HAW HAMBURG

Faculty of Life Sciences

Module compendium

Master degree program
Process Engineering

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Module Compendium

Master's Degree Program

Process Engineering

Faculty of Life Sciences
Department of Process Engineering

2021 with minor corrections (Mai 22nd, 2023)

approved by the Faculty Council of the Faculty of Life Sciences on 25.11.2021

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Aims of the study program

The Master's degree (M.Sc.) program in "Process Engineering" at the Hamburg University of Applied Sciences is open to graduates in Process Engineering, Chemical Engineering and related Engineering programs. It entitles degree holders to execute professional work in all fields of process engineering in industry and academia. Graduates fulfil the formal and scientific requirements to start a PhD-program.

This full-time study program is designed for 3 semesters (1½ years) and covers mathematical, scientific and engineering knowledge and comprehension with emphasis on digitalization / industry 4.0. Non-technical skills focus on asset management and project management as well as project finance. Most lectures and seminars are complemented by associated practical courses with up-to-date software tools and experiments in on-site laboratories. Students are engaged to deepen their gained competences in a scientific project in small groups. Enhanced soft skills are acquired in the seminars and during the lectures through intense discussions and small projects like the preparation of presentations, posters and papers. In the master thesis, the students demonstrate their ability for autonomous scientific work at graduate level. The courses are mainly held in English language.

Students are enabled to design and optimize processes and to plan, construct, operate and maintain process plants. They can define and perform experiments, select, handle and interpret data as well as perform numerical simulations. They learn to evaluate the effect of the systems on the environment, taking into account technical, social, economic and environmental considerations. They can also reflect systematically on the non-technical implications of engineering activities and involve them responsibly in their actions. They are enabled to familiarize themselves quickly, methodically and systematically with new subjects.

After completing the study program, degree holders will have adopted competences in the following learning aims:

- I) Knowledge and Understanding
- II) Use, Application and Generation of Knowledge
- III) Communication and Cooperation
- IV) Scientific self-image and Professionalism

These competences enable degree holders to apply successfully for jobs in the following work fields in industry and academia:

- I) Research and Development
- II) Maintenance and Service
- III) Planning and Design of Plants
- IV) Plant Operation
- V) Management

The study courses are organized in modules based on their topics. Generally, modules are completed with a module exam. The total number of credit points (CP) is 90. One CP is equivalent to 30 work hours (1 hour = 60 minutes). On the following pages all modules are described in detail with information on e.g. course titles, learning content and aims, kind of exam etc. The table below contains a matrix of learning goals organizing the modules according to the learning aims mentioned above.

All Courses have a share in *Knowledge and Understanding*. Courses within *Usage, Application and Generation of Knowledge* include problem solving, in which own solutions can be developed. Courses with team work and poster/oral presentations are ranked under *Communication and Cooperation*. Aspects of decision making and evaluating of different solutions are listed within *Academic Self-Conception and Professionalism*.

Master thesis (Masterarbeit)

The Master thesis represents the written composition of a theoretical, empirical and/or experimental study. With the Master thesis students prove their ability to express a sound scientific study hypothesis, explore its relevant bibliographic background, select, adapt or develop appropriate scientific study methods to collect and analyse gathered data and discuss the results in relation to the study aims and relevant literature conclusively. The time-limit for delivery of the master thesis is six months. It is credited with 30 credit points.

Matrix of study goals

		General learning aims			
No.	Module	Knowledge and Understanding	Usage, Application and Generation of Knowledge	Communication and Cooperation	Academic Self- Conception and Professionalism
1	Mathematics	X			
2	Data Acquisition	X			
3	Advanced Instrumentation and Autom.	X	X	X	
4	Optimization	X	X	X	X
5	Business Skills	X		X	
6	Advanced Basics 1	X			
7	Advanced Basics 2	X			
8	Engineering	X	X	X	X
9	Multiphysics Simulation	X			X
10	Materials and Corrosion	X	X	X	
11	Environmental Technologies	X	X		X
12	Bioenergy – Biofuels	X			X
13	Plant Operation	X			X
14	Project Work	X	X	X	
15	Master Thesis	X	X		

Module and Course Structure

No.	Module		CP	Semester*	Course	Type of course	SHW	Type of assessment	Assessment	Group size
1	C	Mathematics	5	WiSu	Numerical Mathematics	TS	2	PL	WE, OE, PF	20
				WiSu	Numerical Mathematics	Lab	2			
2	C	Digital Plant Design	5	Su	Data Acquisition and Processing incl. Lab. Work	TS	2	PL	WE, H, OP, OE, PF	20
				Su	Digital Plant Design incl. Lab. Work	TS	2			
3	C	Advanced Instrumentation and Automation	5	Su	Advanced Instrumentation and Automation incl. Lab. Work	TS	4	PL	WE, H, OP, OE, PF	20
4	C	Optimization	5	Wi	Process Optimization and Simulation	TS	2	SL	LWC, H, PF	20
				Wi	Process Optimization and Simulation Lab.	Lab	2			
5	C	Business Skills	5	Wi	Project Finance	TS	2	SL	WE, H, OP, OE	20
				Wi	Project Management	TS	2	PL	WE, H, OP, OE	20
6	CE	** Advanced Thermodynamics and Separation Processes	5	Wi	Thermal Separation Processes	TS	2	PL	WE, H, OP, OE	20
				Wi	Adv. Thermodynamics	TS	2			
7	CE	** Advanced Solids Processing and Reaction Engineering	5	Su	Transport and Storage of Solids, incl. Lab. Work	TS	2	PL	WE, H, OP, OE, PF	20
				Su	Chem. Reaction Engineering	TS	2			
8	CE	** Engineering	5	Wi	Plant Engineering	TS	2	PL	WE, H, OP, PF	20
				Wi	Process and Plant Safety	TS	2	PL	WE, H, OP, OE	
9	CE	** Multiphysics Simulation	5	Wi	Computional Simulation Techniques	TS	2	PL	WE, H, OP, OE, PF	20
				Wi	Multiphysics Simulation incl. Lab. Work	TS	2			
10	E	Materials and Corrosion	5	Su	Failure Analysis incl. Lab. Work	TS	2	PL	WE, H, OP, OE, PF	20
				Wi	Advanced Materials and Corrosion incl. Lab. Work	TS	2			
11	E	Environmental Technologies	5	Wi	Recycling Technologies	TS	2	PL	WE, H, OP, OE, PF	20
				Su	Advanced Wastewater Treatment	TS	2	PL	WE, H, OP, OE, PF	
12	E	Bioenergy - Biofuels	5	Su	Bioenergy - Biofuels	TS	4	PL	WE, H, OP, OE	20
13	E	Plant Operation	5	Su	Maintenance	TS	2	PL	WE, H, OP, OE, PF	20
				Su	Asset Management	TS	2			
14	E	Project Work	5	WiSu	Project Work	Pj	4	PL	Pj	1-4
15	C	Master Thesis	30	WiSu	Master Thesis			PL	MT	
		Total	**90**							

SL: Test (not graded)
LWC: Lab work completion
WE: Written exam
H: Home project
OP: Oral presentation
OE: Oral examination
PF: Portfolio examination
MT: Master Thesis

C: Compulsory module
CE: Compulsory elective module
E: Elective module
TS: Taught seminar
Lab: Laboratory
Pj: Project
CP: Credit point
SHW: Semester hours per week
PL: Examination (graded)

* Explanation on “Semester”: Courses will be offered whether every other semester, i.e. winter semester <u>or</u> summer semester (Wi or Su), or every term, i.e. winter <u>and</u> summer term (WiSu).
** Explanation of “Compulsory elective module”: At least one module of module-group 6/7 and module-group 8/9 has to be chosen.

