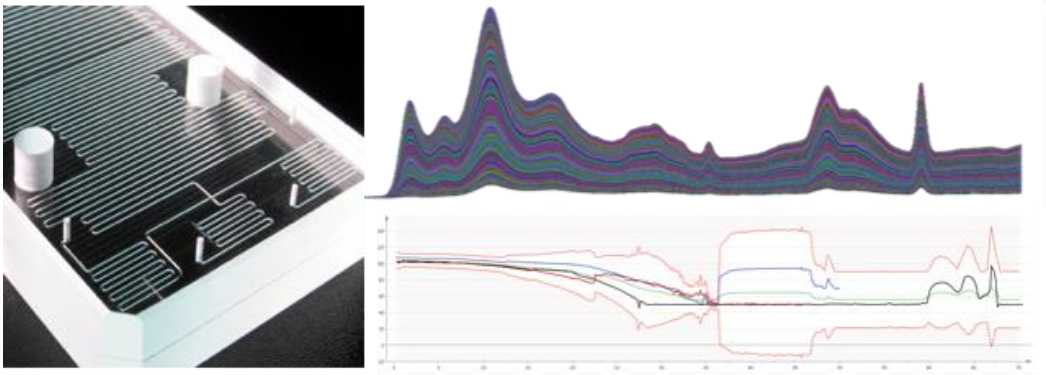
Module Compendium

for the Master's Degree Program

Master of Science

Process Analysis & Technology Management

Valid as of September 2016
School of Applied Chemistry



"Combining reaction and detection in multiphase microfluidic flow is becoming increasingly important for accelerating process development in microreactors. Spectroscopy with microreactors for online process analysis under gas–liquid and liquid–liquid segmented flow conditions is only one excited topic in the study program"

Hochschule Reutlingen
Reutlingen University

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Preliminary Remarks

This module compendium serves the purpose of providing students and instructors a detailed and comprehensive description of the curriculum of the degree program Master of Process Analysis & Technology Management.

The module descriptions present the module goals and intended results of study as well as the contents of the individual courses. Furthermore, all information necessary for academic success is given in the module descriptions. They are also included in the diploma supplement to the master's degree program.

If you have any questions regarding several modules or the course of studies, please contact the office of the Dean of the School of Applied Chemistry.

If you have questions regarding a particular module, please contact the responsible module coordinator which is nominated in the individual course description.

If you have questions regarding a particular course, please contact the instructor.

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Introduction

Objectives of this course of studies

(1) The postgraduate degree program leads to a further qualification of university graduates, who have good chemical and analytical-chemical knowledge as the result of successfully completed undergraduate chemistry-oriented studies.

(2) The aim of the course is to provide students with both a deepening of their methodological knowledge as well as their technical knowledge in the field of analytical chemistry and particularly the process analytics. Thus they are ideally prepared for a professional career or for further education e.g. promotion (Phd). This is achieved through the close link between the teaching of scientific principles on the one hand with a strong project-oriented approach on the other.

(3) In addition to the broader understanding of the industrial importance of chemical analysis, students acquire the practical knowledge and the necessary skills to successfully design and apply process analytical methods. The offered "soft skills" modules aim to the better understanding of the industrial environment. Secondly, they mainly serve to encourage independent, scientific work, competence for problem solving, cooperative activity in a team, scientific communication and the holistic understanding of process analytics.

(4) The independent scientific work of the students shall be achieved through an extended research project in a team, which lasts two semesters. The thesis shall be performed generally in the industry or at research institutes.

(5) On the basis of this course of study, students will learn to perform independent work in the industry and they are equipped with the necessary skills for researchers. The employment area comprises the development and characterization of analytical methods as well as the adaptation and development of those in the process analytical industrial use.

Overview of the course of studies

The curriculum of the master degree program for Process Analysis & Technology Management comprises 3 semesters. The diploma is a professional qualification and enables graduates of Process Analysis & Technology Management with a master's degree in natural science to work in industry or in academia.

Important structural elements of the course of studies are

- one module which deals with management skills in the first semester
- three modules providing the essential scientific skills and methods
- two modules of project-oriented-learning in the first two semesters
- five subject specific modules in the first two semesters
- one elective module, to be absolved within the first two semesters out of a selection of eight other specific modules
- a master's thesis, to be written within 6 months during the third semester.

In the first semester, students will achieve elementary knowledge in the field of process analytics, process control, and in the subject of industrial technology management. Furthermore, they will learn about relevant scientific methods that will be applied in a first part of project-oriented learning.

In the second semester, students will deepen their skills in scientific methods in the fields of statistical and multimodal analysis of big data. In a second part of project-oriented learning, they work in independent teams at Reutlingen University on up-to-date issues of the industry. Higher-level classes in process analytics, bioanalysis and other subjects complete the course of studies.

In the third semester, the individual master's thesis will be written.

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European Credit Transfer and Accumulation System (ECTS)

The Ministry for Science, Research and Art Baden-Württemberg and the Conference of Ministers of Culture require the curriculum of study to be divided into modules. Students‘ performance is recorded by means of the „European Credit Transfer and Accumulation System“ (ECTS). In order to compare the performance of students at various institutions of higher learning — also foreign institutions — the ECT system is based not on the number of course hours per week, but rather on the time that students are required to invest in learning. In this way, student performance can be more objectively compared throughout Europe.

Full-time students can achieve 60 ECTS credit points per academic year. This approximates an average workload of 1800 hours of study. A credit point corresponds to 30 hours workload for a student of average intelligence and aptitude, whereby the workload includes the time during which the student attends class and his/her study time outside of class. Class time is given as weekly number of hours (à 60 minutes) per course (WH).

Example:

WH*	Class attendance	Study time	Workload	Credit points
2	30 h	60 h	90 h	3

WH* = 1 WH equals 15 hours per semester, which normally consists of 15 weeks.

Students can only obtain the ECTS points if the required exams have been successfully and verifiably absolved. Credit points are awarded according to the “all or none” principle.

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Overview of the modules in the course of studies

PAM1 Technology Management

Module No.	Module course	Semester	WH	Credit points
PAM1	Innovation Management / Quality Management / Project Management	1	4	5

PAM2 Scientific Methods 1: Design of Experiments

Module No.	Module course	Semester	WH	Credit points
PAM2	Design of Experiments & Exercises	1	4	5

PAM3 Project Oriented Learning 1

Module No.	Module course	Semester	WH	Credit points
PAM3	Research Seminar	1	2	5
	Team Project	1	4	

PAM4 Process Analytical Technology I

Module No.	Module course	Semester	WH	Credit points
PAM4	Process Spectroscopy and Spectrometry	1	4	5

PAM5 Industry-Related Topics (Regulatory Affairs, IP Management)

Module No.	Module course	Semester	WH	Credit points
PAM5	Regulatory Affairs	1	2	5
	IP Management	1	2	

PAM6 Process Control (Sensors Fundamentals and Applications)

Module No.	Module course	Semester	WH	Credit points
PAM6	Sensors Fundamentals and Applications	1	4	5

PAM7 Scientific Methods 2: Multimodal Data Generation and Analysis

Module No.	Module course	Semester	WH	Credit points
PAM7	Multimodal Data Generation and Analysis	2	4	5

PAM8 Scientific Methods 3: Information Retrieval and Evaluation, Multivariate Data Analysis

Module No.	Module course	Semester	WH	Credit points
PAM8	Information Retrieval and Evaluation	2	2	5
	Multivariate Data Analysis (MVA)	2	2	

PAM9 Project Oriented Learning 2

Module No.	Module course	Semester	WH	Credit points
PAM9	Research Seminar	2	6	5
	Teamproject			

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PAM10 Process Analytical Technology II

Module No.	Module course	Semester	WH	Credit points
PAM10	Sampling and sample preparation	2	2	5
	Measuring and Control Technology	2	2	

PAM11 Bioanalytical Techniques

Module No.	Module course	Semester	WH	Credit points
PAM11	Microscopy and Optics	2	2	5
	In-Process Metabolomics	2	2	

PAM12 Elective Module

Module No.	Module course	Semester	WH	Credit points
PAM12	Elective Subjects	2	2	5

PAM13: Master‘s Thesis

Module No.	Module course	Semester	WH	Credit points
PAM13	Master’s Thesis Project and Defense (internal/external)	3		28
PAM13	Research Seminar for Master’s Thesis	3	2	2

PAM14: Internship semester (Additional Module only for students with 180 ECTS Bachelor's degree)

Module No.	Module course	Semester	WH	Credit points
PAM14	Internship semester	4		30

Catalogue Elective Modules

ACM1: Specialized polymer analytical methods (in German language)

Module No.	Module course	Semester	WH	Credit points
ACM1	Thermische Analyse und Prozesssicherheit / Thermal Analysis and Process Safety	1	2	5
ACM1	Rheologie / Rheology	1	2	

ACM2: Chemical Engineering

Module No.	Module course	Semester	WH	Credit points
ACM2	Process Engineering and Industrial (Bio) Chemistry	1	4	5

ACM7: Polymer Based Materials 2 (in German language)

Module No.	Module course	Semester	WH	Credit points
ACM7	Hybridwerkstoffe / Hybrid Materials	2	2	5
ACM7	Polymere & Flüssigkristalle / Selected Soft Materials	2	2	

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ACM8: Polymer Based Materials 1 (in German language)

Module No.	Module course	Semester	WH	Credit points
ACM8	Advanced Materials / Advanced Materials	2	2	5
ACM8	Konstruktion und Produktdesign / Product Functionality Design	2	2	

BMS1 Analytical Methods in Biomedical Sciences

Module No.	Module course	Semester	WH	Credit points
BMS1	Analytical Methods in Biomedical Sciences	1	2	5
BMS1	Diagnostic Technologies	1	2	

BMS2 Materials and Applications in Biomedical Sciences

Module No.	Module course	Semester	WH	Credit points
BMS2	Functional Implants & Surface Technologies	1	2	5
BMS2	Drug Release and Delivery Systems	1	2	

BMS3 Industry-Related Topics 1 (Drug Discovery & Development / Introduction into medical technology)

Module No.	Module course	Semester	WH	Credit points
BMS3	Drug Discovery & Development	1	2	5
BMS3	Introduction into medical technology	1	2	

BMS7 Biomedical Technologies and Regenerative Medicine

Module No.	Module course	Semester	WH	Credit points
BMS7	Biomedical Technologies and Regenerative Medicine	2	4	5

BMS8 Advanced Pharmacology

Module No.	Module course	Semester	WH	Credit points
BMS8	Biochemical Pharmacology	2	2	5
BMS8	Advanced Bioanalysis	2	2	

PAM15 Module from other schools or universities

Module No.	Module course	Semester	WH	Credit points
PAM15	Modules from other schools or universities with at least 4 SWS and 5 ECTS-credits to be approved by examination commission			5

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Assignment of Marks / Assessment of Quality

Relative ECTS Marks

The international standard foresees that the best 10% of those students who pass receive the mark „A“, regardless of which mark they may receive according to the German marking system. With this system, the performance of students who have passed can be compared more objectively, taking into account that different courses may have different degrees of difficulty.

