Hochschule Düsseldorf
University of Applied Sciences

Fachbereich Maschinenbau
und Verfahrenstechnik
Faculty of Mechanical
and Process Engineering

Last updated: April 2019

Module Manual Master Simulation and Experimental Engineering

Methods (choose 4 out of 5)

Course
Optimisation and Simulation
Design of Experiments
Computer-Based Measurement Technology
Computational Fluid Dynamics
Engineering Mathematics

Abbreviations:

sem. = semester
WS = winter semester; SS = summer semester
SWS = credit hours per week
ECTS = credits according to the European Credit Transfer System
SET = Simulation and Experimental Engineering; ME = Mechanical Engineering; IWI = International Industrial Engineering

Optimisation and Simulation

Module number	Workload	Attendance	Self-study	Semester	Offered in	Duration
11001 11002	180 h	75 h	105 h	Sem. 2	WS	1 sem.

Courses	Credits	Allocation to study programmes
a) Lecture 3 SWS b) Practical Training 1 SWS c) Exercise 1 SWS	6 ECTS	Master SET

1 Learning outcomes / competences

The students

- can characterise, classify and set optimisation assignments in an engineering context,
- are able to select optimisation algorithms for unrestricted and restricted optimisation depending on the case to solve and assess them regarding global and local convergence,
- can apply fundamental optimisation methods algorithmically in MATLAB®, Scilab or Octave and critically assess the numerical results.

2 Contents

Optimisation cases can originate from many different engineering disciplines. Typical optimisation cases are e.g.

- the approximation of functions for finite element methods to solve differential equations and to simulate mechanical systems,
- the regression of data records to empirically analyse cause-effect principles,
- statistical estimations on image-based error detection in production plants or
- geometric cases, such as the calculation of the shortest way for navigation.

Mathematical optimisation theory deals with all kinds of different cases in a consistent framework, i.e. the minimisation of a suitable target function or quality function, possibly under given boundary conditions.

- Numerical optimisation methods are derived and analysed to solve optimisation cases practically within the theoretical framework, independent of concrete application. The lecture teaches the main results of optimisation theory and provides an overview of the most important optimisation algorithms.
- The course focuses on methods based on Gradient’s and Newton’s approaches to solve convex minimisation cases as well as on non-linear problems and stochastic optimisation.
- It deals with how to set an optimisation assignment appropriately, how to apply optimisation tools and analyse the results.
- It also includes application of the methods discussed in the computer laboratory in MATLAB®, Scilab or Octave as well as tests on practical examples.

3 Forms of teaching

- Presentation using presentation techniques suitable for mathematical and technical contents (a)
- Practical application of methods in MATLAB®, Scilab or Octave and experiments on sample cases (b)
- Practical exercises including explanations on theory and simulation experiments on the computer (c)

4	**Recommended prerequisites** • General engineering mathematics • Programming skills in MATLAB®, Scilab or Octave desirable
5	**Types of examination** • Written examination (duration: 120 min.) (= 80 %) • Work on cases in the context of practical training (= 20 %)
6	**Requirements for award of credits** • Passed module examination
7	**Person responsible for the module** • Dr. Frank Eckgold
8	**Language of instruction** • German or English
9	**Further information / references** Lecture slides, examples, exercise and practical training material online Recommended literature: • Boyd/Vandenberghe, Convex Optimization, Cambridge University Press, 2004, https://web.stanford.edu/~boyd/cvxbook/bv_cvxbook.pdf • Geiger/Kanzow, Theorie und Numerik restringierter Optimierungsaufgaben, Springer, 2002 • Jarre/Stoer, Optimierung, Springer, 2004 • Schneider/Kirkpatrick, Stochastic Optimization, Springer, 2006 • Liu, Monte Carlo Strategies in Scientific Computing, Springer, 2001 • Geiger/Kanzow, Numerische Verfahren zur Lösung unrestringierter Optimierungsaufgaben, Springer, 1999

Design of Experiments

Module number	Workload	Attendance	Self-study	Semester	Offered in	Duration
11101 11102	180 h	75 h	105 h	Sem. 2	WS	1 sem.

Courses	Credits	Allocation to study programmes
a) Lecture 2 SWS b) Exercise 1 SWS c) Practical Training 2 SWS	6 ECTS	Master SET

1 Learning outcomes / competences

The students are able to

- design parameter variations and optimisation cases in practical experiments and computer simulations in a targeted and efficient manner – to gain the envisaged insight at the lowest possible effort,
- describe and evaluate the methods used to analyse technical systems as well as their advantages and disadvantages – particularly the characteristics of DoE experimental designs,
- explain relevant technical terms,
- apply statistical methods to plan and conduct experiments and to evaluate the measurement results,
- properly select, configure, conduct and evaluate DoE experimental designs depending on the given boundary conditions – using relevant software tools such as STATISTICA.