Forms of examination

In accordance with § 14 APSO-INGI, as amended from time to time, the forms of examination for the subsequent descriptions are defined as follows:

Home project (HP)

A home project is a piece of written work, to be produced by the student on his or her own and outside class hours, in which the student is to prove that he or she is able to investigate and analyse a set question or subject independently. A maximum of three months is allowed for completion. If the home project constitutes an examination, the program-specific examination and study regulations may specify whether or not a colloquium is to be held once the written project has been submitted. Colloquia should last between 15 and 45 minutes and are generally to be held within one month of submission of the written work.

Written examination (WE)

A written examination is completed under supervision. Students must complete the set questions on their own, either without the use of study aids or with the use of specified study aids only. Written examinations last at least 60 and no longer than 240 minutes.

Lab work completion (LWC)

Lab work is successfully completed when students have successfully conducted the experiments set by the examiner during the semester and have demonstrated their knowledge by taking part in corresponding colloquia and/or by submitting written records of their work and/or by completing set written tasks. Colloquia last for a minimum of 15 and a maximum of 45 minutes. The written work must be submitted by a deadline set by the examiner; the latest deadline is the end of the semester in which the class in question was taken.

Oral examination (OE)

In an oral examination, a student must demonstrate in discussion with the examiner that he or she fully understands the material on which he or she is being examined. Oral examinations generally last at least 15 and no more than 45 minutes. Oral examinations may be conducted as individual or group examinations and are to be conducted by one examiner and one assessor in accordance with Section 13 (4). An oral examination may alternatively be conducted by two or more examiners instead of one, i.e. by a panel of examiners; in such a case, the student is to be examined by one examiner only in each of the various examination subjects. Oral examinations are always assessed and graded by one examiner only, no matter whether they are conducted by several examiners or by an examiner and an assessor. The examiner responsible for grading in each case must consider the views of the other examiners/the assessor before deciding on the grade to be awarded. The main aspects covered in and results of each oral examination are to be recorded. The record is signed by the examiners and assessor and is filed with the examination documents.

Project (Pro)

A project is an interdisciplinary task relating to the area of industry or business for which the course is designed. The results of projects must be documented. At least 6 and no more than 26 weeks are allowed for projects. Project work is generally completed with a colloquium. The applicable program-specific examination and study regulations may specify additional requirements in terms of the form, content and goal of the project, and may specify another form of final assessment instead of a colloquium.

Oral presentation

A paper is a presentation lasting between 15 and 45 minutes on the basis of written preparation by the student. A paper is followed by a discussion led by the student or tutor. Papers should not be read out from detailed notes; students should be able to speak spontaneously. Digital or hard copies of any presentations and graphics used are to be submitted to the examiner. The detailed written paper to be submitted to the examiner should summarize the key findings and conclusions.

Portfolio examination (PP)

A portfolio examination is a form of examination consisting of a maximum of ten examination elements. At least two different forms of examination shall be used for the portfolio examination. The possible forms of examination that can be used result from the forms of examination listed in § 14 paragraph 3 APSO-INGI as well as semester-long exercises. At the beginning of the course, the lecturer determines which examination elements and with which weighting for the individual examination elements the portfolio examination should take place. In the case of an examination performance, the individual examination elements result in an overall grade for the respective portfolio examination according to their weighting. The total scope of the portfolio examination in terms of workload and degree of difficulty may not exceed the scope of the examination form if this were to be selected as the only examination element.

Module Descriptions

Master's Program: Process Engineering M.Sc.	
Module: Mathematics	
Module number	1
Module coordination	Prof. Dr. Anna Rodenhausen
Duration / semester / frequency	One semester / winter or summer semester / every semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 4 SHW x 18 weeks = 72 h Self-study: 150 h – 72 h = 78 h
Type of module	Compulsory module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Informatics • Mathematics • Numerics
Language	• English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • use MATLAB for problem solving. • apply numerical methods to engineering problems.

Content of module	Numerical Mathematics
	• Introduction to MATLAB programming,
	• Introduction to basic problems concerning the representation of numbers and performance of arithmetic operations on a computer (types of errors, error propagation, extinction),
	• Numerical solution of linear equation systems
	  ○ Ill-conditioned linear equation systems,
	  ○ Overdetermined linear equation systems (pseudo-inverse matrix).
	• Curve fitting and interpolation methods
	  ○ Least squares fit,
	  ○ Linearization,
	  ○ Cubic splines.
	• Optimization
	  ○ Nelder-Mead Simplex Algorithm,
	  ○ Use of MATLAB functions for optimization.
	• Numerical integration
	  ○ Trapezoidal rule,
	  ○ Simpson's method,
	  ○ Error estimation,

	o Use of MATLAB functions for numerical integration.
	• Numerical solution of differential equations
	  o Methods of Euler, Heun and Runge-Kutta,
	  o Error estimation,
	  o Use of MATLAB ODE solvers.
	• Numerical solution of partial differential equations
	  o Numerical derivation,
	  o Approximation of a solution on a grid (e.g., Crank-Nicolson Method)
	  o Solution of selected examples of PDE (e.g., the heat equation).

Applicability of module	The understanding of numerical mathematics is important in all aspects of simulations. Therefore, it is applicable in: • Optimization • Multiphysics Simulation • Master Thesis
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: Taught Seminar: written exam (PL) Further possible examination types: oral examination, portfolio examination Where more than one possible examination type is used in the module, the examination type to be used is to be made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Numerical Mathematics (Taught Seminar) Course 2: Numerical Mathematics (Numerical Lab.)
Type of course and media	Taught seminars (computer with projector, blackboard, overhead and problem sheets) and numerical lab.
Literature	• S.C. Chapra: Numerical Methods for Engineers, McGraw-Hill, 2005. • A. Gilat, V. Subramaniam: Numerical Methods – An Introduction with Applications Using MATLAB, SI Version, 2011. • M. Hanke-Bourgeois: Grundlagen der Numerischen Mathematik und des wissenschaftlichen Rechnens, Teubner, 2002. • J. H. Mathews, K.D. Fink: Numerical Methods using MATLAB, Prentice Hall, 2004. • A. Stoyanoyevitch: Introduction to Numerical Ordinary and Partial Differential Equations Using MATLAB, Wiley, 2005. • W. Y. Yang et al.: Applied Numerical Methods Using MATLAB, Wiley, 2005. • W. H. Press et al.: Numerical recipes in C, Cambridge University Press, New York, 1998. • I.N. Bronstein, K.A. Semendyayev et al.: Handbook of Mathematics, 4th Ed. Springer, Berlin Heidelberg, 2004.