Student performance	ECTS mark
the best 10%	A = excellent
the next 25%	B = very good
the next 30%	C = good
the next 25%	D = satisfactory
the next 10%	E = sufficient
	F = failing

Since a large number of students are necessary in order to correctly calculate the relative ECTS marks, the conventional German marking system (1-5) shall be used and adapted as shown in the table below (valid as of February 2011).

ECTS mark	**German mark**	**ECTS definition**	**German translation**
A	1,0 – 1,3	excellent	hervorragend
B	1,4 – 2,0	very good	sehr gut
C	2,1 – 2,7	good	gut
D	2,8 – 3,5	satisfactory	befriedigend
E	3,6 – 4,0	sufficient	ausreichend
FX/F	4,1 – 5,0	failing	nicht bestanden

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Remarks Concerning the Description of Modules

The module descriptions are meant to offer students information regarding the course of studies, curriculum content, qualitative and quantitative requirements, the relationship of the individual modules to other modules and integration of the module into the general concept of the course of studies. The module descriptions are listed in tabular form.

The following remarks will help the reader to understand the terms used in the module descriptions.

Module description / abbreviation:
A module name and abbreviation have been assigned to every module. The module name provides information about the content of the module. The corresponding abbreviation begins with the first letter of the name of the degree program. It ends with a number of a sequence of numbers. Thus, the abbreviation PAM1 stands for the first module in Process Analysis & Technology Management.

Courses:

The courses included in a module are listed separately.

Semester:

The semester in which a module is offered is indicated.

Person responsible for the module:

This person is responsible for the editing of the module.

Instructor:

Instructors are responsible for the content and organization of their courses and/or those courses which are held by an associate instructor.

Language:

The language in which the course is taught is indicated.

Integration with other courses of study:

In the event that a module is also offered in other courses of study, this shall be indicated.

Type of instruction/WH:

The type of instruction as well as the weekly hours of instruction are indicated in tabular form. The abbreviations stand for:
Lecture (L)
Exercise (E)
Lab work (LW)
Seminar (S)

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Workload and credit points:
The workload consists of class attendance and study outside of class. The hours of class attendance are calculated by multiplying the WH (à 60 minutes) x 15, which is the normal number of weeks per semester, excluding the exam week.
The calculation of the time needed for study outside of class presupposes that students will require the time represented by the credit points. Each credit point represents 30 hours workload. The total workload is the sum of the workload resulting from class attendance and the workload resulting from study outside of class.

Requirements according to the examination regulations:
Students must have already completed the listed modules in order to participate in the respective module.

Recommended prerequisites:
Course instructors indicate the knowledge and proficiency that students should have in order to participate in and understand the subject matter of a course.

Goals of the module / desired outcome:
The goals of the module define the academic, technical and, if applicable, professional qualifications that should be achieved with this module. The desired outcome describes which knowledge, skills and competences are to be acquired through study.

Content:
The precise content of the course is described (operative level), with which the desired outcome is to be achieved.

Study and exam requirements:
The type of exam and its duration are indicated.

Media used:
The media (overhead projector, digital projector, flip chart, video, etc.) used in the course are indicated; furthermore, which documents are to be made available to the students when and in which form.

Literature:
A list of literature and, if applicable, information regarding multimedia-supported literature is provided. The literature list includes texts that will prepare students for the upcoming seminar as well as texts to accompany the course work during the semester.

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Module Description

PAM1 – Technology Management

Course of studies	Biomedical Sciences, Process Analysis & Technology Management					
Module	Technology Management					
Abbreviation	PAM01					
Course(s)	• Quality Management • Innovation Management • Project management					
Semester	1					
Person responsible for the module	Prof. Dr. Alexander Schuhmacher					
Instructor	Dr. Held, Dr. Alexander Schulz Prof. Dr. Alexander Schuhmacher					
Language	English					
Status within the curriculum	Mandatory					
Type of course / WH	Course	L	E	LW	S	
	Innovation and Project Management	2				
	Quality Management	2				
Workload in hours	Course	Class attendance		Study outside of class	Total	CP
	Innovation and Project Management	30		45	75	
	Quality Management	30		45	75	
	Total	**60**		**90**	**150**	**5**
Credit points	5					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work	Basic understanding of good laboratory practice and project management principles, no further special prerequisites					

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Module goals / desired outcome	Innovation & project management: • Understanding of innovation strategies and processes. • Understanding of the significance of the context of innovation strategy for the daily business of researchers in an R&D organization. • Learn how a portfolio of projects is managed efficiently and effectively. • Understand the principles of project life-cycle-management. Quality Management: • Understanding the concepts of quality management • Understanding the responsibilities and tasks of QM in daily business
Content	Innovation Management • Economic relevance of innovation • Innovation strategies • Innovation processes • Open innovation • Portfolio management • Product life-cycle-management Quality Management • Basic systems of quality management • QM Tools & procedure • Normative systems and standards • Examples from industry
Study and exam requirements	Written examination (2h)
Media used	Lecture, group work, interactive discussions, board, digital projector, handouts
Literature	Gassmann O. et al. (2004) Leading Pharmaceutical Innovation. Springer Verlag Schein EH (1997) Organizational Culture and Leadership. Jossey-Bass Publishers S. Nokes and S. Kelly. Guide to Project Management. FT Press (2003) L. Brwon and T. Grundy (2011) Project Management for the Pharmaceutical Indsutry. Gower Publishing Company R.D. Austin (2004) Managing projects large and small. Havard Business Essentials PMI (2008) The Standard for Portfolio Management. 2nd edition. Project Management Institute

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	A. Schuhmacher, M. Hinder, O. Gassmann (2015) Value Creation in the Pharmaceutical Industry: The Critical Path Towards Innovation, Wiley International

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PAM2 **–** Scientific Methods 1: Design of Experiments

Course of studies	Process Analysis and Technology Management (MSc)						
Module	Scientific Methods 1 : Design of Experiment (DoE)						
Abbreviation	PAM02 (identical with Module ACM05 in Master study programme Applied Chemistry)						
Course(s)	• Design of Experiment, lecture classes • Design of Experiment, class exercises						
Semester	1						
Person responsible for the module	Prof. Dr.-Ing. habil. Andreas Kandelbauer						
Instructor	Prof. Dr. Andreas Kandelbauer Prof. Dr. Ralph Lehnert						
Language	English						
Status within the curriculum	Mandatory						
Type of course / WH	Course	L	E	LW	S		
	Design of Experiment	2	2				
Workload in hours	Course	Class attendance		Study outside of class	Total	CP	
	Design of Experiment	60		90	150	5	
	Total	**60**		**90**	**150**	**5**	
Credit points	5						
Prerequisites for attending this course	See examination regulations (Studien- und Prüfungsordnung)						
Recommended knowledge / course work	Knowledge of statistics and chemometrics						

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Module goals / desired outcome	General knowledge Successful students will obtain • Profound overview of basic approaches and standard methods of current DoE • Profound understanding of applicability and limitations of statistical experimental designs • Hands-on experience using software packages for planning, evaluating, and visualizing experiments • Ability to plan experiments using scientifically sound approaches and conduct statistically correct analyses Skills: • Ability to use commercial software • Ability to select, use and understand mathematical operations for data analysis (inferring statistics, response surface methodology, regression analysis etc.) • Ability to transform scientific or technical problem in a form suitable for statistical analysis (selection of appropriate factors and response quantities) • Ability to understand, evaluate, summarize, and visualize complex statistical results and to identify experimental key factors • Ability to exploit optimization potential of chemical and technical processes using DoE Social competences: • Ability to work in a self-organized manner and as a member of a team • Ability to do work target-oriented and systematically

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Content	**Design of Experiment** The course consists of a lecture and accompanying class exercises. Class examples will, to a large extent, be chosen from lecture contents. • Experimental domain, factor analysis, response surface analysis, orthogonality, general strategies in DoE • Screening- and optimization designs • Setting-up of experimental designs • Visualization and analysis of data from experimental designs • Handling of commercial software packages
Study and exam requirements	Written exam (2h), term paper (solving exercise sheet and submitting solutions which will be marked)
Media used	Lecture, script as download, board, projector, handouts
Literature	1. Box EP, Hunter JS, Hunter WG, Statistics for Experimenters. Design, Innovation, and Discovery, 2nd edition, Wiley, 2005 2. Myers RH, Montgomery DC, Response Surface Methodology. Process and Product Optimization Using Designed Experiments, Wiley, 2002 3. Cornell J, Experiments with Mixtures. Designs, Models, and the Analysis of Mixture Data, Wiley, 2002 4. Federer WT, King F, Variations on Split Plot and Split Block Experimental Designs, Wiley, 2007 5. Good PI, Hardin JW, Common Errors in Statistics (and how to avoid them), 2nd edition, Wiley, 2006

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PAM3 – Project Oriented Learning 1

Course of studies	Process Analysis and Technology Management (MSc)					
Module	Project Oriented Learning 1					
Abbreviation	**PAM03** (identical with Module ACM06 in Master study programme Applied Chemistry)					
Course(s)	Research Seminar Team Project					
Semester	1					
Person responsible for the module	Prof. Dr. Kandelbauer					
Instructor	Prof. Dr. Kandelbauer, Prof. Dr. Rebner, Prof. Dr. Lehnert, Prof. Dr. Lorenz, Prof. Dr. Baumbach, Prof. Dr. Brecht, Dr. Ostertag, Prof. Dr. Carl-Martin Bell.					
Language	German, English					
Status within the curriculum	Mandatory in ACM, PATM					
Type of course / WH	Course	L	E	LW	S	
	Research Seminar				2	
	Team Project			4		
Workload in hours	Course	Class attendance		Study outside of class	Total	CP
	Research Seminar	25		25	50	
	Team Project			100	100	
	Total	**25**		**125**	**150**	**5**
Credit points	5					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work	Physics, chemistry, mathematics					

