Courses)	Credits	Zuordnung zu den Curricula (Allocation to study programmes)
Seminar: 4 SWS	6	All master's programmes

1 **Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**

- The students know the architecture of microcontrollers (µC) represented by the ARM-microcontroller family. They have basic skills in Python and C programming of microcontrollers. They can use digital and analogue I/O-ports and know how to program timers and interrupts. The students can exchange data via serial bus and read in as well as process analogue signals (such as sensor data) via AD converters. The subjects have been applied in practical exercises and programming tasks. In the course, the students have built up a functional microcontroller project with actuators and sensors. Due to relatively low cost of the used equipment (<100€) and the use of open source software, students could optionally use their own equipment and could literally 'take their project home'. The students have worked out practical tasks in small groups. This has supported their capacity for teamwork and communication skills.

2 **Inhalte (Contents)**

- Range of application for µC
- µC architecture, µC programming
- Basics of Python and C-programming languages
- Cross compilation
- Real-time systems
- I/O ports
- System clock
- Timers and interrupts
- Basic electronics in the peripheral µC-context
- Acquisition of analogue data (ADC)
- Output of analogue data (DAC, PWM)
- Communication via interfaces (serial bus, I²C, RS485…)
- µC as embedded system
- Networking with µCs
- Rapid prototyping of automation algorithms on µC using MATLAB and Simulink
- Basics of Artificial Intelligence on µC: soft sensors, neuronal networks, fuzzy logic and machine learning

3 **Lehrformen (Forms of teaching)**

- Seminar with computer exercises (Embedded Linux, Eclipse, MATLAB, Simulink) including electronic practice sessions in small groups

4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • BEng, BSc or similar degree. • Basic knowledge of PLC or other industrial automation systems is of advantage.
5	**Prüfungsformen (Types of examination)** • Oral or written examination. To be announced at the beginning of the course.
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Passed examination
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr.-Ing. Wolfgang Grote
8	**Sprache (Language of instruction)** • English (or German, if all students in the class are German natives)
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • *Embedded Controller*, R. Asche, Springer-Verlag • https://beagleboard.org/ • https://www.mikrocontroller.net/

Prozessführung und Prozessautomation (Process Control and Process Automation)

Modulnummer (Module number)	Workload	Präsenzzeit (Attendance)	Selbststudium (Self-study)	Studiensemester (Semester)	Angebot im (Offered in)	Dauer (Duration)
	180 h	60 h	120 h	Sem. 2	WS	1 sem.

Lehrveranstaltungen (Courses)	Credits	Zuordnung zu den Curricula (Allocation to study programmes)
Seminar: 4 SWS	6	Alle Masterstudiengänge (All master's programmes)

1 **Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**

- Den Teilnehmern werden Methoden der Prozessautomation aus Energie- und Verfahrenstechnik vermittelt. Sie sollen befähigt werden, Probleme der Prozessautomation zu erkennen, Lösungsvorschläge zu erarbeiten und diese zu erproben. Dies geschieht am Beispiel verfahrenstechnischer Anlagen und deren Simulationsmodellen. Neben industrieller Prozessleittechnik, den Methoden der 'Advanced Process Control' werden Methoden vermittelt, die auf der mathematischen Optimierung basieren: Optimalsteuerung und modell-prädiktive Regelung.
  (The attendees have learned process-automation methods from the fields of energy and process technology. They are able to identify problems in process automation, develop and try out solution suggestions. They have learned this based on the example of process plants and simulation models for such plants. Apart from process control engineering and methods of 'Advanced Process Control', the students have learned methods based on mathematical optimisation: optimal control and model predictive control.)
- In dieser Veranstaltung sollen Team- und Kommunikationsfähigkeit durch die Bildung von Zweiergruppen innerhalb der Software-Anwendung gefördert werden, da die Lösungen gruppenübergreifend vorgestellt und diskutiert werden müssen.
  (This course has promoted teamwork and communication skills: The students have worked in groups of two for software application exercises, then presented and discussed the results with the entire class.)