2 Contents

- Different approaches to plan and conduct experiments: coincidence method, single-factor method, grid cell method, statistical design of experiments (DoE), Simplex, EVOP, neuronal networks
- Statistics
    - Fundamentals: means, standard deviation, frequency distribution and how to graphically illustrate them
    - Spread measurement results in experiments with consistent boundary conditions, true value on a specific point, confidence interval, scope
    - True difference between the experiment results on two specific experiment points, effect, noise, confidence interval of effects, statistical significance
    - Representativity, homoscedasticity, outliers, autocorrelation, data transformation
- Design of Experiments (DoE)
    - Different kinds of experiment designs: full factorial designs, blocking, factorial designs, screening designs, factorial designs with a central point, central composite designs, designs influenced by categorical and continuous variables, D-optimal designs
    - Design, execution and evaluation of experiments: target value, variables, normalisation of the variables, experimental design, randomised execution of the experiments, regression function with total, main effect and interaction, significance check, lack-of-fit test as well as prognosis and observation graphics, visualisation of the results, e.g. effect diagrams, polyoptimisation
    - Operation and use of relevant software tools such as STATISTICA to support the methodology

3	**Forms of teaching** • Lecture (a) • Seminar-like instruction (discussion) and calculation exercises (b) • Exemplary experiments and simulations (c)
4	**Recommended prerequisites** • According to the syllabus
5	**Types of examination** • Written examination (duration: 60 min.) or oral examination (duration: 20 min.) The applicable type of examination will be announced at the beginning of the course. (= 65 %) • Independent planning, execution and evaluation of a DoE experiment (experiment or simulation) and written documentation of the results (= 35 %)
6	**Requirements for award of credits** • Attending the practical training • Passed module examination
7	**Person responsible for the module** • Prof. Dr.-Ing. Mario Adam
8	**Language of instruction** • German
9	**Further information / references** • Lecture slides (as PDF) on Moodle Recommended literature (latest edition): • Kleppmann, Taschenbuch Versuchsplanung – Produkte und Prozesse optimieren, Hanser • Siebertz et al, Statistische Versuchsplanung – Design of Experiments (DoE), Springer • Liebscher, Anlegen und Auswerten von technischen Versuchen – eine Einführung, Fortis FH • Scheffler, Statistische Versuchsplanung und -auswertung – eine Einführung für Praktiker, Deutscher Verlag für Grundstoffindustrie • Bandemer et al, Statistische Versuchsplanung, Teubner

Computer-Based Measurement Technology

Module number	Workload	Attendance	Self-study	Semester	Offered in	Duration
11201 11202	180 h	75 h	105 h	Sem. 1	SS	1 sem.

Courses	Credits	Allocation to study programmes
a) Lecture 2 SWS b) Practical Training 3 SWS	6 ECTS	Master SET, ME

1 **Learning outcome / competences**

Students are able to

- handle hardware and software (i.e. calibration of accelerometers and microphones or oscilloscopes),
- differ between steady-state, transient and dynamic data,
- analyse signals in time and frequency domains,
- verify overall levels in time and frequency domains (Parseval theorem),
- use correlation measurement technique and know the concept of coherence, phase spectrum and time delay.

2 **Contents**

- Overview of the typical measure principles for measurement of position, flow and current, pressure, sound pressure and vibration
- Data acquisition, sampling-rate
- Analogue-to-digital converters
- Windowing, frequency analysis, averaging
- Sound and vibration analysis
- Rotating machinery, Campbell diagram
- Discrete frequency analysis and fast Fourier analysis

3 **Forms of teaching**

- Lecture (PC with projector, overhead slides, blackboard),
- Practical computer training (Dasylab, MATLAB, Scilab, PAK), discussing the experiments
- Practical training with digital oscilloscopes

4 **Recommended prerequisites**

- Basics of data acquisition and numerical mathematics

5 **Types of examination**

- Written assignment (= 60%)
- Feedback talk with PC demonstrations (= 40 %)

6 **Requirements for award of credits**

- Passed examination (feedback talk)

7 **Person responsible for the module**

- Prof. Dr.-Ing. Frank Kameier

8 **Language of instruction**

- English

9	**Further information / references** • Lecture notes (translation in progress), software applications at https://ifs.mv.hs-duesseldorf.de/Vorlesung/master/ Recommended literature: • Karrenberg, Signals, Processes, and Systems, An Interactive Multimedia Introduction to Signal Processing, 3rd edn, Berlin 2013

Computational Fluid Dynamics (CFD)

Module number	Workload	Attendance	Self-study	Semester	Offered in	Duration
11301 11302	180 h	75 h	105 h	Sem. 1	SS	1 sem.