Master's Program: Process Engineering M.Sc.	
Module: Digital Plant Design	
Module number	2
Module coordination	Prof. Dr.-Ing. Kai Freudenthal
Duration / semester / frequency	One semester / summer semester / every other semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 4 SHW x 18 weeks = 72 h Self-study: 150 h – 72 h = 78 h
Type of module	Compulsory module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Basic knowledge of instrumentation and automation • Basic knowledge of process engineering and plant design
Language	• English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • implement and evaluate data acquisition and storage algorithms. • develop adequate evaluation methods for experimental data containing random contributions. • interpret the evaluation of experimental data correctly (especially the results of hypothesis tests). • apply statistical methods. • test the developed evaluation methods by simulation to get more reliable programs. • apply new aspects of digitalization to process engineering (Industry 4.0). • identify the different phases of the life cycle of a plant with their individual aspects.

Content of module	Course 1: Data Acquisition and Processing
	• Introduction to LabVIEW programming,
	• Statistical evaluation of measured data
	  o Basic statistical quantities (mean, variance and standard error, median etc.)
	  o Hypothesis tests
	  o Parameter estimation
	• Acquisition and processing
	  o Fourier transform und series: basics, examples and discretization
	  o Sampling theorem: aliasing, smoothing windows etc.
	  o Digital filters: linear filters (FIR and IIR).

	Course 2: Digital Plant Design
	• Digitalisation / Industry 4.0 in process engineering
	  o Industry 4.0 terms & technologies
	  o Smart Factory vs. Chemical Industry 4.0
	  o Status & potentials
	  o Initiatives and applications
	• Information management of process plants throughout the lifecycle
	  o Requirements by legislation, operation and IT
	  o Types of engineering documents
	  o Typical IT applications and software tools
	  o Databases for information management and data transfer, software tools and industrial applications and references

Applicability of module	The understanding of Digital Plant Design is important for all aspects of Digitalization in Process Engineering. Therefore, it is applicable in: • Advanced Automation and Instrumentation • Engineering • Plant Operation • Master Thesis
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: portfolio examination (PL) Further possible examination types: home project, oral presentation, oral examination or written exam Where more than one possible examination type is used in the module, the examination type to be used is to made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Data Acquisition and Processing incl. Lab. Work (Taught Seminar) Course 2: Digital Plant Design incl. Lab. Work (Taught Seminar)
Type of course and media	Taught seminars (computer with projector, blackboard, overhead and problem sheets) incl. Lab. Work
Literature	Examples of literature related to Data Acquisition and Processing: • W. H. Press et al.: Numerical recipes in C, Cambridge University Press, New York, 1998. • I.N. Bronstein, K.A. Semendyayev et al.: Handbook of Mathematics, 4th Ed. Springer, Berlin Heidelberg, 2004. • R. Jamal, H. Pichlik: LabVIEW Applications, Prentice Hall, 1998. • LabView User Manual, National Instruments, January 1998. • R.W. Hamming: Digital Filters, Englewood Cliffs, New Jersey, 1983. • P.Profos, T. Pfeifer: Grundlagen der Meßtechnik, Oldenburg Verlag, München, 1997. Examples of literature related to Digital Plant Design: • Lecturer's handout • Yang, R. (2009). Process Plant Lifecycle Information Management, Publisher: iUniverse • Langford, G.O. (2012). Engineering Systems Integration: Theory, Metrics, and Methods, edition 1, Publisher: CRC Press.

Master's Program: Process Engineering M.Sc.	
Module: Advanced Instrumentation and Automation	
Module number	3
Module coordination	Prof. Dr.-Ing. Falk Beyer
Duration / semester / frequency	One semester / summer semester / every other semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 4 SHW x 18 weeks = 72 h Self-study: 150 h – 72 h = 78 h
Type of module	Compulsory module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Basic knowledge about instrumentation, control engineering and process automation
Language	English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • differentiate between different structures of safety and automation systems. • differentiate between PLCs and DCSs. • differentiate between communication systems for field devices. • explain the performance of intelligent field devices. **Methodological Competency (use, application and generation of knowledge)** Students are able to …: • structure and plan a safety and automation system. • integrate different process plant sub-systems. • select and make use of the performance of intelligent field devices. **Social Competency (communication and cooperation)** Students are able to …: • discuss and elaborate solutions in interdisciplinary teams. • represent the own point of view.

Content of Module	• Multivariable and model predictive-control techniques • Adv. process control (performance and reliability optimization) • Automation topologies in process plants • PLCs and DCSs • Integration of subsystems like safety instrumented systems (SIS, ESD), machinery monitoring (MMS), motor control center (MCC), analysers and data transfer to DCSs • Internet of things / communication to field devices in process plants (HART, Fieldbus foundation, ProfiBus) • Alarm management systems • Intelligent field devices
Applicability of module	This module is associated with the modules • Mathematics • Digital plant design • Optimization • Engineering • Plant operation • Project work • Master Thesis
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: written exam (PL) Further possible examination types: home project, oral presentation, oral examination or portfolio examination Where more than one possible examination type is used in the module, the examination type to be used is to made known by the responsible lecturer at the start of the course.
Corresponding courses	Advanced Instrumentation and Automation incl. Lab. Work
Type of course and media	Taught Seminars (computer with projector, blackboard, overhead and problem sheets) incl. Lab. Work
Literature	• Love, J.: Process Automation Handbook. Springer, 2007 • Hollender, M.: Collaborative Process Automation Systems. International Society of Automation, 2010 • Seferlis, P. et al.: The Integration of Process Design and Control. Elsevier, 2004 • Dittmar, R.: Advanced Process Control: PID-Basisregelungen, Vermaschte Regelungsstrukturen, Softsensoren, Model Predictive Control. De Gruyter, Oldenbourg, 2017

Master's Program: Process Engineering M.Sc.	
Module: Optimization	
Module number	4
Module coordination	Prof. Dr.-Ing. Marc Hölling
Duration / semester / frequency	One semester / winter semester / every other semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 4 SHW x 18 weeks = 72 h Self-study: 150 h – 72 h = 78 h
Type of module	Compulsory module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Process simulation of chemical plants • Reaction engineering • Thermal separation processes • Heat and mass transfer • Thermodynamics • Numerics
Language	• English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • create simulation models of unit operations and plants. • identify system behaviour with respect to e.g. pressure, temperature, volume flows, etc. • identify potential for process improvement in a given context (costs, efficiency, production increase, quality etc.). **Methodological competency (use, application and generation of knowledge)** Students are able to …: • choose the adequate simulation model with the right level of detail. • identify key parameters and effects to be considered in the simulation. **Social competency (communication and cooperation)** Students are able to …: • work in teams. • discuss solutions in teams and groups. • give oral presentation and/or written reports.