2 **Inhalte (Contents)**

- Es werden Methoden zur Prozessführung und Prozessleittechnik behandelt und an verfahrenstechnischen Simulationsmodellen angewendet. Der zweite Teil der Veranstaltung vertieft dabei Methoden der Prozessautomation, die auf der mathematischen Optimierung basieren, darunter modellprädiktive Regelung und Optimalsteuerung. Die Anwendung und Erprobung der Methoden in den Übungen erfolgt hauptsächlich unter Nutzung von MATLAB-Anwendungen.
  (The course discusses methods of process control and process control engineering which the students apply in process simulation models. The second half of the course covers advanced methods of process automation based on mathematical optimisation (e.g. model predictive control and optimal control). The students apply and try out these methods in exercises, mainly using MATLAB.)
- Gliederung: Einleitung in die Prozessführung; Prozessleittechnik (Leitsysteme, SPS, Feldgeräte) und deren Automatisierungspyramide; Kommunikation von Feldgeräten und Steuerungsebenen; Prozessmodelle und totzeitbehaftete Prozesse, praxistaugliche Regleralgorithmen, Modifikationen von Regelkreisstrukturen (Kaskade, Smith-Prädiktor, Störgrößenaufschaltung, ...), Regler-Tuning;

	Rezeptsteuerung von kontinuierlichen und Batch-Prozessen; Regelung und Entkopplung von Mehrgrößensystemen; Optimalsteuerung; modellprädiktive Regelung (MPC) *(Course structure: introduction to process control; process control engineering (control systems, PLC, field devices) and their automation pyramid; communication between field devices and control levels; process models and particularly fragile or dead-time affected processes, practical control algorithms, modification of control loop structures (cascades, Smith predictor, disturbance rejection etc.), controller tuning; recipe control of continuous and batch processes; control and decoupling of multiple-input-multiple-output systems (MIMO); optimal control; model predictive control (MPC))*
3	**Lehrformen (Forms of teaching)** • Seminaristischer Unterricht und Übungen mit Computernutzung (MATLAB / Simulink) *(Seminar and computer exercises (MATLAB, Simulink)*
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • B.Eng. oder vergleichbarer Abschluss, Grundlagen Regelungstechnik *(BEng or comparable degree, fundamentals of control engineering)*
5	**Prüfungsformen (Types of examination)** • Mündliche Prüfung oder Klausur, wird zu Beginn der Veranstaltung festgelegt. *(Oral or written examination. To be announced at the beginning of the course.)*
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Bestandende Modulprüfung *(Passed module examination)*
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr.-Ing. Wolfgang Grote
8	**Sprache (Language of instruction)** • Deutsch *(German)*
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • Schuler, H., Prozessführung, Oldenbourg-Verlag • Seborg, D. E. et al., Process Dynamics and Control • Dittmar, R., Pfeiffer, B.-M. Modellbasierte prädiktive Regelung: Eine Einführung für Ingenieure, De Gruyter

Stand: Januar 2019 / Last updated: January 2019

Pollutant Sensors in Ambient Air Control and Automobiles
Schadstoff-Sensoren in der Luftreinhaltung und bei Automobilen

Modul-nummer (Module number)	Workload	Präsenzzeit (Attendance)	Selbststudium (Self-study)	Studiensemester (Semester)	Angebot im (Offered in)	Dauer (Duration)
	180 h	60 h	120 h	Sem. 1 or 2	WS/SS	1 sem.

Lehrveranstaltungen (Courses)	Credits	Zuordnung zu den Curricula (Allocation to study programmes)
Seminar: 4 SWS	6	Master ME, Master SET, Master IWI

1 **Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**

- *The attendees know and understand the design and function of low-cost sensors. They also know the potential and limitations of low-cost sensors – especially in comparison with expensive certified analytical instruments used by official environmental agencies. Moreover, they know the design, function and importance of sensors used in automobiles for air pollution control.*

- Die Studierenden kennen und verstehen den Aufbau und die Funktionsweise von low-cost Sensoren. Sie können Möglichkeiten und Grenzen von low-cost Sensoren insbesondere auch im Vergleich mit eignungsgeprüften teuren Analysatoren der Umweltämter einschätzen Sie kennen Aufbau, Funktionsweise und Bedeutung von Sensoren, die bei Automobilen bei der Luftschadstoffreduktion eingesetzt werden.