Courses	Credits	Allocation to study programmes
a) Lecture 3 SWS b) Exercise 1 SWS c) Practical Training 1 SWS	6 ECTS	Master SET, ME

1 Learning outcomes / competences

The attendees have acquired a basic understanding of and the ability to apply CFD to solve engineering problems. They are aware of relevant potentials, limitations and challenges. They are familiar with and have a deep understanding of

- the differential equations that describe the transport of momentum, heat and mass in Newtonian fluids,
- their boundary conditions for a single-phase, steady or unsteady as well as compressible or incompressible flow.

They have fundamental knowledge of

- different physical flow states with corresponding mathematical and numerical implications, flow turbulence and turbulence modelling,
- discretisation principles, gridding techniques and numerical solution procedures including the intricacies involved in modelling highly connective flows and Navier-Stokes solution techniques.

At the end of the course, the attendees are able to apply a general-purpose CFD software to solve technical problems involving a laminar or turbulent single-phase flow, with or without heat transfer, and analyse the results competently. Furthermore, the attendees are able to follow the course and communicate in English.

2 Contents

- Overview of fluid mechanics applications in engineering
- Basic ideas of Computational Fluid Dynamics (CFD)
- The role of CFD in solving engineering problems
- Review of the relevant basic knowledge
- Derivation of the unsteady, three-dimensional differential balance equations for a fluid
- Discussion of the physical and mathematical meanings of the terms and their interrelationship
- Boundary conditions
- Assumptions and simplifications
- The general convective-diffusive transport equation
- Main ingredients of a numerical solution method
- Overview of grid generation
- Overview of discretisation methods including finite difference, finite volume and finite element methods
- Discretisation of the general transport equation by the method of finite volumes
- Accuracy estimation
- Direct and iterative methods for the solution of the discretisation equations
- Convergence control
- Unstructured meshes
- Discretisation in time
- Stability conditions
- Treatment of flows with strong convection

	• Pressure correction and other methods for treating velocity-pressure coupling in solving the Navier-Stokes equations for incompressible and compressible flows • Turbulent flows with and without heat transfer • Turbulence modelling
3	**Forms of teaching** Lecture, seminar, discussion, independent elaboration (in oral or written form)
4	**Recommended prerequisites** Bachelor’s degree in mechanical engineering (or in a related discipline), fluid mechanics, heat transfer, mathematics, differential equations, English
5	**Types of examination** • Written multiple-choice examination (duration: 90 min.) (= 80 %) • Practical training (oral examination) (= 20 %)
6	**Requirements for award of credits** Passed examination
7	**Person responsible for the module** Prof. Dr.-Ing. Ali Cemal Benim
8	**Language of instruction** English
9	**Further information / references** • Hirsch, Numerical Computation of Internal and External Flows, Volume I: Fundamentals of Discretization, Wiley, 1994 • Hirsch, Numerical Computation of Internal and External Flows, Volume II: Computational Methods for Inviscid and Viscous Flows, Wiley, 1995

Engineering Mathematics

Module number	Workload	Attendance	Self-study	Semester	Offered in	Duration
11401 11402	180 h	75 h	105 h	Sem. 1	SS	1 sem.

Courses	Credits	Allocation to study programmes
(a) Lecture 3 SWS (b) Practical Training 2 SWS	6 ECTS	Master ME, SET

1 Learning outcomes / competences

The participants have a solid understanding of and scientific insight into the mathematical foundations of computational engineering – including numerical and algorithmic aspects of modern software tools. Moreover, the participants have acquired competences and skills to solve typical problems of the engineering routine by means of advanced engineering mathematics.