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Module goals / desired outcome	Objective is the education of the students in setting-up, planning and disseminating a research project proposal based on a sound state of the art for a specified research question. POL-1 is the introductory phase for POL-2 (PAM 09) Professional scientific methodological approach: Knowledge • Knowledge on defining a research project: how to structure complex scientific questions and break them down into single steps • Knowledge about and application of tools for practical project planning (Gantt-diagrams, decision gates, milestones, deliverables, etc.) • Knowledge about how to extract information from databases with regard to a specific research question • In-depth knowledge about a specific topic depending on the specified research question Skills • Effective use of technical and scientific data bases • Formulating state of the art • Formulating scientific hypotheses • Understanding scientific methodology • Practical planning of experiments (including logistic and organizational aspects) Technical competences • Selecting appropriate scientific methodology depending on the specific research question • Responsibility regarding research planning • Assimiliation of novel research questions, adaptation to / orientation in a new field • Formulation and writing of a state of the art focused on a very specific research question Social competence • Ability to think conceptually • Working in project teams • Coordinating a project / work organisation • Development and strengthening of team and communication skills
Content	The students will work in teams of 3 to 4 people on a defined research question. The research question is defined by the supervisor at the faculty and will be in accordance with current research activities at the department. The students will prepare a scientific and technological state of the art on this research question and based on this they will define a project plan addressing all relevant issues of a real research project (time schedule, resource plan, objectives, means to arrive at

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	the objectives, required methods, hypotheses, etc.). This project plan will be disseminated as a formal project application with a special focus on a comprehensive state of the art. No single-person projects are admissible and all projects are hosted by the faculty exclusively. The actual research project plan set up by the students will then be realized in POL-2 in the subsequent semester. Preparatory activities such as training / instruction regarding specific methods, organisation of infrastructure / chemicals or even preliminary / orienting experiments that are required for competent formulation of a research proposal or smooth performance of the practical phase (POL-2) in the subsequent semester are possible within the module POL-1 but although recommended are not obligatory.
Study and exam requirements	Written seminar paper (= state of the art), oral presentation of project plan during semester
Media used	Lecture, board, digital projector, handouts
Literature	Chalmers AF (2007) Wege der Wissenschaft. Einführung in die Wissenschaftstheorie, 6. Auflage, Nachdruck, Springer Patzak G, Rattay G (2004) Projektmanagement, 4. Auflage, Linde International Baguley P (1999) Optimales Projektmanagement, Falken Scientific Original papers, depending on the specific research question H.F. Ebel et al. (2006) Schreiben und Publizieren in den Naturwissenschaften, Wiley-VCH Weinheim.

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Course of studies	Process Analysis and Technology Management (MSc)						
Module	Process Analytical Technology I						
Abbreviation	**PAM04**						
Course(s)	• **Process Spectroscopy and Spectrometry**						
Semester	1						
Person responsible for the module	Prof. Dr. Karsten Rebner						
Instructor	Prof. Dr. Karsten Rebner						
Language	English						
Status within the curriculum	Mandatory						
Type of course / WH	Course	L	E	LW	S		
	Process Spectroscopy and Spectrometry	4					
Workload in hours	Course	Class attendance		Study outside of class	Total	CP	
	Process Spectroscopy and Spectrometry	30		45	75		
	Optofluidics System Technologies	30		45	75		
	Total	**60**		**90**	**150**	**5**	
Credit points	5						
Prerequisites for attending this course	See examination regulations (Studien- und Prüfungsordnung)						
Recommended knowledge / course work	Knowledge of instrumental analysis						

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Module goals / desired outcome	The lecture explores the concepts of Process Analytical Technology and its application in the process industry especially chemical and pharmaceutical industry from the point of view of the analytical chemist. **General knowledge:** Successful students will obtain • knowledge to implement process analyzers for monitoring and control of productions plants. • an overview of apply process analyzers in combination with microfluidic systems for medical and biomedical sensing and manipulation. **Skills:** Successful students will be able • to build upon and extend the theoretical and instrumental concepts of process analyzers • to develop the competence and confidence applying process spectroscopy for different industry branches. • assessing analyzer benefits and the trade-off between initial capital costs and ongoing cost-of ownership **Social competences:** • Ability to work in a self-organized manner and as a member of a team • Ability to do work target-oriented and systematically
Content	• Understanding Processes and How to Improve Them • Implementation of Process Analytical Technologies • UV-Visible Spectroscopy for On-line Analysis • Infrared Spectroscopy for Process Analytical Applications • Process Raman Spectroscopy • Process Mass Spectrometry • Optofluidics System Technology
Study and exam requirements	Written exam (2h), term paper (solving exercise sheet and submitting solutions which will be marked)
Media used	Lecture, board, overheads, lecture notes, handouts, exercise sheets

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Literature	1. Kessler RW (Ed.): Prozessanalytik Strategien und Fallbeispiele aus der industriellen Praxis, Wiley-VCH, 2006 2. Bakeev: Process Analytical Technology: Spectroscopic Tools and Implementation Strategies for the Chemical and Pharmaceutical Industries, Wily-VCH, 2010. 3. Rabus: Optofludics System Technology, De Gruyter, 2014 4. Undey, Low, Menezes, Koch: PAT Applied in Biopharmaceutical Process Development and Manufacturing, CRC Press 2012

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PAM5 – Industry_Related Topics (Regulatory Affairs, IP Management)

Course of studies	Biomedical Sciences (MSc)					
Module	**Industry-Related Topics**					
Abbreviation	PAM5					
Course(s)	• Regulatory Affairs • IP Management					
Semester	1					
Person responsible for the module	Prof. Dr. Alexander Schuhmacher					
Instructor	Herr Xiong Prof. Dr. Alexander Schuhmacher					
Language	English					
Status within the curriculum	Mandatory					
Type of course / WH	Course	L	E			
	Regulatory Affairs	2				
	IP Management	2				
Workload in hours	Course	Class attendance		Study outside of class	Total	CP
	Regulatory Affairs	30		45	75	
	IP Management	30		45	75	
	Sum	**60**		**90**	**150**	**5**
Credit points	5					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work	No specific knowledge required					

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Module goals / desired outcome	The primary goal is to understanding the strategic and operational relevance of regulatory affairs and intellectual property (IP) rights for high-tech industries, such as the pharmaceutical, biotechnology and medical device industries. More specifically, it is the understanding of formalities in the development and manufacturing of medical devices and pharmaceutical products – with a focus of the respective national and international registration and authorization rules. In Intellectual Property (IP) Management, students will gain knowledge of the international and European patent laws, patentability requirements, how to file a patent application and the writing of patent claims.
Content:	Regulatory affairs • FDA • EMEA • ICH IP Management • European Patent Convention and Patent Cooperation Treaty • Filing a patent application • Searching for patents • Patentability analysis • Writing patent claims
Study and exam requirements	Written examination (2 hours)
Media used	Lecture, group work, interactive discussions, handouts, flip charts
Literature	• The European Patent Convention (http://documents.epo.org/projects/babylon/eponet.nsf/0/00E0CD7FD461C0D5C1257C060050C376/$File/EPC_15th_edition_2013_de_bookmarks.pdf) • National and international guidelines as accessible via FDA and EMEA

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PAM6 – Process Control (Sensors Fundamentals and Application)

Course of studies	Process Analysis and Technology Management (MSc)						
Module	Process Control (Sensor Fundamentals and Applications)						
Abbreviation	**PAM06**						
Course(s)	• Sensor Fundamentals and Applications						
Semester	1						
Person responsible for the module	Prof. Dr. Ralph Lehnert						
Instructor	Prof. Dr. Ralph Lehnert						
Language	English						
Status within the curriculum	Mandatory						
Type of course / WH	Course	L	E	LW	S		
	Design of Experiment	2	1	1			
Workload in hours	Course	Class attendance		Study outside of class	Total	CP	
	Sensor Fundamentals and Applications	45		105	150	5	
	Total	**45**		**105**	**150**	**5**	
Credit points	5						
Prerequisites for attending this course	See examination regulations (Studien- und Prüfungsordnung)						
Recommended knowledge / course work	Knowledge of physics, physical chemistry, instrumental analytics						

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Module goals / desired outcome	General knowledge: Successful students will obtain • overview of basic electrical and optical measuring methods as well as signal processing approaches • understanding of functional principles, designs and performance factors of physical and bio/chemical sensors • hands-on experience in using sensors in practical situations Skills: Successful students will be able • to analyse and solve a concrete measuring task • to interpret sensor data sheets • to select, put into operation, implement and operate commercial sensors and sensor systems in laboratory and production contexts • to design and build simple customized sensors • to perform adequate basic post-acquisition signal processing and data evaluation Social competences: • Ability to work in a self-organized manner and as a member of a team • Ability to do work target-oriented and systematically
Content	The course consists of a lecture and accompanying class exercises as well as practicals, all treating: • Basic concepts of sensor technology, actor technology, signal processing and evaluation • Working principles, designs and components of physical, chemical and biochemical sensors • Application of such sensors to specific measuring tasks
Study and exam requirements	Written exam (2h), term paper (solving exercise sheet and submitting solutions which will be marked)
Media used	Lecture, board, overheads, lecture notes, handouts, exercise sheets

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Literature	1. Gründler, P. : Chemical Sensors, Springer, 2007 2. Hauptmann, P.: Sensors: Principles and Applications, Prentice-Hall, 1993 3. Eggins, B. R. : Chemical Sensors and Biosensors, John Wiley & Sons, 2004 4. Niebuhr, J., Lindner G.:Physikalische Messtechnik mit Sensoren, Oldenbourg Verlag, München, 2011 5. Freudenberger, A. : Prozessmesstechnik, Vogel Verlag, Würzburg, 2000.