2 **Inhalte (Contents)**

- *Overview of low-cost sensors in air pollution control*
- *Function and design of low-cost sensors for gaseous air pollutants, especially of electrochemical sensors*
- *Function and design of different low-cost sensors for measuring particles*
- *Networks of low-cost sensors and visualisation of measurement results in Google Maps and Google Earth*
- *Limitations of low-cost sensors*
- *Comparison of low-cost sensors with certified expensive analytical instruments*
- *Formation and emission of air pollutants from automobiles and use of sensors for air pollution control in automobiles*
- *Requirements for sensors for automobiles and short overview of sensors for automobiles.*

- Übersicht über low-cost Sensoren in der Luftreinhaltung
- Funktionsweise und Aufbau von low-cost Sensoren für gasförmige Luftschadstoffe, insbesondere von elektrochemischen Sensoren
- Funktionsweise und Aufbau von verschiedenen low-cost Sensoren in der Partikelmesstechnik
- Vernetzung von low-cost Sensoren und Darstellung der Ergebnisse in Google Maps oder Google Earth
- Grenzen der Leistungsfähigkeit von low-cost Sensoren
- Vergleich von low-cost Sensoren mit eignungsgeprüften teuren Analysatoren in der Luftreinhaltung
- Grundlagen der Schadstoffentstehung bei Automobilen und Einsatz von Sensoren bei der Luftschadstoffreduktion

	• Anforderungen an Sensoren bei Automobilen je nach Einsatzweck und Überblick für den Einsatz von Sensoren bei Automobilen
3	**Lehrformen (Forms of teaching)** • *Impulse lecture* • *Seminar* • *Discussion* • Einführende Vorlesung • seminaristischer Unterricht • Diskussion
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • *Fundamentals of physics, electrical engineering, electronics* • Grundlagen der Physik, Elektrotechnik, Elektronik.
5	**Prüfungsformen (Types of examination)** • *Oral examination or written assignment, to be announced at the beginning of the course* • Mündliche Prüfung oder schriftliche Hausarbeit, wird zu Beginn der Lehrveranstaltung bekanntgegeben.
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Passed examination (100 %)
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr. Konradin Weber (Lecturer / Dozent)
8	**Sprache (Language of instruction)** • English. On demand, also in English and German.
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • Moretto, Ligia, Kalcher, Kurt, Environmental Analysis by Electrochemical Sensors and Biosensors, Springer-Verlag 2017 • Mead, M.I. et al.: The use of electrochemical sensors for monitoring urban air quality in low-cost, high density networks, Atmospheric Environment 70 (2013) 186-2013 • Reif, K., Sensoren im Kraftfahrzeug, Springer Vieweg 2012 • LUBW Hrsg., LUBW-Bericht zu Feinstaubsensoren, Stuttgart 2017 • Internet resources such as / Internetquellen wie: http://alphasense.com; http://www.citi-sense.eu/ www.luftdaten.info; http://www.ch.cam.ac.uk/files/aw534/RLJ%20AAMG%20 • More literature to be announced at the beginning of the course. / Weitere Literatur wird aktuell am Beginn der Veranstaltung angegeben.

Stand: Januar 2019 / Last updated: January 2019

Energy Storage and Flexibility Options						
Modulnummer (Module number)	**Workload**	**Präsenzzeit (Attendance)**	**Selbststudium (Self-study)**	**Studiensemester (Semester)**	**Angebot im (Offered in)**	**Dauer (Duration)**
	180 h	60 h	120 h	Sem. 1 or 2	SS/WS	1 semester
Lehrveranstaltungen (Courses)		**Credits**	**Zuordnung zu den Curricula (Allocation to study programmes)**			
Seminar: 4 SWS		6	Master SET, IWI (EUT, UPT), ME			

1	**Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**
	• The attendees have gained in-depth knowledge of a broad range of currently available energy-storage technologies and flexibility options – which are, or can be, used in the electricity, heat and mobility sectors. They are able to recall the basic theory behind different systems. So they can
	  • explain their functional principles,
	  • state application areas as well as (dis)advantages and
	  • evaluate their need, potential and cost in energy systems, in particular in systems based on renewable energy.

2	**Inhalte (Contents)** • Flexibility options and energy storage demand in energy systems, in particular in systems based on renewable energy • Applications and use cases in centralised and decentralised systems • Mechanical, electrical, electro-chemical, chemical and thermal energy storage systems • Flexibility options, e.g. demand-side management • Power-to-x technologies (gas, liquid, heat) and their potential for the heat and mobility sector • Cost evaluation • Sustainability evaluation
3	**Lehrformen (Forms of teaching)** • Lecture • Discussion
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • Bachelor's degree in a relevant discipline • Thermodynamics • English
5	**Prüfungsformen (Types of examination)** • Written examination (duration: 90 min.) or oral examination (duration: 30 min.). To be announced at the beginning of the course.
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Passed examination (100 %)
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr.-Ing. Franziska Schaube
8	**Sprache (Language of instruction)**

	• English. Upon request, attendees may choose to take the examination in German.
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • Course materials on Moodle.