2 Contents

- Linear and non-linear systems of equations (properties, numerical solution method, algorithmic aspects)
- The engineering eigenvalue problem (algebraic properties, solution strategies, numerical solution methods and algorithmic aspects)
- Numerical algorithms (numerical interpolation, numerical differentiation, numerical integration in 1D, 2D and 3D)
- Algebra of relations (Boolean algebra, transitive closure)
- Graph theory (types of graphs and applications)
- Paths in networks (path algebra, weighted graphs)

3 Forms of teaching

Lecture, exercise, seminar, discussion

4 Recommended prerequisites

Bachelor’s degree in engineering; Java-programming skills, fundamentals of engineering mathematics and mechanics

5 Types of examination

Assessment in two parts according to the following weighting for the final grade:

I. Worked and defended practical (= 30 %)
II. Written examination (duration: 90 min.) (= 70 %)

The students must pass each of the two parts with a minimum of 50 % of the used grading scheme.

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 / references

Lecture slides and lecture notes (partly)

Specialisation – choose 1

Course
Specialisation: Energy and Environmental Technology
Heating and Cooling – Renewable Energies, Combustion, Heat and Mass Transfer
Electrical Power – Conversion, Storage, Distribution
Environment – Noise Protection, Measurement Technology Air
Specialisation: Environmental and Process Technology
Computer-Aided Process and Process Plant Design
Energy and Environmental Process Optimisation
Environment – Noise Protection, Measurement Technology Air

Specialisation:

Energy and Environmental Technology

Heating and Cooling – Renewable Energies, Combustion, Heat and Mass Transfer

Module number	**Workload**	**Attendance**	**Self-study**	**Semester**	**Offered in**	**Duration**
21001	180 h	60 h	120 h	Sem. 1	SS	1 sem.

Courses	**Credits**	**Allocation to study programmes**
a) Lecture 2 SWS b) Exercise 2 SWS	6 ECTS	Master SET, IWI

1 Learning outcomes / competences

The students are able to

- describe energy-efficient device and system solutions for technical plants producing heating and cooling from renewable energies and assess the properties and specifics of such solutions,
- assess the structure and hydraulics of plants, i.e. identify typical weak points in planning and implementation and suggest energy-efficient alternatives,
- analyse and assess practical operations using measurement data and distinguish between properties relevant for practice and results from measurements in the laboratory,
- apply their knowledge to specific applications abroad, especially in emerging and developing countries.

Furthermore the attendees can analyse

- engineering problems in heat and mass transfer involving two-phase flows with phase change and
- the combustion of liquid and solid fuels and have knowledge on the firing systems on such fuels.

2 Contents

- Heating and cooling using renewable energies and efficiency technologies
  - Solar technology: larger solar systems for apartment buildings, building heating and process heating, (thermal and electric) solar cooling
  - (reversible) heat pumps and refrigerating machines: cycles, geothermics, passive cooling
  - Biomass: boiler, cogeneration
  - Heat and cold storage: technologies, hydraulic integration
  - Heat and cold distribution, heat and cold transfer
  - Energy-efficient overall concepts for different fields of application (best practice examples)
- Engineering relevance of two-phase flows, classification of two-phase flows, phase change, condensation and evaporation
- Heat and mass transfer in two-phase or multi-component flows
- Combustion of liquid fuels, combustion of solid fuels

3 Forms of teaching

- Lecture (a)
- Discussion and independent elaboration (b)
- Seminar-like instruction, presentations (c)

4 Recommended prerequisites

- Prerequisites according to the relevant examination regulations; bachelor’s degree in mechanical engineering (or in a relevant discipline)
- Relevant knowledge from the fields of renewable energies and efficiency technologies on a bachelor’s programme level
- Thermodynamics. Heat Transfer. Technical Combustion. Fluid Dynamics.

5	**Types of examination** • Written examination (multiple choice) (duration: 90 min.) or oral examination (duration: 30 min.) The applicable type of examination will be announced at the beginning of the course.
6	**Requirements for award of credits** • Passed module examination / passed examination
7	**Person responsible for the module** Prof. Dr.-Ing. Mario Adam, Prof. Dr.-Ing. Ali Cemal Benim
8	**Language of instruction** German and English
9	**Further information / references** • Lecture slides (as PDF) on Moodle Recommended literature (latest edition): • Quaschning, Regenerative Energiesysteme, Hanser • Wesselak/Schabbachm, Regenerative Energietechnik, Springer • Peuser et al, Solare Trinkwassererwärmung mit Großanlagen – praktische Erfahrungen, Bine • Fisch et al, Solarstadt – Konzepte, Technologien, Projekte, Kohlhammer • Bollin et al, Solare Wärme für große Gebäude und Wohnsiedlungen, Fraunhofer IRB • Ochsner, Wärmepumpen in der Heizungstechnik: Praxishandbuch für Installateure und Planer, C.F. Müller • Reichelt (ed), Wärmepumpen – Stand der Technik, C.F. Müller • Bockelmann et al, Erdwärme für Bürogebäude nutzen, Fraunhofer IRB • Urbaneck, Kältespeicher, Oldenbourg • Schramek (ed), Taschenbuch für Heizung- und Klimatechnik, Oldenbourg • Baehr/Stephan, Wärme-und Stoffübertragung, Springer, 2008 • Incropera/DeWitt/Bergman/Lavine, Fundamentals of Heat and Mass Transfer, Wiley, 2011 • Dolezal, Dampferzeugung: Verbrennung, Feuerung, Dampferzeuger, Springer, 1985