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PAM7 – Scientific Methods 2: Multimodal Data Generation and Analysis

Course of studies	Process Analysis and Technology-Management (MSc)					
Module	Scientific Methods 2: Multimodal Data Generation and Analysis (MDGSA)					
Abbreviation	**PAM07** (identical with Module ACM10 in Master study programme Applied Chemistry)					
Course(s)	Multimodal Data Generation and Analysis I Multimodal Data Generation and Analysis II					
Semester	2					
Person responsible for the module	Prof. Dr. Jörg Ingo Baumbach					
Instructor	Prof. Dr. Jörg Ingo Baumbach Prof. Dr. Karsten Rebner					
Language	English					
Status within the curriculum	Mandatory					
Type of course / WH	Course	L	E	LW	S	
	Multimodal Data Generation and Analysis I	2				
	Multimodal Data Generation and Analysis II	2				
Workload in hours	Course	Class attendance	Study outside of class	Total	CP	
	Multimodal Data Generation and Analysis I	30	45	75		
	Multimodal Data Generation and Analysis II	30	45	75		
	Total	60	90	150	5	
Credit points	5					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work	Basic data handling procedures, data base structures					
Module goals / desired outcome	A large number of single and especially the combination of analytical methods find the way from laboratory applications into the environment outside to monitor different e.g. industrial					

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	processes. Besides temperature, pressure, flow, density and filling level specific data arising from sensors, spectrometers and spectroscops. Furthermore, in the field of medical diagnostics the data and more general the information of different methods including different time constants lime GC/MS and MCC/IMS are combined. Sometimes, off-line and on-line data, bed-site and laboratory data – multimodal data are to be considered in process and medical monitoring processes. The students know and could calculate the sensitivity, the specificity, the accuracy, the uncertainty with respect to the question: how to make a decision. Errors should be considered and included into decision strategies. In contrast to multivariate methods investigating many variables of one method strategies to use combined methods were established, including multi-bloc methods, parallel factor analysis. Examples from real situations in different process and medical applications of sensors and spectrometers are considered in detail. **General knowledge:** Successful students will obtain • knowledge and methods to combine different methods directly. • Know how to of combining different measuring methods and how information could be generated with respect on process, bed-site or early recognition of different diseases. **Skills:** Successful students will be able • to describe the multimodal and big data landscape including examples of process analytical technology problems and approaches • identify the high level components in the data science lifecycles and associated data flow • to explain multimodal effects and why each impacts the collection, monitoring, storage, analysis and reporting • identify big data problems and be able to recast problems as data science questions. **Social competences:** • Ability to work in a self-organized manner and as a member of a team • Ability to do work target-oriented and systematically

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Content	• Data Pre-Processing • Three-Way Component and Regression Models • PARAFAC: Parallel factor analysis • Multivariate analysis of multiblock and multigroup data • Data handling, big data and smart data • Data analysis and process monitoring/control • Supervised and unsupervised learning methods • Applications I: Exploratory analysis in chromatography, spectroscopy and designed data • Applications II: Exploratory analysis in chromatography, mass spectrometry, coupled methods like GC/MS, ion mobility spectrometry, coupled methods like MCC/IMS • NIST database, NIST chembook • Mathlab, Mathematica
Study and exam requirements	Written examination (2h), presentation / assignments
Media used	PowerPoint slides, flip charts, board, lecture videos, software Matlab PLS Toolbox,
Literature	Scientific publications

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PAM8 – Scientific Methods 3: Information Retrieval and Evaluation
Multivariate Data Analysis

Course of studies	Process Analysis and Technology Management (MSc)						
Module	**Scientific Methods 3: Information Retrieval and Evaluation and Multivariate Data Analysis**						
Abbreviation	**PAM08** (Identical with module ACM11 in Master study programme Applied Chemistry)						
Course(s)	• **Information Retrieval and Evaluation** • **Multivariate Data Analysis (MVA)**						
Semester	2						
Person responsible for the module	Prof. Dr. Karsten Rebner						
Instructor	Prof. Dr. Ralph Lehnert (Information retrieval) Prof. Dr. Karsten Rebner (Multivariate data analysis)						
Language	English						
Status within the curriculum	Mandatory						
Type of course / WH	Course	L	E	LW	S		
	Information Retrieval and Evaluation	2					
	Multivariate Data Analysis	2					
Workload in hours	Course	Class attendance			Study outside of class	Total	CP
	Information Retrieval and Evaluation	30			45	75	
	Multivariate Data Analysis	30			45	75	
	Total	**60**			**90**	**150**	**5**
Credit points	5						
Prerequisites for attending this course	See examination regulations (Studien- und Prüfungsordnung)						
Recommended knowledge / course work							

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Module goals / desired outcome	General knowledge: Successful students will obtain • overview of how to use relevant literature data bases with respect to scientific publications, patents, reviews, and monographs • understanding of how search engines and citation management programs function and can be used • understanding of standard methods in the field of multivariate data analysis Skills: Successful students will be able • to conduct systematic and efficient scientific literature searches (source identification and exploitation) • to efficiently evaluate and document relevant publications and text/content therein • to cite literature correctly according to respective scientific standards and to save citations using citation managers • to apply and operate commercial multivariate data analysis software packages • to conduct complete multivariate analyses of complex data sets Social competences: • Ability to work in a self-organized manner and as a member of a team • Ability to do work target-oriented and systematically
Content	Information Retrieval and Evaluation • Reference data bases, search engines, citation managers • Literature search examples/exercises based on concrete scientific questions Multivariate Data Analysis (MVA) • Data reduction and information extraction from complex data sets • Basic methods of MVA such as classification and regression, principal componenents analysis (PCA), partial least squares regression (PLS) and cluster analysis
Study and exam requirements	Written exam (2h), presentation
Media used	Lecture, board, overheads, lecture notes, handouts, exercise sheets, software practicals in CIP-pool

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Literature	1. Kessler, W.: Multivariate Datenanalyse für die Pharma-, Bio- und Prozessanalytik, Wiley-VCH, 2007 2. Esbensen, Kim H.: Multivariate Data Analysis – in Practis, CAMO Press AS, 2002 3. Beebe, K., Pell, R., Seasholtz, M.: Chemometrics - A Practical Guide, John Wiley & Sons, 1998 4. Brereton, R. : Chemometrics, Data Analysis for the Laboratory and Chemical Plant, John Wiley & Sons, 2003

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PAM9 – Project Oriented Learning 2

Course of studies	**Process Analysis & Technology Management (MSc)**					
Module	Project Oriented Learning 2					
Abbreviation	**PAM09** (identical with Module ACM12 in Master study programme Applied Chemistry)					
Course(s)	Research Seminar Team Project					
Semester	2					
Person responsible for the module	Prof. Dr. Kandelbauer					
Instructor	Prof. Dr. Kandelbauer, Prof. Dr. Rebner, Prof. Dr. Lehnert, Prof. Dr. Lorenz, Prof. Dr. Baumbach, Prof. Dr. Brecht, Dr. Ostertag, Prof. Dr. Carl-Martin Bell.					
Language	German, English					
Status within the curriculum	Mandatory in ACM, PATM					
Type of course / WH	Course	L	E	LW	S	
	Research Seminar				2	
	Team Project			4		
Workload in hours	Course	Class attendance		Study outside of class	Total	CP
	Research Seminar	25		25	50	
	Team Project			100	100	
	Total	**25**		**125**	**150**	**5**
Credit points	5					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work	Physics, chemistry, mathematics					

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Module goals / desired outcome	Objective is the education of the students in setting-up, planning and performing a project aiming at the solution of a speficic research question. POL-2 is a continuation of POL-1 (PAM-03) Professional scientific methodological approach: Knowledge • Knowledge on defining, performing and controlling a research project. • Knowledge about and application of tools for practical project management (action items, meeting organisation, work documentation, efficient use of resources, coordination, etc.) • Knowledge on specific scientific and technological methods as well as materials depending on the specific actual research question Skills • Effective use of technical and scientific data bases • Formulating project reports, final project report • Formulating scientific hypotheses • Understanding scientific methodolgy • Planning and performing experiments • Adapting to and applying scientific equipment • Performing accurate measurements • Discussing competently experimental results in the light of the state of the art and comparing own findings to the scientific literature Technical competences • Selecting and applying appropriate scientific methodology depending on the specific research question • Responsibility regarding research planning • Assimiliation of novel research questions, adaptation to / orientation in a new field • Formulating and writing a project report (state of the art) • Discussion of experimental results • Proper presentation and scientifically sound defense of own findings in front of a panel of experts (=councel of supervisors) Social competence • Ability to think conceptually • Working in / managing a project team • Coordinating a project / work organisation • Development and strengthening of team and communication skills

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Content	The students will work in teams of 3 to 4 people on a defined research question for which in POL-1 (ACM06) they have prepared a proper state of the art and research plan. The research question is defined by the supervisor at the faculty and will be in accordance with current research activities at the department. The students will perform the necessary scientific and technological experiments based on the state of the art on this research question and their research proposal. The students organize their project by themselves and are guided by the supervising professor. The project results will be disseminated as a formal final project report. The results will also be presented at a final oral defense in front of a panel of all supervising professors and a poster presentation will be prepared.
Study and exam requirements	Written seminar paper (= final project report), oral presentation of project status during semester (status meetings), final project defense, poster presentation
Media used	Lecture, board, digital projector, handouts
Literature	Chalmers AF (2007) Wege der Wissenschaft. Einführung in die Wissenschaftstheorie, 6. Auflage, Nachdruck, Springer Patzak G, Rattay G (2004) Projektmanagement, 4. Auflage, Linde International Baguley P (1999) Optimales Projektmanagement, Falken Scientific Original papers, depending on the specific research question H.F. Ebel et al. (2006) Schreiben und Publizieren in den Naturwissenschaften, Wiley-VCH Weinheim.

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PAM10 – Process Analytical Technology II

Course of studies	Process Analysis and Technology-Management (MSc)					
Module	Process Analytical Technology II					
Abbreviation	PAM10					
Course(s)	Sampling and sample preparation SSP Measuring and Control Technology MCT					
Semester	2					
Person responsible for the module	Prof. Dr. Karsten Rebner					
Instructor	Prof. Dr. Karsten Rebner Prof. Dr. Jörg Ingo Baumbach					
Language	English					
Status within the curriculum	Mandatory					
Type of course / WH	Course	L	E	LW	S	
	Sampling and sample preparation	2				
	Measuring and Control Technology	2				
Workload in hours	Course	Class attendance		Study outside of class	Total	CP
	Sampling and sample preparation	30		45	75	
	Measuring and Control Technology	30		45	75	
	Total	60		90	150	5
Credit points	5					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work	basic knowledge of measurement of physical and chemical analytical methods					

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Module goals / desired outcome	**General knowledge:** Successful students will obtain • a general introduction to industrial sampling systems • state of the art extract techniques for organic and inorganic analytes • Sampling preparation in biological measurements • knowledge about the wide range of rather simple sensors as used to measure temperature, pressure, humidity, acceleration and density • overview about online process analytical methods with chemical backround like FTIR, NIR, MIR, MS, GC/MS, MCC/IMS, LC/MS **Skills** Successful students will be able • outlining the reasons why sampling is often unreliable and some ways to improve them • calculating of time delay effects in each segment of the sample transport system. • evaluating existing or proposed locations for the sampling nozzle and making a decision. • to develop strategies to make samples compatible to the analyzers they serve • to interpret sensor, spectrometric and spectroscopic data with respect to remote process control • to compare laboratory and process analytical methods and results of applications in the field and in the lab • to compare on-line, in-line, at-line and off-line methods including sampling strategies and control technologies • to bring sampling strategies and measurement and control techniques together within industrial and non-industrial monitoring systems
Content	**Sampling and sample preparation** • Core Principles of Sample System Design • Evalulation and Design of Sample Transport Lines • Location and Design of Process Sampling Taps • Preconditioning the Process Sample • Sample Conditioning and Disposal • Sample Isolation and Switching Systems **Measuring and Control Technology** • Sensors: temperature, pressure, humidity, density, refraction index • Chemical sensors • Process-Spectrometers: GC, LC, MS, IMS, NMR, … • Process-Spectroscopy: FTIR, NIR, MIR, Raman, …