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Industrial Services Marketing and Business Development						
Module number	**Workload**	**Attendance**	**Self-study**	**Semester**	**Offered in**	**Duration**
40201	180 h	60 h	120 h	Sem. 1/2	SS	1 sem.
Courses		**Credits**	**Allocation to study programmes**			
Seminar: 4 SWS		6 ECTS	Master IWI, ME, SET			

1	**Learning outcomes / competences** The attendees have acquired a scientific understanding and scientific insight into the marketing and business development of industrial services. The compulsory elective course has links to and deepens the contents of the following courses: • Life Cycle and Services Management as well as International Technical Sales Management at master's level, • Marketing and Sales as well as Service Management at bachelor's level. The students have learned about the importance of professional services and their role in the revenue stream of industrial enterprises. For this purpose, the students have learned methods of how to • identify profitable business areas and • develop a successful communication strategy for industrial services for the customers. The students can apply the theoretical results of the course to practical interviews with practitioners in industry. Therefore the course serves as a basis for a successful entry into a career in industrial services in practice.
2	**Contents** Methods and technologies of industrial services marketing (e.g. 7P method). Methods and technologies of industrial business development, service strategies for manufacturing companies, strategic fit between strategy and capabilities, exploitation approaches, case studies of industrial service companies, service strategy and process planning and execution
3	**Forms of teaching** Lecture, seminar, discussion, group work, interviews in industry Due to the practical interviews at top management level in industry, the course is limited to 20 participants.
4	**Recommended prerequisites** Bachelor's degree in business administration and mechanical engineering or equivalent (e.g. industrial engineering) or mechanical engineering with regard to business aspects
5	**Types of examination** Project work in groups or written examination (duration: 90 min.). The applicable type of examination will be announced at the beginning of the course.
6	**Requirements for award of credits** Passed examination (100 %)
7	**Person responsible for the module** Prof. Dr.-Ing. Dipl.-Wirt.-Ing. Jörg Niemann / adjunct lecturer

8	**Language of instruction** English
9	**Further information and references** Gilmore, Services Marketing and Management, SAGE, 2003 Fischer et al, Service Business Development, Strategies for Value Creation in Manufacturing Firms, Cambridge Press, 2012 Brenner/Misu, Internationales Business Development, Berlin, Heidelberg, Springer, 2015 Becker, Nachhaltiges Business Development Management, Berlin, Heidelberg, Springer, 2017 Brodel/Schwarz-Musch, Business Development: Grundlagen – Konzepte – Methoden, Berlin, Heidelberg, Springer, 2014 Niemann, Die Service Manufaktur, Shaker, 2016 Müller, Service Marketing, Springer, 1995 Bruhn et al, Services Marketing: Managing the Service Value Chain, Pearson, 2006

Advanced Computational Methods						
Module number	**Workload**	**Attendance**	**Self-study**	**Semester**	**Offered in**	**Duration**
	180 h	60 h	120 h	Sem. 1/2	WS/SS	1 sem.
Courses		**Credits**	**Allocation to study programmes**			
Seminar: 4 SWS		6 ECTS	Master IWI, ME, SET			

1	**Learning outcomes / competences** The participants have a basic understanding of and scientific insight into numerical simulation methods in engineering and science – beyond the standard principles of the finite element method. They have advanced knowledge in the following fields of computational engineering: (i) development, implementation and application of finite element methods of higher order (p-version), (ii) the interaction of geometric modelling and structural analysis and (iii) the design of freeform structures with B-splines and NURBS. Furthermore, they have knowledge about the fundamentals of embedded domain methods and isogeometric analysis. The acquired competences and skills are ideal prerequisites for academic and industrial research and development in all fields of numerical analysis and simulation in mechanical, civil and aerospace engineering.
2	**Contents** • Theory, properties, choice and application of hierarchical higher order approximation spaces • Element formulation and implementation aspects for quadrangle and hexahedral elements • Mesh generation and boundary approximation, solution properties • Refinement aspects, convergence behaviour and error estimation • Solid and structure elements for static and dynamic analyses • Theory, geometric and numerical modelling aspects of isogeometric analysis • Application of higher order approximation in the context of embedded domain methods for analysis domains of high geometric complexity
3	**Forms of teaching** Lecture, seminar, discussion, independent elaboration (in oral or written form)
4	**Recommended prerequisites** Bachelor's degree in engineering, fundamentals of mathematics and engineering mechanics, differential equations, finite element method
5	**Types of examination** Written examination (duration: 90 min.)
6	**Requirements for award of credits** Passed examination (100 %)
7	**Person responsible for the module** Prof. Dr.-Ing. habil. Martin Ruess
8	**Language of instruction** English