	Self-competency (scientific self-image, professionalism) Students are able to …: • evaluate different solutions. • make justified decisions.
Content of module	• Application of simulation software for process engineering • Calculation of mass / enthalpy balance as well as chemical and vapour-liquid equilibrium etc. • Analysis of process losses and physical optimum, identification of "bottlenecks", sensitivity analysis, • Increase of energy efficiency, production and/or product quality • pumps/blower optimization, pinch point analysis regression techniques / data analysis to consider real life data in simulation
Applicability of module	Plant simulation and optimization is an important tool for process engineers to solve real life problems. The competencies of this lecture will help students in understanding unit operations and plants. It can be applied in: • Chemical Reaction Engineering • Thermal Separation Processes • Digital Plant Design
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: Lab work completion (SL) Further possible examination types: home project or portfolio examination Where more than one possible examination type is used in the module, the examination type to be used is to made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Process Optimization and Simulation Course 2: Process Optimization and Simulation (Num. Lab.)
Type of course and media	Course 1: Taught Seminar (computer with projector, blackboard, problem sheets) Course 2: Numerical Lab. (simulation software)
Literature	Manual and tutorials of simulation software Lecturer's handout

Master's Program: Process Engineering M.Sc.	
Module: Business Skills	
Module number	5
Module coordination	Prof. Dr.-Ing. Veit Dominik Kunz
Duration / semester / frequency	One semester / winter semester / every other semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 4 SHW x 18 weeks = 72 h Self-study: 150 h – 72 h = 78 h
Type of module	Compulsory module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Economics • Project Management
Language	• English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • differentiate between the different phases of a project incl. their content, main deliverables and interactions. • be aware of different project management techniques and frameworks. • successfully conceptualize, plan, execute and terminate projects. • apply a structured and systematic approach assessing the risks associated with project finance transactions. • recognize the key characteristics of a robust project and identify weaknesses of a proposed structure. • interpret the risks identified and propose (contractual) mechanism to allocate these risks. • identify the various project funding sources available (equity/debt/mezzanine/bonds). **Social competency (communication and cooperation)** Students are able to …: • work task-oriented, independently and self-critically in a project team and accept different roles in the team.
Content of module	Course 1: Project Finance • Fundamentals of project financing (financial rationale, parties involved, development phases) • State and trends of the project finance market • Role of sponsors, lenders and advisors • Project due diligence and risk identification

	• Risk management / contractual risk allocation • Funding of project finance transactions by equity, debt, mezzanine and/or project bonds • Role of commercial banks, international financial institutions and export credit agencies • Arranging and structuring financing • Introduction to project and financing documentation • Introduction to legal aspects in project finance Course 2: Project Management • Product / project life cycle • Project management frameworks • Leadership in PM • Managing teams • Project change and risk management • Project management tools and documentation • Special methods like lean management, agile project management • Change management
Applicability of module	The module can be applied in e.g.: • Plant Operation • Master Thesis
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type in Project Finance: written exam (SL) Further possible examination types: home project, oral presentation or oral examination. Regular examination type in Project Management: oral presentation (PL) Further possible examination types: written exam, home project or oral examination. Where more than one possible examination type is used in the course, the examination type to be used is to made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Project Finance Course 2: Project Management
Type of course and media	Taught seminars, (computer with projector, blackboard, overhead and problem sheets)
Literature	Examples of literature related to Project Finance: • Lecturer’s handout Examples of literature related to Project Management: • Lecturer’s handout

Master's Program: Process Engineering M.Sc.	
Module: Advanced Thermodynamics and Separation Processes	
Module number	6
Module coordination	Prof. Dr. Anika Sievers
Duration / semester / frequency	One semester / winter semester / every other semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 4 SHW x 18 weeks = 72 h Self-study: 150 h – 72 h = 78 h
Type of module	Compulsory elective module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Reaction engineering / chemical engineering • Thermal separation processes (basics) • Heat and mass transfer • Thermodynamics (basics)
Language	• English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • create process design for thermal separation processes. • design process layouts for thermal separation processes. • identify system behaviour with respect to e.g. pressure, temperature, volume flows, etc. • identify potential for process improvement in a given context (costs, efficiency, production increase, quality etc.).
Content of module	• Balancing of processes • Deepening of knowledge of thermal separation processes, e.g. evaporation, condensation, distillation, rectification, crystallization, drying, ad- and absorption • Heat and mass transfer processes, e.g. fluidized beds, (packing) columns, column trays • Process design of thermal separation processes • Thermodynamics of thermal separation processes • Multicomponent and multiphase thermodynamics • High pressure thermodynamics • Chemical thermodynamics

Applicability of module	The competences of this lecture will help students in understanding unit operations and plants. It can be applied in: • Multiphysics Simulation • Advanced Instrumentation and Automation • Project Work • Master Thesis
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: written exam (PL) Further possible examination types: home project, oral presentation or oral examination Where more than one possible examination type is used in the module, the examination type to be used is to made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Thermal Separation Processes Course 2: Advanced Thermodynamics
Type of course and media	Taught seminars (computer with projector, blackboard, overhead and problem sheets)
Literature	Examples of literature related to Thermal Separation Processes: • Lecturer's handout • Sattler, K., Feindt, H. J. (1995). Thermal separation processes: principles and design: VCH Weinheim • Henley, E. J., Seader, J. D. (1981). Equilibrium-stage separation operations in chemical engineering: Wiley: New York • King, C. J. (1980). Separation Processes: McGraw-Hill: New York • Van Swaij, W. P. M., Afgan, N. H. (1984). Heat and Mass Transfer in Fixed and Fluidizes Beds: ICHMT Symposium: Dubrovnik, Yugoslavia • VDI-Gesellschaft Verfahrenstechnik und Chemieingenieurwesen (2013). VDI-Heat Atlas, 11. Edition, Berlin, Heidelberg: Springer. Examples of literature related to Advanced Thermodynamics: • Ira N. Levine: Physical Chemistry. 5th Ed., McGraw-Hill, New York 2003 • Stanley I. Sandler: Chemical and Engineering Thermodynamics. 3rd Ed., John Wiley, New York 1999 • Michael Modell, Robert C. Reid: Thermodynamics and its Applications. 2nd Ed., Prentice-Hall, London 1983 • G. Brunner: Supercritical Fluids as Solvents and Reaction Media. Elsevier, Amsterdam 2004 • Daniel R. Stull, Edgar F. Westrum, Jr. & Gerard C. Sinke: The Thermodynamics of Organic Compounds. John Wiley, New York 1969