Electrical Power – Conversion, Storage, Distribution

Module number	**Workload**	**Attendance**	**Self-study**	**Semester**	**Offered in**	**Duration**
21011	180 h	60 h	120 h	Sem. 2	WS	1 sem.

Courses	**Credits**	**Allocation to study programmes**
a) Lecture 2 SWS b) Exercise 2 SWS	6 ECTS	Master SET, IWI

1 Learning outcomes / competences

The students are able to

- understand and assess technical and economic interdependencies between energy carriers, energy conversion systems, energy storage systems and energy distribution systems,
- solve complex tasks to determine balances and factors improving performance and efficiency as well as check plausibility,
- dimension processes for thermal power plants and their components, discuss deviations from common results.

2 Contents

- Centralised and decentralised power supply
- National supply structures
- Distribution systems and grids
- Storage technologies, grid connection and development potentials
- Layout of power plants
- Designing power plant components (steam generators, turbines, ...)
- Dimensioning power plants according to the demand
- Grid stability

3 Forms of teaching

- Lecture (a)
- Seminar-like instruction and exercises (b)

4 Recommended prerequisites

- In-depth knowledge of the fundamentals of thermodynamics, electrical power engineering and power plant engineering

5 Types of examination

- Written examination (duration: 120 min.) or oral examination (duration: 30 min.)
- Partial examination in the form of a presentation or written assignment possible
- The applicable type, scope and extend of examination will be announced at the beginning of the course.

6 Requirements for award of credits

- Passed module examination

7 Person responsible for the module

- Prof. Dr.-Ing. Franziska Schaube

8 Language of instruction

- German and English

9	**Further information / references** • All course documentation (lecture slides, exercises, mock examinations) on Moodle Recommended literature (latest edition): • Kuegeler/Phlippen, Energietechnik, Springer Vieweg (standard reference)

Environment – Noise Protection, Measurement Technology Air

Module number	Workload	Attendance	Self-study	Semester	Offered in	Duration
21021 21022	180 h	60 h	120 h	Sem. 1/2	WS	1 sem.

Courses	Credits	Allocation to study programmes
a) Lecture 2 SWS b) Exercise 2 SWS	6 ECTS	Master SET, IWI

1 Learning outcomes / competences

The students

- have in-depth knowledge of air pollutant and noise measurement by official authorities,
- have in-depth knowledge of measurement systems for air pollutants and noise used in research,
- have learned how to familiarise with specific methods to measure air pollutants and solve measurement tasks independently,
- have learned how to analyse research assignments in environmental metrology and solve them using state-of-the-art measurement technology,
- know the physical basics and practical limitations of immission and simulation models for air pollutants and noise,
- are able to assess measures for noise control.

2 Contents

- Measurement methods used in practice in accordance with legal provisions for measuring air pollutants
- Innovative measurement methods used and further developed in the environmental metrology laboratory at the Faculty of Mechanical and Process Engineering
- Measurement and assessment of noise over time and frequencies
- Measurement of meteorological parameters in addition to and for the assessment of air pollutant and noise immission
- Advanced particulate measurement
- Immission and simulation models
- Legal basis, norms and regulations
- Current research work at the environmental metrology laboratory at the faculty

3 Forms of teaching

- Lecture, seminar-like instruction, exercises in project groups

4 Recommended prerequisites

- Bachelor’s degree

5 Types of examination

- Partial examination 1: written examination (duration: 60 min.),
- Partial examination 2: oral examination (duration: 30 min.)