9	**Further information and references** Lecture slides and Cottrell/Hughes/Bazilevs, Isogeometric Analysis: Toward Integration of CAD and FEA, Wiley 2009

Software Lab						
Module number	**Workload**	**Attendance**	**Self-study**	**Semester**	**Offered in**	**Duration**
	180 h	60 h	120 h	Sem. 1/2	WS/SS	1 sem.
Courses		**Credits**	**Allocation to study programmes**			
Seminar: 4 SWS		6 ECTS	Master IWI, ME, SET			

1	**Learning outcomes / competences** The participants have a basic understanding of software development in the context of engineering solutions. They have advanced knowledge in the following fields of computational engineering: (i) advanced programming skills of a high-level programming language and object-oriented modelling, (ii) project-oriented co-operative software design and development, (iii) efficient algorithms and data-structures and (iv) assessment of computational complexity. The acquired competences and skills are ideal prerequisites for academic and industrial research and development in all fields of numerical analysis and simulation including mechanical engineering, civil engineering, aerospace engineering and beyond.
2	**Contents** • Computer-based and project-related software development in the context of engineering solutions • Research or industry-driven problems with or without external cooperation partners • Design and development of software solutions
3	**Forms of teaching** Lecture, seminar, discussion, independent project work
4	**Recommended prerequisites** Bachelor's degree in engineering, proficiency in English, solid programming background with a high-level programming language (Java, C, C++, Python etc.)
5	**Types of examination** Two intermediate presentations (duration: 20 min. = 10 min. presentation and 10 min. discussion) on the project status (project specification, project planning and milestones, bottlenecks etc.) and a final presentation of the project results (duration: 30 min.)
6	**Requirements for award of credits** Passed examination (100 %)
7	**Person responsible for the module** Prof. Dr.-Ing. habil. Martin Ruess
8	**Language of instruction** English
9	**Further information and references** Lecture slides. Project-related literature will be recommended with the project specification.

Heterogeneous Catalysis

Modulnummer (Module number)	Workload	Präsenzzeit (Attendance)	Selbststudium (Self-study)	Studiensemester (Semester)	Angebot im (Offered in)	Dauer (Duration)
40011	180 h	60 h	120 h	Sem. 1/2	WS/SS	1 sem.

Lehrveranstaltungen (Courses)	Credits	Zuordnung zu den Curricula (Allocation to study programmes)
a) Lecture 2 SWS b) Seminar 2 SWS	6 ECTS	Master SET, IWI (UPT/EUT)

1 **Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**

The heterogeneous catalysis plays a decisive role for more than 80 % of large-scale processes in the chemical industry.

In this module, the students have gained sound insight into the fundamentals of heterogeneous catalysis. They know all essential aspects of selection, preparation and characterisation of catalysts, their application in important industrial reactions and evaluation of kinetic measurement data for further process optimisation.

During the accompanying seminar, the students have

- transferred the acquired contents to selected sample processes independently and
- discussed them based on the current state of research.

This module has enabled the students to

- study the highly interdisciplinary field of heterogeneous catalysis thoroughly and
- pursue their own research activity in this field.

2 **Inhalte (Contents)**

- Introduction to heterogeneous catalysis: beginnings of catalysis research; industrial significance; concepts and definitions in heterogeneous catalysis
- Fundamentals of heterogeneous catalysis: reaction course; physisorption and chemisorption; adsorption equilibria; elementary steps
- Catalysts: classification, preselection and preparation; methods of catalyst synthesis; promoters and catalyst poisons
- Characterisation: methods to determine catalyst parameters; texture, porosity and surface; volume methods; surface methods
- Catalyst performance: selection of reactors; design of experiments and optimisation; evaluation of kinetic measurement data; catalyst testing
- Kinetics and reaction mechanisms: a) microkinetics (surface reaction; structure-activity relationship; kinetic approaches; b) macrokinetics (film diffusion; pore diffusion)
- Study of important heterogeneous catalysed reactions: hydrogenation reactions; oxidation reactions; acid-base catalysis; bifunctional catalysis
- Concepts for laboratory-scale and industrial-scale rectors
- *Seminar*: oral presentation of selected industrial processes including current research activities and patent applications