Master's Program: Process Engineering M.Sc.	
Module: Advanced Solids Processing and Reaction Engineering	
Module number	7
Module coordination	Prof. Dr.-Ing. Martin Geweke
Duration / semester / frequency	One semester / summer semester / every other semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 4 SHW x 18 weeks = 72 h Self-study: 150 h – 72 h = 78 h
Type of module	Compulsory elective module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Mechanical process technology • Fluid mechanics • Chemical Engineering • Thermodynamics
Language	• English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • evaluate the flow behaviour and the critical flow conditions of powder as a result of the characteristic data of the bulk material • develop suitable concepts for the storage, the dosage and transport of bulk material • analyse (flow- and storage-) problems of bulk material in existing plants and develop technical solutions on the basis of scientific knowledge • apply component and enthalpy balances to non-isothermal reactors • design chemical reactors for selected reactions • identify the rate determining step for heterogeneous catalysis
Content of module	Course 1: Transport and Storage of Solids • flow behaviour of powder • mechanical, pneumatic and hydraulic transport of bulk material • design of silos and storage vessels • lab work: flow behaviour of powder Course 2: Chemical Reaction Engineering • non-isothermal and special reactors including scale-up • heterogeneous catalysis • selected reaction types like polymerization, cracking, combustion etc.

Applicability of module	The knowledge of the flow behaviour of powder as well as the chemical reaction of solids and fluids will help students in understanding the exact processes of several unit operations and plants. It can be applied in: • Master Thesis • Project Work • Optimization • Digital Plant Design
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: written exam (PL) Further possible examination types: home project, oral presentation, oral examination or portfolio examination Where more than one possible examination type is used in the module, the examination type to be used is to made known by the responsible lecturer at the start of the course.
Corresponding courses	Course 1: Transport and Storage of Solids incl. Lab. Work Course 2: Chem. Reaction Engineering
Type of course and media	Taught seminars, lab work (computer with projector, blackboard, overhead and problem sheets)
Literature	Examples of literature related to Transport and Storage of Solids: • Lecturer's handout • Rhodes, M. (2008): Introduction to Particle Technology, 2nd edition, John Wiley and Sons, Ltd. • Mills, D., Agarwal, V.K. (2009): Pneumatic Conveying Systems, 2nd edition, Vogel – Verlag, • Schubert, H. (2003): Handbuch der mechanischen Verfahrenstechnik, 1. Auflage, Weinheim, WILEY-VCH Verlag • Lodewijks, G. (2010): Current Development in Bulk Solids Handling, 1st edition, Vogel – Verlag • Schulze, D. (2008): Pulver und Schüttgüter, 2. Auflage, Springer – Verlag Examples of literature related to Chemical Reaction Engineering: • Levenspiel, O. (1999): Chemical Reaction Engineering, 3rd edition, John Wiley & Sons • Davis, M.E., Davis, R.J. (2003): Fundamentals of Chemical Reaction Engineering, McGraw-Hill Higher Education

Master's Program: Process Engineering M.Sc.	
Module: Engineering	
Module number	8
Module coordination	Prof. Dr.-Ing. Falk Beyer
Duration / semester / frequency	One semester / winter semester / every other semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 4 SHW x 18 weeks = 72 h Self-study: 150 h – 72 h = 78 h
Type of module	Compulsory elective module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Basic knowledge about process engineering/design and process plants
Language	English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • differentiate between the phases of a process plant asset life cycle. • define and interpret requirements of the different phases of a process plant life cycle. • define interfaces between the different phases of a process plant life cycle. • select methods for the evaluation of the safety of processes and process plants. • define measures to ensure safe processes and process plants. **Methodological competency (use, application and generation of knowledge)** Students are able to …: • structure and plan process plant engineering and construction projects. • execute projects along the asset life cycle. • design safe processes and to build and operate safe plants. **Social competency (communication and cooperation)** Students are able to …: • discuss and elaborate solutions in interdisciplinary teams. • represent their own point of view. • give presentations. • write papers.

	Self-competency (scientific self-image, professionalism) Students are able to …: • justify their own professional actions with theoretical and methodological knowledge and reflect on alternative designs.
Content of module	Course 1: Plant Engineering • Projects: phases, execution structures, involved parties • Technology development • Preliminary planning, feasibility study • Basic and detail engineering, FEED • Procurement, expediting and inspection • Civil and construction • Commissioning and operation • Maintenance/inspection Course 2: Process and Plant Safety • Hazard potentials and risks in chemical plants and processes • Quantitative risk assessment (QRA) • Reliability, availability, reliability function, failure rate of components • Failure Mode and Effects Analysis (FMEA) • Fault and Event Tree Analysis (FTA, ETA) • Hazard and Operability Analysis (HAZOP) • Legal framework(s) for safe process operation • Risk communication
Applicability of module	This module mainly covers the phases of the asset life cycle with an emphasis on process and plant safety. As such, it is associated with the modules • Digital Plant Design • Adv. Automation • Optimization • Plant Operation and • the non-technical module business skills • Project Work • Master Thesis
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type for Plant Engineering: oral presentation (PL) Further possible examination type: home project, written exam, portfolio examination Regular examination type for Process and Plant Safety: written exam (PL) Further possible examination types: home project, oral presentation, oral examination Where more than one possible examination type is used in the course, the examination type to be used is to made known by the responsible lecturer at the start of the course.

Corresponding courses	Course 1: Plant Engineering Course 2: Process and Plant Safety
Type of course and media	Taught Seminar (computer with projector, blackboard, overhead and problem sheets)
Literature	• Helmus, F. P.: Process Plant Design – Project Management from Inquiry to Acceptance. WILEY-VCH Verlag, Weinheim, 2008. • Moran, Sean: An applied guide to process and plant design. Butterworth-Heinemann, Oxford 2015 • Mosberger, E.: Chemical Plant Design and Construction, Ulmann's Encyclopedia of Industrial Chemistry. WILEY-VCH Verlag, Weinheim, 1992, 5th, p 477-558. • Peters, M. et al.: Plant Design and Economics for Chemical Engineers. McGraw-Hill Professional, 2003. • Sattler, K., Kasper, W.: Verfahrenstechnische Anlagen – Planung, Bau und Betrieb, Band 1 und 2. WILEY-VCH Verlag, Weinheim, 2000. • Bernecker, G.: Planung und Bau verfahrenstechnischer Anlagen. Springer Verlag, Berlin, 2001.