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	• Differences laboratory and process analysis • Measuring and control technology as part of the quality management system • Measurement and control technology and process engineering • Interpretation of analytical data sets and remote sensing
Study and exam requirements	Written examination (2h), presentation / assignments
Media used	PowerPoint slides, flip charts, board, software practicals in CIP-Pool
Literature	1. Tony Waters, Industrial Sampling Systems, 2014, Swagelok 2. Cazes, Analytical Instrumentation Handbook, CRC Press, 2012 3. John Kenkel, Analytical Technics for Technicians, CRC Press, 2003 4. Michael E. Schwartz, Analytical techniques in combinatorial chemistry, Marcel Dekker, 2000 5. Jack Cazes, Analytical Instrumentation Handbook, Marcel Dekker, 2005 6. Paul, C.H. Li: Fundamentals of Microfluidics and Lab on a Chip for biological analysis and discovery, CRC Press, 2010 7. Michael E. Swartz, Ira S. Krull: Analytical Validation, CRC Press 2012 8. Donald A. Burns, Emil W. Ciurczak: Handbook of Near-Infrared Analysis – CRC Press, 2008 9. David M. Scott, Industrial Process Sensors, CRC Press, 2008 10. Krzysztof Iniewski, Smart sensors for industrial applications, CRC Press 2013 11. Hassan Y. Aboul-Enein et al. Quality and Reliability in Analytical Chemistry, CRC Press 2001 12. Kessler, R. Prozessanalytik, Strategien und Fallbeispiele aus der industriellen Praxis, Wiley, 2006 13. Scientific publications

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PAM11 – Bioanalytical Techniques (BT)

Course of studies	Process Analysis and Technology-Management (MSc)					
Module	Bioanalytical Techniques (BT)					
Abbreviation	PAM 11					
Course(s)	Microscopy and Optics In-Process Metabolomics IPM					
Semester	2					
Person responsible for the module	Prof. Dr. Jörg Ingo Baumbach					
Instructor	Prof. Dr. Marc Brecht Prof. Dr. Jörg Ingo Baumbach					
Language	English					
Status within the curriculum	Mandatory					
Type of course / WH	Course	L	E	LW	S	
	Microscopy and Optics	2				
	In-Process Metabolomics	2				
Workload in hours	Course	Class attendance	Study outside of class	Total	CP	
	Microscopy and Optics	30	45	75		
	In-Process Metabolomics	30	45	75		
	Total	60	90	150	5	
Credit points	5					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work	Knowledge of biochemistry, bioanalytics, instrumental analytics, chemistry, material science, fundamental knowledge of optics, sensors and spectrometers, biology					

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Module goals / desired outcome	General knowledge Successful students will obtain • Profound overview of current in-process metabolomics including different bioanalytical techniques that are significant in clinical, biomedical and pharmaceutical research and practice • Profound understanding of advantages and disadvantages of different methods in metabolics, especially for clinical and diagnostic applications • Profound understanding of technologies and functioning of laboratory investigations, diagnostics and applications Skills: • Understanding of complex relationships in bioanalytics • Understanding of the aspects of material science that are relevant for R&D in biotechnology, pharmaceutical and diagnostics industries • Understanding of principles of interaction of biological systems and molecules with different materials including nutrition effects • Understanding of principles of structure of sensoric, spe trometric and diagnostic systems and pre-requisites for certain applications in life science, medical applications and fermentation processes • Ability to name limitations of existing analytical technologies • Ability to evaluate various methods of laboratory diagnostics • Ability to read and understand scientific publications Social competences: • Students develop skills in research, reading and interpretation of scientific texts • Students gain an awareness of process aspects in the development of control of metabolomics processes.

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Content	Optical technologies are a cornerstone of all analytical technologies. The lecture starts with a short repetition of geometric optics. We will discuss wave optics in free space and waveguides, followed by the basic function of lasers including modes in optical resonators and Fourier transformations in the description of optical setups. Then we will consider aberrations of optical elements, lens design and technical optics. In the second part we will focus on microscopy, we will discuss the resolution of a conventional microscope as well as methods of resolution improvement like structured illumination, 4Pi, STED, STROM and FLIM microscopy and single-molecule sensitive detection. In all parts examples for applications will be give. Mostly, processes in biology and more general in life sciences are related to exchange of material and energy - all are highly parallel running. In general, analytical technologies and strategies including data analysis are mostly well understood. In contrast, on the other hand metabolic processes are not well described, including Genomics and Proteomics. Especially, regulatory processes need still further investigation. Therefore, the lectures will consider metabolomic processes the influence of different materials and pharmaceuticals. Here, metabolom stands for all characteristic metabolic processes within a cell, a tissue, an organ or an organism. Therefore, effects of flow rates, metabolite levels, activities of enzymes and interactions between different metabolic pathways and interactions of different compartments are considered and discussed in detail. Especially, metabolic processes, interactions and relations between cells and the identification and quantification of metabolites are discussed. Basis analytical methods like GC/MS, LC/MS, NMR und Ion-Mobility-Spectrometry (IMS) are included, relation between Genomics, Proteomics and Metabolomics exemplarely explained and conclusions with respect to regulatory processes at medical and biological processes including fermentation and human health characterization.
Study and exam requirements	Written examination (2h), presentation / assignments
Media used	PowerPoint slides, flip charts, board
Literature	Hecht, E.: Optics, Addison-Wesley, 2001 Demtröder, W.: Laser spectroscopy I & II, Springer; 5th ed. 2014 Murphy, D.B.: Fundamentals of Light Microscopy and Electronic Imaging, Wiley-Blackwell; 2nd ed. 2012 Issaq, H.J.: Proteomic and Metabolomic Approaches in Biomarker Discovery, Academic Press, 2013 Lämmerhofer, M., Weckwerth, W.: Metabolomics in Practice: Successful Strategies to Generate and Analyze Metabolic Data, Wiley-VCH, 2013

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	Weckwerth, W.: The Handbook of Plant Metabolomics (Molecular Plant Biology), Wiley Blackwill, 2013 Teresa Whei-Mei Fan, Andrew N. Lane: The handbook of metabolomics. Humana Press 2016 Alessandra Sussulini: Metabolomics: From Fundamentals to Clinical Applications (Advances in Experimental Medicine and Biology) 2016 David Beale: Microbial Metabolomics: Applications in Clinical, Environmental, and Industrial Microbiology – Springer, 2016 Scientific publications

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PAM12 – Elective Module

Course of studies	Process Analysis and Technology-Management (MSc)					
Module	Elective Module					
Abbreviation	PAM-12					
Course(s)	Elective course(s)					
Semester	2					
Person responsible for the module	Prof. Dr. Wolfgang Honnen					
Instructor	All members of faculty					
Language	English or German					
Status within the curriculum	Mandatory in PA&TM					
Type of course / WH	Course	L	E	LW	S	
	Elective Subject	2				
	Elective Subject	2				
Workload in hours	Course	Class attendance		Study outside of class	Total	CP
	Elective Subject	30		45	75	
	Elective Subject	30		45	75	
	Total	**60**		**90**	**150**	**5**
Credit points	5					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work	None					
Module goals / desired outcome						
Content						
Study and exam requirements	Student must document successful participation in a university course					

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Media used	Depends on elective
Literature	Depends on elective

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PAM13 – Master's Thesis

Course of studies	Process Analysis and Technology-Management (MSc)					
Module	Master's Thesis					
Abbreviation	PAM-13					
Course(s)	Master Thesis Seminar on topics related to Master Thesis					
Semester	1					
Person responsible for the module	Prof. Dr. Wolfgang Honnen					
Instructor	All instructors of faculty					
Language	English or German					
Status within the curriculum	Mandatory in PA&TM					
Type of course / WH	Course	L	E	LW	S	
	Master Thesis	-	-		-	
	Seminar	-	-	-	2	
Workload in hours	Course	Class attendance		Study outside of class	Total	CP
	Master Thesis			840	840	28
	Seminar	30		30	60	2
	Total	**30**		**870**	**900**	**30**
Credit points	30					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work	Successful completion of research project					

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Module goals / desired outcome	Knowledge • Ability to do detailed and in-depth research on a defined scientific field of study Skills • Ability to work independently in a team on a defined research project • Ability to evaluate and implement insights / findings of scientific literature • Ability to prepare and present scientific results Technical competences • Ability to apply modern adequate strategies for finding scientific solutions Social competences: • Ability to promote team work in a research group
Content	Students will work independently on a defined research project in a research group at the Reutlingen University or at an external research institution. Students will work under the direction of a professor of our faculty. Their work will culminate in a master's thesis, to be written by each student individually and independently. The thesis work may also be done in an industrial R&/orD department, provided a professor of the Faculty of Applied Chemistry supervises the project. Each student will research a defined scientific topic, present his/her findings to a board of experts and prepare a scientific publication of the results. Work on the thesis will be accompanied by regular attendance of seminars on the topic of research.
Study and exam requirements	Master Thesis: The thesis will be evaluated by the mentoring professor as well as by a second reviewer Seminar on topics related to master's thesis: After completing the master's thesis, students will hold an oral presentation on their work
Media used	Oral presentation, written thesis, digital projector, PowerPoint slides
Literature	Depends on actual research project

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PAM14 – Internship semester (Additional Module only for students with 180 ECTS Bachelor's degree)

Course of studies	Process Analysis and Technology-Management (MSc)					
Module	Internship semester					
Abbreviation	PAM-14					
Course(s)	Internship semester					
Semester	1					
Person responsible for the module	Prof. Dr. Wolfgang Honnen					
Instructor	All instructors of faculty					
Language	English or German					
Status within the curriculum	Mandatory in PA&TM					
Type of course / WH	Course	L	E	LW	S	
	Internship semester	-	-	-	-	
Workload in hours	Course	Class attendance	Study outside of class	Total	CP	
	Internship semester		900	900	30	
	Total		**900**	**900**	**30**	
Credit points	30					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work	Successful completion of semesters 1 and 2					