3 **Lehrformen (Forms of teaching)**

- Lecture (a)
- Oral presentations and discussions (b)

4	**Empfohlene Voraussetzungen (Recommended prerequisites)** (recommended, but not mandatory) • Chemistry; mechanical, thermal, and chemical process engineering
5	**Prüfungsformen (Types of examination)** • Combined examination: oral examination (duration: 30 min.) (= 67 %) and oral presentation during the seminar (duration: 45 min.) (= 33 %)
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Passed examination
7	**Modulverantwortliche(r) (Person responsible for the module)** • Prof. Dr. Stefan Kaluza
8	**Sprache (Language of instruction)** • English or German
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • All presentations and lecture notes on Moodle • Reschetilowski, Einführung in die Heterogene Katalyse, Springer, 2015

Angewandte verfahrenstechnische Simulation
(Applied Simulation in Process Technology)

Modulnummer (Module number)	Workload	Präsenzzeit (Attendance)	Selbststudium (Self-study)	Studiensemester (Semester)	Angebot im (Offered in)	Dauer (Duration)
	180 h	60 h	120 h	Sem. 1 or 2	WS	1 sem.

Lehrveranstaltungen (Courses)	Credits	Zuordnung zu den Curricula (Allocation to study programmes)
a) Vorlesung / *Lecture*: 2 SWS b) Übung / *Exercise*: 2 SWS	6 ECTS	Master SET

1 **Lernergebnisse (Learning outcomes) / Kompetenzen (Competences)**

Die Studierenden lernen am Beispiel verfahrenstechnischer Problemstellungen, den Umfang und die Herausforderungen eines simulationstechnischen Projektes zu beurteilen und geeignete Methoden auszuwählen. Sie können mögliche Probleme und Einschränkungen bezüglich der verwendeten Methoden oder der verfügbaren Daten erkennen und bewerten. Im Rahmen der Lehrveranstaltung werden zum einen bestehende Simulationswerkzeuge analysiert, zum anderen werden auch Modelle und Lösungsstrategien für neue Fragestellungen (weiter-)entwickelt. Dabei liegt der Fokus weniger auf der Modellentwicklung und Implementierung im Detail, sondern auf der Betrachtung aller Aspekte einer Simulationsstudie. Dies umfasst auch die Parametrierung und Validierung von Modellen sowie die Auswertung und Bewertung von Ergebnissen. Die betrachteten Themen werden dabei durch Beispiele aus der industriellen Praxis und anwendungsnahen Forschung begleitet.

Die Studierenden verstehen zudem den grundlegend den Unterschied zwischen „klassischen" chemisch-physikalischen und nicht-deterministischen, datengetriebenen Modelle basierend auf maschinellem Lernen. Sie können die Möglichkeiten und Einschränkungen der verschiedenen Konzepte grundlegend bewerten und können geeignete Werkzeuge für praktische Problemstellungen auswählen.

Based on practical problems from the field of process technology, the students have gained the competence to estimate the complexity and the challenges of a modelling and simulation project. They are able to select suitable methods and models. They can also identify and assess possible problems and limitations regarding methods and available data. During the course, the students have not only analysed existing simulation tools, but also developed new models and solution strategies (further). The focus of the course is on the holistic consideration of all aspects of a simulation study in general – rather than on the detailed development and implementation of specific models. This includes parameterisation and validation as well as evaluation of outcomes in a practical context. Examples from industrial practice and applied research illustrate the topics discussed.

The students understand the basic difference between 'classical' chemical-physical models and non-deterministic, data-driven models (based on machine learning). They are able to assess the potential and limitations of the different concepts and can select suitable tools for practical cases.