Master's Program: Process Engineering M.Sc.	
Module: Multiphysics Simulation	
Module number	9
Module coordination	Prof. Dr.-Ing. Rainer Stank
Duration / semester / frequency	One semester / winter semester / every other semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 4 SHW x 18 weeks = 72 h Self-study: 150 h – 72 h = 78 h
Type of module	Compulsory elective module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Mathematics
Language	• English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • apply numerical simulations and in particular CFD simulations. They can use commercial CFD packages in order to simulate the flow fields occurring in the area of process engineering. • conduct the five steps of a numerical simulation process and distinguish the details, settings and functions of the geometry, meshing, pre-, main- and post-processing. • assess the quality of the numerical results by evaluating the mesh and the convergence behaviour. • analyse the flow and improve the flow path and/or the technical application based on their physical understanding and the obtained numerical results. • identify the key parameters of the flow field and use them for further evaluations and analysis. • isolate the important geometrical features for the flow based on CAD data or blueprints and to generate appropriate computational meshes. • generate converged and consistent numerical solutions. **Social competency (communication and cooperation)** Students are able to …: • communicate about all aspects of numerical simulations and the underlying physical principles in order to make justified decisions. • learn creatively and in small teams and analyse the numerical results together before including them in a report. • present work results in a scientific and convincing manner. • compare their numerical simulated results with experimental data and interpret the results of the numerical simulations with respect to their reliability.

Content of module	Course 1: Computational Simulation Techniques
	• Governing equations of CFD-Simulation (RANS)
	• Physical flow phenomena of laminar and turbulent flow
	• Numerical techniques to solve coupled partial differential equations
	  o First order and higher order schemes
	  o Time integration
	• Numerical parameters to influence the convergence behaviour and how to handle convergency problems (relaxation factors)
	• Different types of meshes suited for the numerical simulations
	• Best practical guidelines to generate reliable numerical results
	• Commercial software packages ANSYS CFX or/and Siemens starccm+
	Course 2: Multiphysics Simulation
	• Instationary computations
	• Multicomponent non reacting flow
	  o Mixtures consisting of gas/gas phases
	  o Mixtures consisting of liquid/liquid phases
	  o Additional variables for mixing description
	• Heat transfer mechanisms from flow field into housings/casings or the surrounding
	• Particle flow in process engineering components (e.g. cyclone)
	• Porous media and the numerical models

Applicability of module	• Optimization • Project Work • Master Thesis
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: portfolio examination (PL) Further possible examination types: home project, written exam, oral presentation, oral examination Where more than one possible examination type is used in the course, the examination type to be used is to made known by the responsible lecturer at the start of the course
Corresponding courses	Course 1: Computational Simulation Techniques Course 2: Multiphysics Simulation Lab. Work
Type of course and media	Taught seminars (computer with projector, blackboard, problem sheets) Presentations (projector/overhead projector) Teamwork in small groups with supervision for using the commercial software package ANSYS CFX or Siemens starccm+
Literature	• Lecturer’s handout • Manuals and Tutorials from ANSYS-CFX and Siemens starccm+ • Jiyuan Tu et all: Computational Fluid Dynamics: A practical approach, Butterworth-Heinemann • Ferziger, J.H.; Peric, M.: Computational Methods for Fluid Dynamics, Springer Verlag • Versteeg, H.K.; Malalasekera, W.: An Introduction to Computational Fluid Dynamics, The Finite Volume Method, Pearson • Welty, J.R. et al (2000). Fundamentals of Momentum, Heat and Mass Transfer. John Wiley and Sons • Munson et all: Fundamentals of Fluid Mechanics, Wiley

Master's Program: Process Engineering M.Sc.	
Module: Materials and Corrosion	
Module number	10
Module coordination	Prof. Dr.-Ing. Bernd Sadlowsky
Duration / semester / frequency	Two semester / summer and winter semester Failure Analysis incl. Lab. Work: summer semester Advanced Materials Science and Corrosion incl. Lab. Work: winter semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 4 SHW x 18 weeks = 72 h Self-study: 150 h – 72 h = 78 h
Type of module	Elective module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Material Science (basics) • Technical Mechanics (basics)
Language	• English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • characterize the properties of different materials used in process engineering. • characterize the in-service conditions. • identify deterioration of material properties that may occur during service operation. • identify equipment failure modes and causes **Methodological competency (use, application and generation of knowledge)** Students are able to …: • select the right material from the many thousands that are available. • make economic considerations. • perform failure analysis. **Social competency (communication and cooperation)** Students are able to …: • work in teams. • discuss solutions in teams and groups. • give oral presentations and/or written reports.

Content of module	Course 1: Failure analysis • Common failure analysis techniques • General procedures for failure analysis • Ductile and brittle failures • Fatigue failures • Wear failures • Corrosion failures • Elevated-temperature failures • Pract. training Course 2: Advanced Materials and Corrosion • Synthesis, fabrication and processing of ceramics (glasses and glass-ceramics) and polymers • Various types of composite materials: particle-reinforced composites, fiber-reinforced composites • Detailed knowledge about the theoretical basis for selected types of corrosion • The effect of microstructure, mechanical properties, load and environment on metals exposed to hydrogen • Corrosion protection with special focus on cathodic protection and coating/surface modification • Pract. training
Applicability of module	• Plant Design • Maintenance • Business Skills
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: written exam (PL) Further possible examination types: home project, oral presentation, oral examination or portfolio examination Where more than one possible examination type is used in the course, the examination type to be used is to made known by the responsible lecturer at the start of the course
Corresponding courses	Course 1: Failure Analysis incl. Lab. Work Course 2: Advanced Materials Science and Corrosion incl. Lab. Work
Type of course and media	Taught seminars (computer with projector, blackboard, overhead and problem sheets) and Lab. Work (material investigations and failure analysis)
Literature	Literature for Course 1: Failure analysis incl. Lab. Work: • VDI Technical rules 3822 – „Failure analysis - Fundamentals and performance of failure analysis, 2011 • G. Lange, M. Pohl. M. (Hrsg.), “Systematische Beurteilung technischer Schadensfälle”, • A. Neidel (Hrsg.), “Schadensfallanalysen metallischer Bauteile” 2015 • Stahlinstitut VDEh (Hrsg.), “The Appearance of Cracks and Fractures in Metallic Materials”

	• A. Neidel, L. Engel, H. Klingele, J. Völker, „Handbuch Metallschäden: REM-Atlas und Fallbeispiele zur Ursachenanalyse und Vermeidung“, 2011 • G.W. Ehrenstein, L. Engel, H. Klingele, H. Schaper (Hrsg.), “Scanning Electron Microscopy of Plastics Failure” 2010 Literature for Course 2: Advanced Materials and Corrosion • W. D. Callister, D. Rethwisch, Fundamnetals of Materials Science and Engineering, • P. R. Roberge, “Handbook of Corrosion Engineering”, 1999, McGraw-Hill

Master's Program: Process Engineering M.Sc.	
Module: Environmental Technologies	
Module number	11
Module coordination	Prof. Dr.-Ing. Jörn Einfeldt
Duration / semester / frequency	Two semester / winter and summer semester Recycling Technologies: winter semester Advanced Wastewater Treatment: summer semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 4 SHW x 18 weeks = 72 h Self-study: 150 h – 72 h = 78 h
Type of module	Elective module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Thermal separation processes • Mechanical Separation Processes (Bachelor)
Language	• English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • understand, choose and design technologies for advanced wastewater treatment. • understand, choose and design selected recycling technologies and waste treatment plants. • identify potential for process improvement in a given context (costs, efficiency, quality etc.). **Methodological competency (use, application and generation of knowledge)** Students are able to …: • evaluate different technologies for advanced wastewater treatment. • evaluate different unit operations for recycling and waste treatment. **Self-competency (scientific self-image, professionalism)** Students are able to …: • make justified professional decisions.