6 Requirements for award of credits

- Passed module examination

7 Person responsible for the module

- Prof. Dr. Konradin Weber, Prof. Dr. Frank Kameier

8	**Language of instruction** • German or English according to agreement
9	**Further information / references** • Material and publications of the environmental metrology laboratory at the faculty • Werner/Klein/Weber, Laser in der Umweltmesstechnik, Springer • Schrimer/Kuttler/Löbel/Weber, Lufthgiene und Klima, VDI • Baumbach, Luftreinhaltung, Springer • Maute, Technische Akustik und Lärmschutz, Carl Hanser • Sinambari/Sentpali, Ingenieurakustik: Physikalische Grundlagen und Anwendungsbeispiele, Springer Fachmedien, Wiesbaden

Last updated: April 2019

Specialisation:

Environmental and Process Technology

Computer-Aided Process and Process Plant Design

Module number	**Workload**	**Attendance**	**Self-study**	**Semester**	**Offered in**	**Duration**
21101	180 h	60 h	120 h	Sem. 1	SS	1 sem.

Courses	**Credits**	**Allocation to study programmes**
a) Lecture 2 SWS b) Exercise 2 SWS	6 ECTS	Master SET, IWI

1 Learning outcomes / competences

The students

- have developed a fundamental understanding of the potential and limitations of process simulation models and programs,
- can split a given process-related task into modules and develop a suitable production line,
- are able to determine physical properties and thermodynamic substance data in a suitable manner in a given substance system,
- can simulate selected unit operations (e.g. rectification, chemical reactor),
- have developed a fundamental understanding of the potential and limitations of integrated tools to design process plants,
- can transfer selected unit operations into an intelligent 3D model using a planning tool.

2 Contents

- Introduction to the simulation of industrial process plants
- Introduction to a simulation software
- Unit operations
- Process flow diagram
- Substance data calculation using thermodynamic models
- Modelling using selected examples
- Interconnection of single models
- Introduction to process plant design using integrated planning tools
- Data transmission and further processing in tool modules
- Virtual reality – application in process plant design

3 Forms of teaching

- Seminar-like instruction
- Designing and conducting simulations on the computer independently
- Operating a virtual reality application on the computer independently

4 Recommended prerequisites

- Bachelor's degree in process engineering, particularly thermal process engineering, chemical process engineering, process plant design

5 Types of examination

- Oral examination (duration: 45 min.) or written examination (duration: 120 min.) on the contents mentioned above
  The applicable type of examination will be announced at the beginning of the course.

6 Requirements for award of credits

- Passed module examination

7	**Person responsible for the module** • Prof. Dr.-Ing. Walter Müller, Prof. Dr.-Ing. Martin Nachtrodt
8	**Language of instruction** • German
9	**Further information / references** • Documents relevant for the assignment available on Moodle Recommended literature: • Schuler, Prozesssimulation, VCH Weinheim • Sattler/Kasper, Verfahrentechnische Anlagen, VCH Weinheim • Dörner, Virtual und Augmented Reality (VR/AR), Springer

Energy and Environmental Process Optimisation

Module number	Workload	Attendance	Self-study	Semester	Offered in	Duration
21111	180 h	60 h	120 h	Sem. 2	WS	1 sem.

Courses	Credits	Allocation to study programmes
a) Lecture 2 SWS b) Exercise 2 SWS	6 ECTS	Master SET

1 **Learning outcomes / competences**

The students are able to

- calculate the energetic optimisation of evaporation processes by thermocompression,
- calculate the efficiency of the use of waste heat using the ORC method,
- calculate the minimal amount of heat to feed into or discharge from a process plant using the PINCH analysis method,
- design process plants according to the optimal heat exchange,
- apply energy management systems (EMAS) to industrial processes,
- calculate CO_2 balances.

2 **Contents**

- Calculation of mass and energy balances of industrial processes
- Conducting PINCH analyses on simple processes
- Application of energy management systems
- Assessment of evaporation systems
- Heat recovery systems
- ORC systems
- Heat storage systems
- Emissions from chemical unit operations
- CO_2 balancing

3 **Forms of teaching**

- Experimental lecture (a)
- Seminar-like instruction and exercises (b)

4 **Recommended prerequisites**

- Thermodynamics

5 **Types of examination**

- Written examination (duration: 120 min.)
  Scope and extend will be announced at the beginning of the course.

6 **Requirements for award of credits**

- Passed module examination

7 **Person responsible for the module**

- Prof. Dr. Karl-Erich Köppke (a) and (b)

8 **Language of instruction**

- German

9	**Further information / references** • Lecture presentations • BREF Energy Efficiency, European Commission

Environment – Noise Protection, Measurement Technology Air

Module number	**Workload**	**Attendance**	**Self-study**	**Semester**	**Offered in**	**Duration**
21021 21022	180 h	60 h	120 h	Sem. 1/2	WS	1 sem.