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Module goals / desired outcome	Knowledge: • insight into the structure, organization and operations of an industrial company or a research institution Skills: • introduction to the independent processing of specific tasks within projects Competencies: • ability for determining the status of development / research by literature search • Acquiring the skills for independent implementation of projects • Competence for systematic and structured approach • competence to work scientifically Social competence: • learning the manners and practices in the work environment • improve the team and communication skills through participation in the working group • intercultural competence acquisition
Content	The internship semester is performed in close co-operation between the internship site, the student and the internship Office of the school of Applied Chemistry. In 24 weeks, interns work on projects in their industrial enterprises or their institutions, which are connected to the thematic study content of the curriculum.
Study and exam requirements	Continuos assessment, regular reporting, preparation of a project report manuscript, certificate of the internship site
Media used	“Richtlinie für das Nachholen fehlender Kompetenzen im Master-Studiengang Process Analysis & Technology Management“ of the examination commission
Literature	Depends on actual project

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ACM1 – Specialized polymer analytical methods

Course of studies	**Angewandte Chemie (MSc)**					
Module	Specialized polymer analytical methods					
Abbreviation	ACM01					
Course(s)	• Thermal Analysis and Process Safety • Rheology					
Semester	1					
Person responsible for the module	Prof. Dr. Andreas Kandelbauer					
Instructor	Prof. Dr. Andreas Kandelbauer Prof. Dr. Roy Hornig					
Language	German					
Status within the curriculum	Mandatory in ACM / elective in others					
Type of course / WH	Course	L	E	LW	S	
	Thermal Analysis and Process Safety	2				
	Rheology	2				
Workload in hours	Course	Class attendance		Study outside of class	Total	CP
	Themal Analysis and Process Safety	30		45	75	
	Rheology	30		45	75	
	Total	**60**		**90**	**150**	**5**
Credit points	5					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work	Physics, chemistry, mathematics					

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Module goals / desired outcome	Knowledge • Principles and theory of thermal analytical methods such as Differential Scanning Calorimetry (DSC), Thermogravimetry (TGA), Dynamic Mechanical Analysis (DMA), Rheology, Reaction Calorimetry (RC) and other calorimetric methods • Determination of basic characteristic values of material constants (melting points, glass transition temperatures, reaction enthalpies, etc.) • Derivation of complex information from calorimetric and rheometric measurements (reaction kinetics, activation energy barriers, thermal stability parameters, etc.) • Derivation of data which are relevant in the context of thermal process safety • Derivation and prediction of technologically important information regarding process windows, process optimization and process safety Skills • How complex experiments must be set-up in order to study the physical / chemical systems (guidelines for thermal and rheological analysis) • Spezialized data treatment methods • Derivation of technologically relevant information from thermal and rheological data • Mathematical methods for Data treatment (kinetic modelling) • Use of commercial software packages Technical competences • Competence to select thermal and rheological analysis protocols depending on the problem • Competence to critically examine experimental results • Correct use of thermal and rheological material data and application of these data for process understanding and optimization • Competence to interpret such technical systems in the students' future careers or to virtually understand, operate and master complete processes based on the acquired knowledge. • Competence to assess critically conventional solutions, to improve or to replace them with new solutions. Social competence • Self-organization • Target-oriented working • Ability to think conceptually • Development and strengthening of team and communication skills

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Content	1. Thermal Analysis and Process Safety • Basics and application of standard and advanced thermal analytical and calorimetric methods in teh laboratory • Principles and experimental set-ups of different kinds of calorimetry • Judgement of the advantages and disadvantages, application fields and limits of the various thermal analytical methods • Reaction calorimetry / microcalorimetry, Application of real-time temperature / heat-flow measurements in chemical reactions • Classic and advanced means of data treatment (e.g., model-based and model-free kinetic data analysis) • Prerequisites for obtaining good data • Derivation of quality relevant characteristic data • Use of thermal data in the risk assessment of thermally stimulated physical/chemical processes 2. Rheology • Rheometric characteristics and numbers • Flow and viscosity curves • Velocity gradients during processing / manufacturing • Influences on viscosity • Newtonian and non-Newtonian liquids • Methods of practical viscosity measurement • Methods of absolute viscosity measurement • Different types of viscosimeters (such as capillary viscosimeter and other) • Data collection and data evaluation of flow curves with practical exercises • Recognize faulty measurements • Determinationof viscoelastic properties of liquids and solids • Systematics of rheological analysis
Study and exam requirements	Written examination (2h), presentation
Media used	Lecture, board, digital projector, handouts

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Literature	Ehrenstein GW, Riedel G, Trawiel, Thermal Analysis of Plastics: Theory and Practice, Hanser, 2004 Frick A, Stern C, DSC-Prüfung in der Anwendung, Hanser, 2013 Sarge SM, Höhne GWH, Hemminger W, Calorimetry. Fundamentals, Instrumentation, and Applications, Wiley, 2014 Stoessel F, Thermal Safety of Chemical Processes. Risk Assessment and Process Design, Wiley, 2008 Vyazovkin S, Isoconversional Kinetics of Thermally Stimulated Processes, Springer, 2015 Wissenschaftliche Originalliteratur (Aufgaben-bezogene Artikel aus peer-reviewed Zeitschriften) Brummer R, Rheology Esseentials of Cosmetic and Food Emulsions, Springer Berlin, 2005 Mezger Th, The Rheology Handbook, Vincentz, 2006 Schramm G, Einführrung in die Rheologie und Rheometrie, Gebr. Haake, Karlsruhe

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ACM2 – Chemical Engineering

<table>
<tr><td>Course of studies</td><td colspan="5">Angewandte Chemie Master / plus Biomedical Sciences Master as elective / plus Process Analysis & Technology Management Master as elective</td></tr>
<tr><td>Module</td><td colspan="5">Chemical Engineering</td></tr>
<tr><td>Abbreviation</td><td colspan="5">ACM2</td></tr>
<tr><td>Course(s)</td><td colspan="5">Process Engineering and Industrial (Bio) Chemistry</td></tr>
<tr><td>Semester</td><td colspan="5">1</td></tr>
<tr><td>Person responsible for the module</td><td colspan="5">Prof. Dr. Wolfgang Honnen</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Honnen
Prof. Dr. Kemkemer</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">Mandatory in ACM / elective in others</td></tr>
<tr><td rowspan="4">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Process Engineering and Industrial (Bio) Chemistry</td><td>4</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="5">Workload in hours</td><td>Course</td><td colspan="2">Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Process Engineering and Industrial (Bio) Chemistry</td><td colspan="2">60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td><td></td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Total</td><td colspan="2">60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td>Credit points</td><td colspan="5">5</td></tr>
<tr><td>Prerequisites for attending this course</td><td colspan="5">See examination regulations</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Physics, chemistry, mathematics</td></tr>
</table>

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Module goals / desired outcome	Knowledge • Knowledge of important fundamentals in chemical engineering • Knowledge of the importance of mechanical and thermal unit operations • Knowledge of important examples of industrial chemical and bio chemical plants Skills • Ability to apply principles of fluid mechanics in calculations for technical processes • Ability to understand the physical basis of chemical engineering and to govern methods based on it. • Ability to understand the significance of heat and mass transfer and in nature and technology and estimate and calculate heat and mass transfer processes Technical competences • Competent application of the mechanical and thermal unit operations, which are important in the assessment of devices or equipment in the process engineering industries • Competence to interpret such technical systems in the students' future careers or to virtually understand, operate and master complete processes based on the acquired knowledge. • Competence to assess critically conventional solutions, to improve or to replace them with new solutions. Social competence • Ability to think conceptually • Development and strengthening of team and communication skills

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Content	1. Fundamentals of chemical engineering • Mass and energy conservation • Fluid mechanics (fluid statics, fluid dynamics, Bernoulli's energy equation and metering of flows with examples) • Phase transitions • Heat and mass transfer 2. Selection of mechanical and thermal unit operations • Mixing and agitation • Filtration • Heat exchange, in particular heat transfer processes with phase change • Distillation • Adsorption • Absorption • Crystallization • Drying 3. Selected flowsheets (examples of industrial chemical and bio-chemical plants)
Study and exam requirements	Written examination (2h), presentation
Media used	Lecture, board, digital projector, handouts
Literature	Jess, Andreas; Wasserscheid, Peter: Chemical Technology, An Integral Textbook, Wiley-VCH (2013) McCabe, Warren L.; Smith, Julian C.;Harriott, Peter: Unit Operations of Chemical Engineering, International Edition, McGraw-Hill Higher Education, 7th ed. (2005) Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2. ed. (2012) Katoh, Shigeo; Horiuchi, Jun-ichi; Yoshida, Fumitake: Biochemical Engineering, A Textbook for Engineers, Chemists and Biologists, Wiley-VCH , 2nd, rev. and enl. ed. (2015)

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ACM7 – Polymer Based Materials 2 (in german language)

Course of studies	**Angewandte Chemie (MSc)**					
Module	Polymer-basierte Materialien 2					
Abbreviation	ACM-07					
Course(s)	Polymere und Flüssigkristalle / Selected Soft Materials Hybridwerkstoffe / Hybrid Materials					
Semester	2					
Person responsible for the module	Prof. Dr. Ralph Lehnert					
Instructor	Prof. Dr. Ralph Lehnert (Polymere und Flüssigkristalle) Prof. Dr. Roy Hornig (Hybridwerkstoffe)					
Language	Deutsch					
Status within the curriculum	Pflichtmodul in ACM / elective in others					
Type of course / WH	Course	L	E	LW	S	
	Polymere und Flüssigkristalle	2				
	Hybridwerkstoffe	2				
Workload in hours	Course	Class attendance		Study outside of class	Total	CP
	Polymere und Flüssigkristalle	30		45	75	
	Hybridwerkstoffe	30		45	75	
	Total	**60**		**90**	**150**	**5**
Credit points	5					
Prerequisites for attending this course	Laut Studien- und Prüfungsordnung					
Recommended knowledge / course work	Physik, Chemie, Mathematik					

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Module goals / desired outcome	Erweitertes Grundlagenwissen ausgewählter polymerwissenschaftlicher Inhalte mit Schwerpunkt auf Struktur-Funktionalitätsbeziehungen und Grenzflächen. Kenntnisse • Vertieftes Grundlagenwissen über Eigenschaften, Ordnungszustände, Strukturbildung und Phasen-übergänge verschiedener Arten weicher Materie. • Zusammenhänge zwischen mikroskopischen Eigenschaften, mesoskopischer Ordnung und makroskopischen Materialeigenschaften. • Grundverständnis der Kompatibilität zwischen verschiedenen Materialien (organisch/polymer-anorganisch) • Formulierung und Compounding von Elastomeren • Technologische Verfahren zur Herstellung von Kunststoff-Metallverbunden Fertigkeiten Erfolgreiche Studenten • verstehen materialwissenschaftliche Aspekte von Relevanz für Anwendung und F&E in Polymerindustrie und industrieller Werkstoffentwicklung • verstehen wie makroskopische Eigenschaften von mikroskopischen und/oder mesoskopischen Stellgrößen abhängen • können relevante Materialien für vorgegebene Anwendungen / Eigenschaftsprofile (z.B. Polymere, Lösemittel, Elastomere, Haftvermittler) auswählen Fachliche Kompetenzen • Zusammenhangswissen zur Lösung polymerwissen- • schaftlicher Problemstellungen in der Anwendung • Material- und Methodenauswahl unter technologischen Aspekten • Studenten kennen Anwendungsbreite und Limitation bestehender Materialien und Technologien • Vorgehensweise zur Werkstoffkompatibilisierung Soziale Kompetenzen • Fördern des abstrakten Denkvermögens • Selbstorganisation und Motivation • Teamfähigkeit