Content of module	Fundamentals of recycling technologies and waste processing: The knowledge of the standard technologies for material cycles and recycling and the competence of decision making in the field of selection of material related technologies will be improved. • Classification of waste, generation rates, properties of solid waste • Use and demand of metals and minerals in society. Fundamentals of primary and secondary production of raw materials (e.g. steel, aluminium, phosphorous, copper, precious metals, specialty metals, synthetics). • Collection systems and concepts. • Mechanical pre-treatment and advanced sorting technologies. Examples of waste recycling plants. • Waste-to-energy. • Landfill design and landfill operation. Background and application of various wastewater treatment technologies. Both high-tech and low-tech systems are discussed which are applicable in industrialized and developing countries: • Biological wastewater treatment and nutrient removal, incl. membrane bioreactors • Precipitation, coagulation, flocculation, bed filtration • Advanced oxidation processes, activated carbon, removal of pharmaceutical residues • Anaerobic sewage treatment and anaerobic reactor technologies • (Re)source-oriented sanitation • Sludge treatment and phosphorus recovery • WWTP 2030
Applicability of module	• Plant Design • Maintenance
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type for each course: written exam (PL) Further possible examination types: home project, oral presentation, oral examination or portfolio examination Where more than one possible examination type is used in the course, the examination type to be used is to made known by the responsible lecturer at the start of the course
Corresponding courses	Course 1: Recycling Technologies Course 2: Advanced Wastewater Treatment
Type of course and media	Course 1: Taught seminar (computer with projector, blackboard, problem sheets) Course 2: Taught seminar (computer with projector, blackboard, problem sheets)
Literature	• Wastewater Engineering: Treatment and Resource Recovery, 2 Vols. 2013, 5th ed., 1856 Pages, McGraw-Hill Professional • Kranert M. (Hrsg., 2017). Einführung in die Kreislaufwirtschaft, Planung -- Recht – Verfahren (in german) • Lecturer’s handout

Master's Program: Process Engineering M.Sc.	
Module: Bioenergy - Biofuels	
Module number	12
Module coordination	Prof. Dr.-Ing. Thomas Willner
Duration / semester / frequency	One semester / summer semester / every other semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	In-class lecture: 4 SHW x 18 weeks = 72 h Self-study: 150 h – 72 h = 78 h
Type of module	Elective module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Engineering and Chemical Thermodynamics (basics)
Language	• English
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • create process concepts for advanced biofuels. • calculate energy efficiency of biofuel process concepts. • evaluate biofuel process concepts. • identify potential of biofuels in the context of renewable energies. • identify potential for process improvement in a given context (costs, efficiency, production increase, quality etc.). **Self-competency (scientific self-image, professionalism)** Students are able to …: • apply time and project management skills.
Content of module	• understand fundamentals of conventional and alternative fuels • understand biomass properties related to biofuels • understand engineering and chemical thermodynamics • apply thermodynamics to biofuel process concepts • understand 1st generation biofuels • understand 2nd generation biofuels • understand advanced 2nd generation biofuels

Applicability of module	The competencies of this lecture will help students in understanding bioenergy concepts. It can be applied in: • Advanced Basics 1 and 2 • Project Work • Master Thesis
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: written exam (PL) Further possible examination types: home project, oral presentation or oral examination Where more than one possible examination type is used in the course, the examination type to be used is to made known by the responsible lecturer at the start of the course
Corresponding courses	Bioenergy - Biofuels
Type of course and media	Taught seminars (computer with projector, blackboard, overhead and problem sheets)
Literature	Examples of literature related to bioenergy and biofuels: • Lecturer's handout • DECHEMA position paper: Advanced alternative liquid fuels – For climate protection in global raw material change. ProcessNet, Frankfurt Juli 2017 • W. Leitner et al.: Advanced Biofuels and Beyond: Chemistry Solutions for Propulsion and Production. Angew. Chem. Int. Ed. 2017, 56, 5412-5452 • Soltes, Milne: Pyrolysis Oils from Biomass – Producing, Analyzing and Upgrading. ACS Symposium Series 376, Washington DC 1988 • Bridgwater, Grassi: Biomass Pyrolysis Liquids Upgrading and Utilisation. Elsevier Applied Sciences, New York 1991 Examples of literature related to Thermodynamics: • Ira N. Levine: Physical Chemistry. 5th Ed., McGraw-Hill, New York 2003 • Stanley I. Sandler: Chemical and Engineering Thermodynamics. 3rd Ed., John Wiley, New York 1999 • Levenspiel: Chemical Reaction Engineering • Michael Modell, Robert C. Reid: Thermodynamics and its Applications. 2nd Ed., Prentice-Hall, London 1983 • Daniel R. Stull, Edgar F. Westrum, Jr. & Gerard C. Sinke: The Thermodynamics of Organic Compounds. John Wiley, New York 1969

<table>
<tr><th colspan="2">Master's Program: Process Engineering M.Sc.</th></tr>
<tr><th colspan="2">Module: Plant Operation</th></tr>
<tr><td>Module number</td><td>13</td></tr>
<tr><td>Module coordination</td><td>Prof. Dr.-Ing. Kai Freudenthal</td></tr>
<tr><td>Duration / semester / frequency</td><td>One semester / summer semester / every other semester</td></tr>
<tr><td>Credit Points (CP) / semester hours per week (SHW)</td><td>5 CP / 4 SHW</td></tr>
<tr><td>Workload</td><td>In-class lecture: 4 SHW x 18 weeks = 72 h
Self-study: 150 h – 72 h = 78 h</td></tr>
<tr><td>Type of module</td><td>Elective module</td></tr>
<tr><td>Module prerequisites
Requirements for participation / previous knowledge</td><td>Recommended:
Project Management
Economics
Basic knowledge of process plant life cycle</td></tr>
<tr><td>Language</td><td>English</td></tr>
<tr><td>Competencies gained / Learning Outcome</td><td>Specialist competency (knowledge and understanding)
Students are able to …:
identify equipment failure modes and causes.
choose adequate maintenance strategies for different processes.
evaluate maintenance costs as well as reliability performance.
characterize plant lifecycle steps and their key deliverables.
evaluate risks and apply risk management to plant design and operation.
apply rules of information management to documentation of process plants.
Self-competency (scientific self-image, professionalism)
Students are able to …:
evaluate different solutions for application of maintenance strategies.
make justified decisions.
take human factors into account.</td></tr>
<tr><td>Content of module</td><td>Course 1: Maintenance
Equipment failures: failure modes, causes and failure analysis
Risk evaluation: severity-probability-matrix
Reliability: key performance indices
Maintenance strategies
reactive maintenance
preventive maintenance
predictive maintenance</td></tr>
</table>