Courses	**Credits**	**Allocation to study programmes**
a) Lecture 2 SWS b) Exercise 2 SWS	6 ECTS	Master SET, IWI

1 Learning outcomes / competences

The students

- have in-depth knowledge of air pollutant and noise measurement by official authorities,
- have in-depth knowledge of measurement systems for air pollutants and noise used in research,
- have learned how to familiarise with specific methods to measure air pollutants and solve measurement tasks independently,
- have learned how to analyse research assignments in environmental metrology and solve them using state-of-the-art measurement technology,
- know the physical basics and practical limitations of immission and simulation models for air pollutants and noise,
- are able to assess measures for noise control.

2 Contents

- Measurement methods used in practice in accordance with legal provisions for measuring air pollutants
- Innovative measurement methods used and further developed in the environmental metrology laboratory at the Faculty of Mechanical and Process Engineering
- Measurement and assessment of noise over time and frequencies
- Measurement of meteorological parameters in addition to and for the assessment of air pollutant and noise immission
- Advanced particulate measurement
- Immission and simulation models
- Legal basis, norms and regulations
- Current research work at the environmental metrology laboratory at the faculty

3 Forms of teaching

- Lecture, seminar-like instruction, exercises in project groups

4 Recommended prerequisites

- Bachelor’s degree

5 Types of examination

- Partial examination 1: written examination (duration: 60 min.),
- Partial examination 2: oral examination (duration: 30 min.)

6 Requirements for award of credits

- Passed module examination

7 Person responsible for the module

- Prof. Dr. Konradin Weber, Prof. Dr. Frank Kameier

8	**Language of instruction** • German or English according to agreement
9	**Further information / references** • Material and publications of the environmental metrology laboratory at the faculty • Werner/Klein/Weber, Laser in der Umweltmesstechnik, Springer • Schrimer/Kuttler/Löbel/Weber, Lufthgiene und Klima, VDI • Baumbach, Luftreinhaltung, Springer • Maute, Technische Akustik und Lärmschutz, Carl Hanser • Sinambari/Sentpali, Ingenieurakustik: Physikalische Grundlagen und Anwendungsbeispiele, Springer Fachmedien, Wiesbaden

R&D Projects

Course
Study Project 1 incl. Project Seminar (Research & Development)
Engineering Conferences
Master's Thesis incl. Colloquium

Study Project incl. Project Seminar (Research & Development)

Module number	Workload	Attendance	Self-study	Semester	Offered in	Duration
30011	180 h	30 h	150 h	Sem. 2	SS/WS	1 sem.

Courses	Credits	Allocation to study programmes
Seminar 2 SWS	6 ECTS	Master SET, IWI, ME

1 Learning outcomes / competences

The students can apply and extend the methodical and specialised technical knowledge acquired during their studies. They have faced interdisciplinary questions, goal and deadline-oriented work in teams and, thus, strengthening of their social competences, promotion of structured, cross-disciplinary thinking, rhetoric and presentation.

2 Contents

Either independent work on a specific, motivating task with a practical orientation from the fields of production, process, energy or environmental technology; or an interdisciplinary task in groups. Special emphasis is on

- teamwork,
- the necessity of obtaining data and documents by themselves and
- the obligation of presenting the results in written and oral form.

3 Forms of teaching

Introductory presentation and explanations, self-study, teamwork, regular supervision and discussion with the lecturer

4 Recommended prerequisites

Subject-related bachelor’s degree as well as courses relevant to the specific project from the fields of process, energy and/or environmental technology, management techniques, production

5 Types of examination

Written documentation of the project work, presentation, oral examination

6 Requirements for award of credits

Participation in the project and successful presentation of the results

7 Person responsible for the module

Various

8 Language of instruction

German and English

9 Further information / references

Relevant literature depending on the task will be recommended.

Engineering Conferences

Module number	Workload	Attendance	Self-study	Semester	Offered in	Duration
30031	180 h	60 h	120 h	Sem. 3	WS/SS	1 sem.

Courses	Credits	Allocation to study programmes
Seminar 4 SWS	6 ECTS	Master ME, SET, IWI

1 **Learning outcomes / competences**

The students

- understand how scientific and engineering conferences work,
- know what to do to submit their own work to an international conference,
- can employ common techniques of producing a scientific paper,
- can identify relevant work of other researchers in relation to their own work and extract similarities and distinctions,
- can digest, condense, select and express information relevant to produce a thread of their own research work,
- can assess a scientific paper in oral form or as a poster.