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Content	4. Polymere und Flüssigkristalle • Kräfte, Energien, Zeit- und Längenskalen in polymerer und flüssigkristalliner Materie verschiedener Phasen • Stabilität, Phasenverhalten, Ordnungszustände, Selbstorganisationsphänomene, Rolle von Ober- und Grenzflächeneffekten • Eigenschaften von Polymeren in Lösung, Schmelze und Festkörper sowie von Flüssigkristallen 2. Hybridwerkstoffe • Grundlagen Klebstoff- und Elastomertechnologie • Kompatibilität zwischen Kunststoffen und Metallen • Reinigung und Aktivierung von Substratoberflächen • Chemie und Technologie der Haftvermittler • Technologie der Elastomer-Metallverbunde • Prüfverfahren und Qualitätskontrolle
Study and exam requirements	Klausur 2h, Präsentation
Media used	Tafelanschrieb, Overheads, Skriptum, Tischvorlagen
Literature	Gedde, UW, Polymer Physics, Kluwer Academic Publishers, 2001 Jones, R. A. L.: Soft Condensed Matter, Oxford University Press, 2002 Hamley, I, Introduction to Soft Matter. Synthetic and Biolological Self-assembling Materials, Wiley, 2000 Kickelbick G, Hybrid Materials, Wiley-VCH, 2008 Stokes RJ, Evans DF, Fundamentals of Interfacial Engineering, Wiley-VCH, 1997 Plüddemann EP, Silane Coupling Agents, 2nd edition, Kluwer, 1991 Mittal KL, Pizzi A, Adhesion Promotion Techniques. Technological Applications, Marcel Dekker, 2002 Ausgewählte wissenschaftliche Originalarbeiten und Review-Artikel

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ACM8 – Polymer Based Materials 1 (in german language)

Course of studies	**Angewandte Chemie MSc**					
Module	Polymer-basierte Materialien 1					
Abbreviation	ACM-08					
Course(s)	Advanced Materials Product Functionality Design					
Semester	2					
Person responsible for the module	Prof. Dr. Andreas Kandelbauer					
Instructor	Prof. Dr. Andreas Kandelbauer (Advanced Materials) Prof. Dr. Richard Schilling (Product Functionality Design)					
Language	Deutsch					
Status within the curriculum	Pflichtmodul in ACM / elective in others					
Type of course / WH	Course	L	E	LW	S	
	Advanced Materials	2				
	Product Functionality Design	2				
Workload in hours	Course	Class attendance		Study outside of class	Total	CP
	Advanced Materials	30		45	75	
	Product Functionality Design	30		45	75	
	Total	**60**		**90**	**150**	**5**
Credit points	5					
Prerequisites for attending this course	Laut Studien- und Prüfungsordnung					
Recommended knowledge / course work	Physik, Chemie, Mathematik					

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Module goals / desired outcome	Vertieftes Grundlagenwissen ausgewählter materialwissenschaftlicher Inhalte mit Schwerpunkt auf Struktur-Funktionalitätsbeziehungen. Einführung in anwendungsorientierte Fragestellungen der wechselseitigen Abhängigkeit zwischen Materialfunktionalität und Produkteigenschaften. Kenntnisse • Kennenlernen der Eigenschaften und Strukturen von Hochleistungspolymeren, Anwendungen • Architekturen und Chemismus verschiedener Nanomaterialien, Hochleistungspolymere und Polymerverbundwerkstoffe • Spezielle Strategien zur Performanceverbesserung von Werkstoffen • Prinzipien der Verbundwerkstofftechnologie; Herstellungs- und Verarbeitungsverfahren • Methodenkompetenz für eine funktionsgerechte, designorientierte Materialauswahl und ein materialgerechtes Design • Problemlösungskompetenz zur Formulierung von Design- und Materialanforderungsprofilen Fertigkeiten • Studenten verstehen materialwissenschaftliche Aspekte von Relevanz für Anwendung und F&E in Polymerindustrie, Medizinprodukte-Industrie und Werkstoffentwicklung • Verständnis, wie makroskopische Eigenschaften von mikroskopischen Eigenschaften abhängen • Fähigkeit über wissenschaftliche Literatur und Datenbanken relevante Materialien für bestimmte Anwendungen / Eigenschaftsprofile auszuforschen • Analytisch-systematische Suche und Auswahl von komplexen Materialsystemen anhand von Material- und Produktlastenheften • Umgang mit Software zur Materialauswahl, Eigenschaftsvorhersage und Prototypen-konstruktion • Umsetzung von funktionalen Materialkonzepten von der Modellbildung bis zum Prototypen Fachliche Kompetenzen • Studenten können Anwendungsbreite und Limitation bestehender Materialien und Technologien benennen • Zusammenhangswissen zur Lösung materialwissenschaftlicher Problemstellungen • Materialauswahl unter technologischen und Designgesichtspunkten Soziale Kompetenzen • Fördern des abstrakten Denkvermögens • Selbstorganisation und Motivation • Teamfähigkeit

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Content	1. Advanced Materials • Hochleistungsfasern • Hochleistungspolymere • Hochleistungsverbundwerkstoffe • Biobasierte Materialien • Nanomaterialien u. a. „Emerging Technologies“ • Spezielle Funktionalitäten: Selbstheilung, interaktive („stimulus-responsive“) Materialien, „smarte“ Materialien • Herstellung und Verarbeitung von Verbundwerkstoffen (SMC, BMC, Pultrusion, RIM, RTM, etc.) • Spezielle und aktuelle Themen anhand konkreter wissenschaftlicher Originalliteratur 2. Product Functionality Design • Allgemeine Prinzipien der mathematisch-physikalischen Modellbildung anhand konkreter technischer Fragestellungen • Methoden der systematischen Materialauswahl • Durchführung von Life-Cycle Analysen • Grundlegende Konzepte der ökologischen und nachhaltigen Produktion • Abstimmung von Design und Material zur Optimierung der Gebrauchseigenschaften anhand von Fallbeispielen • Verfahren zur Beschleunigung des Designprozesses durch z.B. 3D-Scanning Methoden • Rapid Prototyping und moderne Verarbeitungsmethoden wie z:B. 3D-Druck
Study and exam requirements	Continuous Assessment, Klausur 2h, Hausarbeit, Präsentation
Media used	PPT, Tafelanschrieb, Overhead-Folien, Skriptum, Tischvorlagen, Formelsammlungen, Übungen
Literature	Ullmann´s Encyclopedia of Industrial Chemistry, Wiley 2012 Ghosh SK, Self-Healing Materials, Wiley, 2012 Krueger A, Carbon Materials and Nanotechnology, Wiley, 2012 Dodiuk H, Goodman S, Handbook of Thermosetting Plastics, CRC / Elsevier, 2014 KLumar C, Nanomaterials for the Life Sciences (Series) Vols. 1-10, Wiley, 2012 Current scientific original papers Kickelbick G, Hybrid Materials, Wiley-VCH, 2008 Stokes RJ, Evans DF, Fundamentals of Interfacial Engineering, Wiley-VCH, 1997

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	Methodik der Werkstoffauswahl: Der systematische Weg zum richtigen Material, Carl Hanser Verlag GmbH & Co. KG; Auflage: 1 (2006), ISBN-10: 9783446406803 Nash WA, Schaum's Outline of Strength of Materials (Schaum's Outlines) 432 Seiten , Schaum Outline Series; Auflage: 4 Sub (1998) Englisch , ISBN-13: 978-0070466173 Software: CES Edu Pack 2013, Grantadesign, Cambridge

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BMS1 – Analytical Methods in Biomedical Sciences

<table>
<tr><td>Course of studies</td><td colspan="5">Biomedical Sciences (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Analytical Methods in Biomedical Sciences</td></tr>
<tr><td>Abbreviation</td><td colspan="5">BMS1</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Analytical Methods in Biomedical Sciences
• Diagnostic Technologies</td></tr>
<tr><td>Semester</td><td colspan="5">1</td></tr>
<tr><td>Person responsible for the module</td><td colspan="5">Prof. Dr. Reinhard Kuhn</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Reinhard Kuhn
Prof. Dr. Ralf Kemkemer</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">Mandatory</td></tr>
<tr><td rowspan="4">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Analytical Methods in Biomedical Sciences</td><td>1</td><td></td><td></td><td>1</td></tr>
<tr><td>Diagnostic Technologies</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td></td></tr>
<tr><td rowspan="5">Workload in hours</td><td>Course</td><td colspan="2">Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Analytical Methods in Biomedical Sciences</td><td colspan="2">30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Diagnostic Technologies</td><td colspan="2">30</td><td>45</td><td>75</td><td></td></tr>
<tr><td></td></tr>
<tr><td>Total</td><td colspan="2">60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td>Credit points</td><td colspan="5">5</td></tr>
<tr><td>Prerequisites for attending this course</td><td colspan="5">See examination regulations</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Knowledge of biochemistry, bioanalytics, instrumental analytics, chemistry, material science, biology</td></tr>
</table>

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Module goals / desired outcome	General knowledge Successful students will obtain • Profound overview of current bioanalytical techniques that are significant in biomedical and pharmaceutical research • Profound understanding of materials for diagnostic applications • Profound understanding of technologies and functioning of laboratory diagnostics and applications • Fundamental understanding of principles of cell biology, cell culture techniques and molecular biology Skills: • Understanding of complex relationships in bioanalytics • Understanding of the aspects of material science that are relevant for R&D in biotechnology, pharmaceutical and diagnostics industries • Understanding of principles of interaction of biological systems and molecules with materials • Understanding of principles of structure of diagnostic systems and prerequisites for certain applications • Ability to name limitations of existing technologies • Ability to evaluate various methods of modern cell culture techniques and laboratory diagnostics • Ability to read and understand scientific publications Social competences: • Ability to prepare and deliver a scientific presentation for a seminar • Ability to do scientific research and to present scientific findings