	- reliability-centered maintenance - selection criteria for overall maintenance strategy • Spare part strategies • Inspections and testing • Maintenance costs & benefits • Tasks and responsibilities Course 2: Asset Management • Life cycle of plants • Planning and construction of plants • Operation and maintenance • Asset strategy and Investment strategies • Increase or decrease of production capacity • Risk management • Plant life cycle information management
Applicability of module	• Digital Plant Design • Business Skills
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: written exam (PL) Further possible examination types: home project, oral presentation, oral examination or portfolio examination Where more than one possible examination type is used in the course, the examination type to be used is to made known by the responsible lecturer at the start of the course
Corresponding courses	Course 1: Maintenance Course 2: Asset Management
Type of course and media	Taught seminars, lab work (computer with projector, blackboard, overhead and problem sheets)
Literature	Literature for Course 1: Maintenance • Smith, D.J. (2017). Reliability, Maintainability and Risk: Practical Methods for Engineers, 9th edition, Publisher: Butterworth-Heinemann. • Manna. A. (2013). A Textbook of Reliability and Maintenance Engineering, Publisher: IK International Publishing House Literature for Course 2: Asset Management • Campbell, J.D., Jardine, A.K.S. McGlynn, J. (editors) (2011). Asset Management Excellence: Optimizing Equipment Life-Cycle Decisions, 2nd edition (Mechanical Engineering), Publisher: CRC Press. • Tweeddale, M. (2003). Managing Risk and Reliability of Process Plants, Publisher: Gulf Professional Publishing. • Yang, R. (2009). Process Plant Lifecycle Information Management, Publisher: iUniverse

Master's Program: Process Engineering M.Sc.	
Module: Project Work	
Module number	14
Module coordination	Prof. Dr.-Ing. Martin Geweke
Duration /semester / frequency	One semester / summer or winter semester / every semester
Credit Points (CP) / semester hours per week (SHW)	5 CP / 4 SHW
Workload	150 h, laboratory work, private study
Type of module	Elective module
Module prerequisites **Requirements for participation / previous knowledge**	Recommended: • Appropriate knowledge from previous academic studies • Depending on the field of work
Language	• English, German if agreed by the examiners
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • approach and handle complex problems, tasks and projects in the field of process engineering • understand and apply complex laboratory equipment to solve the project tasks **Methodological competency (use, application and generation of knowledge)** Students are able to …: • autonomously design, develop and implement laboratory experiments/software/hardware. • find and understand appropriate literature, assess and understand complex information and apply it to the project (e.g. literature data bases, specialized publications). • autonomously design, keep records and interpret measurements using appropriate mathematical and scientific methods. • provide and track a project plan. **Social competency (communication and cooperation)** Students are able to …: • autonomously organize project groups, organize meetings and communication among the project participants and identify and solve all problems typical to scientific projects. • get in contact with experts, where necessary, discuss project and test plans with co-workers and project sponsors and defend plans and results against critical objections.

	Self-competency (scientific self-image, professionalism) Students are able to …: • handle projects responsibly, with awareness of cost, risk and safety. • evaluate different solutions. • make justified decisions.
Content of module	• project skills in practice • the scientific matters depend on the projects, which must be supervised/approved by a professor of the Faculty of Life Science • the projects should address scientific research and development level problems from any aspect in the field of process engineering
Applicability of module	Practical work on a scientific level (incl. methods and analysis, research and development, …) will help students in understanding the exact processes of several unit operations and plants. It can be applied in mostly all courses, in particular in: • Project management • Master Thesis
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: project (PL)
Corresponding courses	Project Work
Type of course and media	Typically: experimental laboratory work/hardware and software engineering/literature work/seminar/presentations/project meetings/project documentation/web-based cooperation
Literature	• scientific literature depending on the project

Master's Program: Process Engineering M.Sc.	
Module: Master Thesis	
Module number	15
Module coordination	Prof. Dr.-Ing. Martin Geweke
Duration / semester / frequency	One semester / summer or winter semester / every semester
Credit Points (CP) / semester hours per week (SHW)	30 CP
Workload	900 h, autonomous private study
Type of module	Compulsory module
Module prerequisites **Requirements for participation / previous knowledge**	• The master's thesis may only be commenced when 45 CP have been earned from the first academic year. • Before the official start of the assignment the subject-matter and the supervisors must be approved by the board of examiners of the Department of Process Engineering/Faculty of Life Sciences. • The first examiner must be a professor of the Department of Process Engineering/Faculty of Life Sciences.
Language	• English (exceptions can be made by agreement with the student, the supervisors and on permission of the examination committee, if the institution or company, where the student is doing the master thesis, requires documents in the institution's / company's principal language)
Competencies gained / Learning Outcome	**Specialist competency (knowledge and understanding)** Students are able to …: • analyse and systematize complex scientific tasks in the field of process technology and to define relevant tasks from complex problems with scientific methodical and analytical skills, • define the state of the art of the specific task by using international reports and literature including data bases. **Methodological competency (use, application and generation of knowledge)** Students are able to …: • get familiar with the experimental fundamentals, to develop a reasonable and effective experimental program, to conduct the experiments self-consistently, to analyse the results accurately and systematically and to define further steps in case of experimental focused tasks, • to review the state of the art in a critical manner, to compare the state of the art with the knowledge learned in the program, to correlate this knowledge with analogous scientific fields and to develop scientific conclusions, guidelines and instructions in case of a theoretical focused task, • to solve a given task problem based on efficient working skills and in an given time. **Social competency (communication and cooperation)** Students are able to …:

	• perform the given scientific task self-consistently as a part of the team, to organize a team and to delegate subtasks if necessary, in case of complex tasks, • guide and coordinate a potential team, to moderate and to solve possible conflicts of the team, • identify and define possible interfaces in interdisciplinary projects, • conclude and present the results of scientific work in a presentation and a report. **Self-competency (scientific self-image, professionalism)** Students are able to …: • handle projects responsibly with awareness of cost, risk and safety. • evaluate different solutions. • make justified decisions.
Content of module	• Specific projects related to the scientific work done currently at the Faculty of Life Sciences of the Hamburg University of Applied Science or companies working in the field of process engineering.
Applicability of module	-/-
Requirements for the award of credit points **(Study and exam requirements)**	Regular examination type: Report (Master Thesis) (PL)
Corresponding courses	Master Thesis
Type of course and media	• Discussion between supervising professor and student based on experimental results and progress reports • Possible presentation of preliminary results
Literature	• scientific literature depending on the subject

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