2	**Inhalte (Contents)** • Praktische Anwendung: Ausbildungssimulator für Zementwerke • Systemanalyse eines verfahrenstechnischen Prozesses • Anwendung von Simulationswerkzeugen in Zerkleinerungsprozessen • Simulation von Hochtemperaturprozessen • Parametrierung und Validierung von Modellen • Planung und Durchführung von Messreihen zur Validierung • Bewertung von Simulationsergebnissen • Potentiale von nicht-deterministischen / daten-basierten Modellen Als Anwendungsszenarien stehen verschiedene verfahrenstechnische Prozesse z.B. aus der Zementherstellung zur Auswahl, darunter messtechnisch schwer zugängliche Zerkleinerungs- und Hochtemperaturprozesse. Der Anwendungsschwerpunkt liegt primär auf Zerkleinerungsmodellen. • *Practical application: Training simulator for cement plants* • *System analysis of industrial processes* • *Application of simulation tools in comminution* • *Simulation of high-temperature processes* • *Parameterisation and validation of models* • *Planning and execution of measurement and sampling campaigns for validation* • *Evaluation and assessment of results* • *Potential of non-deterministic, data-driven models* *Examples of application are taken from practical process technology, e.g. from cement manufacturing. This includes areas which are not accessible by measurement technology like comminution or high-temperature processes. A focus area is comminution (grinding) of materials.*
3	**Lehrformen (Forms of teaching)** • Seminaristischer Unterricht • Aufbau und Parametrierung einfacher Modelle am Rechner • Exkursion (Probenahme, Begutachtung einer realen Anlage) • *Seminar-like instruction* • *Computer-aided development or parameterisation of simple models* • *Field trip (sampling, visit to a real plant)*
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** • Bachelor-Studium in Verfahrens-/Prozesstechnik, insbesondere Thermische / Mechanische Verfahrenstechnik • Grundlagen Modellierung und Simulation, Informatik (grundlegende Programmierkenntnisse) • *Bachelor's degree in process engineering, particularly thermal and mechanical process engineering* • *Fundamentals of modelling and simulation, computer science (basic programming skills)*

5	**Prüfungsformen (Types of examination)** • Mündliche Prüfung (Dauer: 30 Minuten) • *Oral examination (duration: 30 min.)*
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Bestandene Modulprüfug • *Passed module examination*
7	**Modulverantwortliche(r) (Person responsible for the module)** Prof. Dr. Philipp Fleiger
8	**Sprache (Language of instruction)** Deutsch oder Englisch (abhängig von den Teilnehmerinnen und Teilnehmern) *German or English (depending on participants)*
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** • Vorlesungsunterlagen in MOODLE / script on MOODLE • Haarmann / ECRA – Auswahl, Implementierung und Validierung von Modellierungskonzepten für die trockene Feinzerkleinerung • Cameron, Hangos – Process Modelling and Model Analysis

Aktuelle Entwicklungen in der internationalen Energiewirtschaft
(Current Developments in International Energy Economics)

Modulnummer (Module number)	Workload	Präsenzzeit (Attendance)	Selbststudium (Self-study)	Studiensemester (Semester)	Angebot im (Offered in)	Dauer (Duration)
	180 h	60 h	120 h	Sem. 1 or 2	WS/SS	1 sem.

Lehrveranstaltungen (Courses)	Credits	Zuordnung zu den Curricula (Allocation to study programmes)
Seminar: 4 SWS	6 ECTS	Master SET, IWI (EUT, UPT)

1 **Lernergebnisse (Learning outcomes)**

Nach erfolgreicher Teilnahme haben die Studierenden die folgenden Kenntnisse und Fähigkeiten erworben:

- Sie haben im Themenfeld komplexer Energiesysteme mit einem hohen Anteil erneuerbarer Energien eine wissenschaftliche Fragestellung entwickelt.
- Sie können die Veränderungen von Energiesystemen hinsichtlich technischer, sozialer, politischer, ökonomischer und umweltrelevanter Faktoren bewerten.
- Sie haben sich grundlegende Prinzipien zur Bewertung der Nachhaltigkeit von Energiesystemen angeeignet und können diese unter Berücksichtigung der verschiedenen Wechselwirkungen anwenden.
- Sie sind in der Lage, sich selbstständig wissensbasiert einer aktuellen energiepolitischen Fragestellung zu nähern, diese in Bezug zu anderen Fragestellungen zu setzen und darüber hinaus kontrovers mit ihren Abhängigkeiten zu diskutieren.
- Sie sind in der Lage, aus der Fragestellung eine eigene Meinung und Stellungnahme zu entwickeln und diese in einer Diskussion zu vertreten.