2 **Contents**

- Group work on selected conference papers, to train the technical understanding, recognition of structure, distillation of core content and critical review
- Exercises in writing up scientific or technical work
- Exercises in scientific (poster and oral) presentation, using modern technical means
- Discussion and assessment of scientific presentations
- Tutorials and exercises in online search for relevant information in connection with publishing research at an international conference
- Small mock conference with poster session and short oral presentations

3 **Forms of teaching**

- Seminar

4 **Recommended prerequisites**

- None

5 **Types of examination**

- Submission of a scientific paper, participation in review process, poster preparation and presentation

6 **Requirements for award of credits**

- Completed paper and poster, successful short oral presentation of the poster
- Attendance at the following mandatory sessions: introduction and registration, conference session day, poster presentation day

7 **Person responsible for the module**

- Prof. Dr.-Ing. Thomas Zielke, Prof. Dr.-Ing. Matthias Neef

8 **Language of instruction**

- English

9 Further information / references

Recommended literature:

- Alley, The craft of scientific presentations. Critical steps to succeed and critical errors to avoid, 2nd edn, New York, Springer, 2013
- Alley, The craft of scientific writing. 4th edn, New York, Springer, 2014
- Cargill/O'Connor, Writing scientific research articles. Strategy and steps, 2nd edn, Chichester, Wiley-Blackwell, 2013
- Hofmann, Scientific writing and communication. Papers, proposals, and presentations, 2nd edn, New York, Oxford University Press, 2014
- Holst, Scientific Paper Writing – A Survival Guide, CreateSpace Independent Publishing Platform, Bergen, 2015

List of important, popular conferences within the scope of our courses:

- http://icpr-eame.com
- CIRP Conference on Industrial Product Service Systems
- ISES Solar World Congress
- Solar Heating and Cooling for Buildings and Industry conference (SHC)
- ASME Turbo Expo (https://www.asme.org)

IEEE engineering publications:
http://ieeexplore.ieee.org

Master's Thesis

Module number	Workload	Attendance	Self-study	Semester	Offered in	Duration
80001				Sem. 3	WS/SS	1 sem.

Courses	Credits	Allocation to study programmes
	21 ECTS	Master ME, IWI, SET

1	**Learning outcomes / competences** The students are able to work on a complex problem from their field – independently and in a professional manner, in accordance with scientific methods, within a prescribed period of time.
2	**Contents** The thesis serves to work on a scientific assignment, within a prescribed extent and period of time (16 weeks). The subject of the thesis can be of theoretical or experimental nature and can originate from any teaching or research field of the faculty.
3	**Forms of teaching** None
4	**Recommended prerequisites** The students must have successfully passed all modules, except the ones scheduled for the last semester.
5	**Types of examination** The thesis is a piece of written examination work.
6	**Requirements for award of credits** None
7	**Person responsible for the module** Dean
8	**Lecturer** Various supervisors
9	**Further information / references** Alternatively, the students can write their theses in the research department of an industrial enterprise or in another scientific organisation of the professional field, if the thesis can be sufficiently supervised.

Colloquium

Module number	**Workload**	**Attendance**	**Self-study**	**Semester**	**Offered in**	**Duration**
80011				Sem. 3	SS/WS	1 sem.

Courses	**Credits**	**Allocation to study programmes**
	3 ECTS	Master ME, IWI, SET

1	**Learning outcomes / competences** The candidates are able to present the results of their theses incl. technical principles, interdisciplinary correlations and non-technical references orally, justify the theses independently, defend them against objections and assess its importance for the practical application.
2	**Contents** The colloquium is an oral examination complementing the thesis. The examiners of the thesis jointly conduct and evaluate the colloquium. The colloquium can include a short presentation by the student on the thesis contents and results.
3	**Forms of teaching** None
4	**Recommended prerequisites** Examiners’ confirmation that they graded the thesis with the minimum passing grade or better.
5	**Types of examination** The colloquium is an oral examination (duration: 45 min.).
6	**Requirements for award of credits** None
7	**Person responsible for the module** Dean
8	**Lecturer** Various supervisors
9	**Further information / references** None

Compulsory Elective Modules

Course
Compulsory Elective Module 1 (to choose from list of elective modules)
Compulsory Elective Module 2 or Study Project 2 (to choose from list of elective modules)