Having successfully completed the module, the students have acquired the following knowledge and skills:

- *They have developed a research question within the field of complex energy systems featuring a high percentage of renewable energies.*
- *They can assess changing energy systems regarding technological, social, political, economic and environmental factors.*
- *They have studied fundamental principles for the assessment of the sustainability of energy systems and can apply them, considering various interdependencies.*
- *They are able to approach current issues in energy politics independently, put them into context and discuss them considering relevant factors.*
- *They can draw conclusions from such issues to form their own opinion and defend it in a discussion.*

Kompetenzen (Competences)

Nach dem Anwenden von wissenschaftlichen Grundlagentechniken wie Recherchieren oder Exzerpieren von Aufsätzen sollen die Inhalte in Gruppendiskussionen verdeutlicht und begründet werden. Entsprechend dieser Grundlage liegt der Fokus des Seminars auf:

- Analyse, Untersuchung und Gegenüberstellung der wesentlichen Argumente im Sinne der Nachhaltigkeitsbewertung
- Entwicklung einer wissenschaftlichen Fragestellung anhand der zuvor erarbeiteten Argumente

	• Ausarbeitung einer eigenen Meinung unter Berücksichtigung der Abhängigkeiten zu weiteren im Seminar behandelten Fragestellungen • Vertretung der Ausarbeitung *The students have applied basic scientific methods, e.g. literature research or extraction of relevant information from articles, and then presented and justified the results in groups. On this basis, the seminar focuses on:* • *Analysis of, investigation into and comparison of essential arguments for sustainability assessment* • *Development of a research question based on the arguments gathered* • *Formation of one's own opinion taking into account interdependencies between the different research questions developed within the seminar* • *Justification of the opinion formed*
2	**Inhalte (Contents)** Basierend auf den Grundlagen der Energiewirtschaft und des heutigen Energiesystems werden energiepolitische Themen behandelt. Schwerpunkt sind hierbei insbesondere tagesaktuelle Fragestellungen im internationalen Kontext unter dem Aspekt der Nachhaltigkeit (z.B. aktuelle Veränderungen in der Energiewirtschaft verschiedener Länder, international diskutierte politische Entscheidungen oder Diskussionen, Wirkung des Einsatzes von innovativen Technologien, Relevanz gesellschaftlicher Trends auf die Energiewirtschaft). Für die Themenauswahl können auch eigene Vorschläge der Studierenden berücksichtigt werden. *Based on the fundamentals of energy economics and today's energy system, the students discuss current topics in energy politics. The focus of the course is particularly on topical issues in an international context considering sustainability aspects (e.g. changes in current energy economics of different countries, political decisions or discussions of international relevance, the impact of the use of innovative technologies, implications of societal trends for energy economics). Students' suggestions are welcome for the choice of topics to discuss.*
3	**Lehrformen (Forms of teaching)** • Dozentenvortrag • Seminaristischer Unterricht • Gruppenarbeit • Gruppendiskussionen • *Lecture* • *Seminar-like instruction* • *Group work* • *Group discussions*
4	**Empfohlene Voraussetzungen (Recommended prerequisites)** Formal: keine Inhaltlich: • Kapitel der Vorlesung Energiewirtschaft, -speicherung und –verteilung: Energiehandel, Ressourcen, Klimapolitik • Lehrmaterialien (bereitgestellt): Nachhaltigkeit und Transformation

	• Vorlesungsinhalte Erneuerbare Energien und Energieeffizienz *No formal prerequisites* *Subject-related prerequisites:* • *Chapter of the module Energy Economics, Storage and Distribution: Energy Trade, Resources, Climate Policies* • *Study material on sustainability and transformation (provided)* • *Contents from the module Renewable Energies and Efficiency Technologies*
5	**Prüfungsformen (Types of examination)** • Besondere Prüfungsform: Schriftliche Seminararbeit und/oder Gruppenkolloquium • Prüfungsform und Gewichtung wird zu Beginn der Lehrveranstaltung festgelegt. • *Special type of examination: written assignment and/or oral examination in groups* • *The applicable type of examination and, if applicable, the weighting of the partial examinations will be announced at the beginning of the course.*
6	**Voraussetzungen für die Vergabe von Leistungspunkten (Requirements for award of credits)** • Teilnahme an Seminarterminen zur Präsentation und Diskussion von Zwischenergebnissen • Zwei schriftliche Kurzberichte (max. 1 Seite) der Zwischenergebnisse im Semester als Diskussionsgrundlage • Bestandende Modulprüfung • *Attendance at seminar sessions for presentation and discussion of first results* • *Two short written reports (maximum 1 page each) summarising first results during the semester as a basis for discussion* • *Passed module examination*
7	**Modulverantwortliche(r) (Person responsible for the module)** Prof. Dr.-Ing. Franziska Schaube
8	**Sprache (Language of instruction)** Deutsch / *German*
9	**Sonstige Informationen / Literaturempfehlungen (Further information and references)** Aktuelle themenspezifische Literatur *Current subject-specific literature*