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Content	**Analytical Methods in Biomedical Sciences** The course consists of a lecture and a seminar. Students must choose a research topic on which they will prepare and hold a scientific presentation. The following fields of study will be covered in the lecture and seminar: • Proteomics and metabolomics • Biomoarkers • Pharmaceutical analysis • Clinical laboratory analysis • Selected topics of bioanalysis, e.g. blotting techniques, two-hybrid systems, FRET, Patch Clamp, **Diagnostic Technologies** • Structure, function and application of laboratory diagnostic methods, in particular micro-technologies and microfluidics, lab-on-a-chip technology, cell biology, cell culture technologies, microscopy
Study and exam requirements	Written exam (2h), presentation, term paper
Media used	Lecture, script as download, board, student presentations, digital projector, handouts
Literature	• Rehm, H., Letzel, T.: Der Experimentator – Proteinbiochemie/Proteomics, Spektrum Verlag • Vishal, S.: Biomarkers in Medicine, Drug Discovery and Environmental Health, Wiley • Matson, R.S.: Applying Genomic and Proteomic Microarray Technology in Drug Discovery, CRC Press • Lovric, J.: Introducing Proteomics, Wiley-Blackwell • Russel, S., Meadows, L.A., Russel, R.R.: Microarray Technology in Practice, Academic Press • Issaq, H.J.: Proteomic and Metabolomic Approaches in Biomarker Discovery, Academic Press • Lämmerhofer, M.: Metabolomics in Practice, Wiley-VCH • Molecular Diagnostics : Fundamentals, Methods and Clinical Applications, 2nd Edition, Lela Buckingham PhD, MB, DLM(ASCP) ISBN-13: 978-0-8036-2677-5, 2012 Paperback, 576 pages • Scientific publications

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BMS2 – Materials and Applications in Biomedical Sciences

Course of studies	Biomedical Sciences (MSc)					
Module	Materials and Applications in Biomedical Sciences					
Abbreviation	BMS2					
Course(s)	• Functional Implants & Surface Technologies • Drug Release and Delivery Systems					
Semester	1					
Person responsible for the module	Prof. Dr. Rumen Krastev					
Instructor	Prof. Dr. Ralf Kemkemer Prof. Dr. Rumen Krastev					
Language	English					
Status within the curriculum	Mandatory					
Type of course / WH	Course			L	E	LW	S
	Drug Release and Delivery Systems			2			
	Functional Implants & Surface Technologies			2			
Workload in hours	Course	Class attendance	Study outside of class	Total		CP	
	Drug Release and Delivery Systems	30	45	75			
	Functional Implants & Surface Technologies	30	45	75			
	Total	**60**	**90**	**150**		**5**	
Credit points	5						
Prerequisites for attending this course	See examination regulations						
Recommended knowledge / course work	Basic understanding (BSc-level) of chemistry, biology and biomedical technology, material sciences						

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Module goals / desired outcome	Basic knowledge - Knowledge of materials for biomedical application in in-vitro and in-vivo applications - Understanding of technologies for surface modifications for implants and related methods - Knowledge of biomedical implant technologies - application examples and challenges - Understating of drug delivery concepts and application of polymers - Understanding of drug release methods, kinetics and applications Technical competences: - Students will be able to understand surface and polymer chemistry technologies and transfer these to appropriate applications in the biomedical field - Students will be able to identify technical working principles of complex implants - Students will be able to understand the complexity of tissue-material interaction and relate this to material properties - Students will be able to classify the suitability of different materials classes for specific applications - Students will be able to name limitations of current technologies in the field Social competences: - Students develop skills in research, reading and interpretation of scientific texts - Students gain an awareness of ethical aspects in the development of medical products.
Content	• Functional Implants & Surface Technologies Materials and design principles of passive and active implants, examples and applications, surfaces and surface modifications, technical principles of active implants (examples), micro and nanotechnology, surface chemistry, interaction of cells with materials. • Drug Release and Delivery Systems Medical devices (active and passive) as drug delivery systems examples and applications Approaches, formulations, technologies, and systems for transporting of active pharmaceutical compounds as needed to achieve the desired therapeutic effect Immobilisation and delivery of “biologicals” e.g. peptides, proteins, antibodies, vaccines and gene based drugs Release based on diffusion, degradation, swelling, and affinity-based mechanisms

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	Current approaches – site and time specific targeting, facilitated pharmacokinetics Example techniques – thin polymer film delivery, acoustic or light targeted delivery, liposomal delivery.
Study and exam requirements	Written exam (2h), presentation /assignments
Media used	PowerPoint slides, flip charts, board
Literature	King M.R.: Principles of Cellular Engineering – Understanding the Biomolecular Interface, Academic Press, 2006 Ritter A.B., et al.: Biomedical Engineering Principles, CRC Press, 2012 Narayan R.: Biomedical Materials, Springer Publisher, 2009 Ratner B.D. et al.: Biomaterial Sciences, Elsevier Oxford, 2012 Wintermantel E., H. Suk-Woo Ha: Medizintechnik: Life Science Engineering, Springer 2009

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BMS3 – Industry-Related Topics 1 (Drug Discovery & / Development
Introduction into medical technology)

Course of studies	Biomedical Sciences (MSc)					
Module	Industry-Related Topics 1					
Abbreviation	BMS3					
Course(s)	• Drug Discovery & Development • Introduction into Medical Technology					
Semester	1					
Person responsible for the module	Prof. Dr. Alexander Schuhmacher					
Instructor	Prof. Dr. Alexander Schuhmacher, Dr. Wiedmann Prof. Dr. Günter Lorenz, Dr. Schüle					
Language	English					
Status within the curriculum	Mandatory					
Type of course / WH	Course	L	E			
	Drug Discovery & Development	2				
	Introduction into Medical Technology	2				
Workload in hours	Course	Class attendance		Study outside of class	Total	CP
	Drug Discovery & Development	30		45	75	
	Introduction into Medical Technology	30		45	75	
	Sum	**60**		**90**	**150**	**5**
Credit points	5					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work	Basic understanding, knowledge of the principles of pharmaceutical and medical technology industries Basic knowledge of natural sciences					

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Module goals / desired outcome	Basic knowledge of the pharmaceutical and medical technology industries Understanding of strategic and operational topics concerning drug discovery, drug development, medical and biomedical technologies. In “Drug Discovery and Development”, students will receive information on state-of-the-art developments, research, and expert opinions in the pharmaceutical industry. Furthermore, the key success factors in research and development (R&D) as well as value creators in pharmaceutical innovation will be discussed. The topics addressed in the textbook include the innovation process, pharmaceutical R&D, research and innovation strategies. Students will gain an overview of the pharmaceutical industry and how pharmaceutical R&D works operationally. In the “Introduction to Medical Technology”, students will gain a basic understanding of fundamental technologies in bio-medical engineering, focusing on the medical background and basic principles of related methods (MRT, CT, sonography, PET, dialysis, heart-lung machine, artificial lungs, stents, heart valves, pace makers). Students will know: (1) the definition of biomedical engineering and (2) the basic principles and medical background of different technologies. Thus, students will improve their ability to (1) understand and use new vocabulary (2) read, summarize and discuss scientific topics and (3) prepare and present scientific results in the form of short presentations in teams.
Content:	**Part 1: Drug Discovery and Development** • Global epidemiology • Pharma-economics • Drug costs • Financing of innovation • Drug targets • Preclinical safety • Pharmaceutical development • Translational medicine • Clinical development • Antibodies • Vaccines • Outsourcing • Pharmaceutical strategies

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	Part 2: Introduction to Medical Technologies Introduction • Definition • Overview • Short summary of the basics Medical background and technology fundamentals: Medical imaging • MRT • CT • Sonography • PET • etc. Life support systems: • Dialysis • Heart-lung machine • Artificial lung • etc. Implants • Stent • Heart valve • Cochlear • Retinal
Study and exam requirements	Preparation and presentation of at least one scientific topic in the module; written examination (2 hours)
Media used	Lecture, group work, interactive discussions, handouts, flip charts
Literature	• Wintermantel, E., Ha, S. W.: Medizintechnik: Life Science Engineering. Interdisziplinarität, Biokompatibilität, Technologien, Implantate, Diagnostik, Werkstoffe, Zertifizierung, Business Springer, Berlin; Auflage: 5., überarb. u. erw. A. 2009 • Ratner, B. D., Hoffman A.S. et al. (eds.): Biomaterials Science - An Introduction to Materials in Medicine, Elsevier Academic Press, 2004 • Joseph Bronzino and Donald R. Peterson : The Biomedical Engineering Handbook, Fourth Edition: Four Volume Set, Crc Pr Inc; 2015 • Pierre Morgon (2014) Sustainable Development in the Healthcare System, Springer

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<table>
<tr><td>Course of studies</td><td colspan="6">Biomedical Sciences (MSc)</td></tr>
<tr><td>Module</td><td colspan="6">Biomedical Technologies</td></tr>
<tr><td>Abbreviation</td><td colspan="6">BMS7</td></tr>
<tr><td>Course(s)</td><td colspan="6">• Regenerative Medicine
• Biomedical Technologies - Biofabrication</td></tr>
<tr><td>Semester</td><td colspan="6">2</td></tr>
<tr><td>Person responsible for the module</td><td colspan="6">Prof. Dr. Petra Kluger</td></tr>
<tr><td>Instructor</td><td colspan="6">Prof. Dr. Petra Kluger</td></tr>
<tr><td>Language</td><td colspan="6">English</td></tr>
<tr><td>Status within the curriculum</td><td colspan="6">Mandatory</td></tr>
<tr><td rowspan="4">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td colspan="2">S</td></tr>
<tr><td>Biomedical Technologies</td><td>2</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Regenerative Medicine</td><td>2</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td></td><td></td><td></td><td></td><td colspan="2"></td></tr>
<tr><td rowspan="4">Workload in hours</td><td>Course</td><td colspan="2">Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Biomedical Technologies</td><td colspan="2">30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Regenerative Medicine</td><td colspan="2">30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Total</td><td colspan="2">60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td>Credit points</td><td colspan="6"></td></tr>
<tr><td>Prerequisites for attending this course</td><td colspan="6">See examination regulations</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="6">Cell biology, physiology, biomaterials, tissue engineering, biomedical engineering</td></tr>
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Module goals / desired outcome	• *students get insight into biofabrication technologies for future perspectives in biomedical engineering* • *students get an overview of the materials and techniques used in Regenerative Medicine; state of the art in various clinical applications and the global market* *students know:* • *how to define biofabrication* • *basic principles for automation, especially for automated cell and tissue culture as well as clinical applications* • *different biofabrication technologies, their characteristics and their pros & cons* • *needed properties for a bioink, different materials used as bioink and their limitations* • *possible applications of these biofabrication technologies in biomedical sciences* • *how to define regenerative medicine* • *the characteristics of stem cells and their clinical use* • *different matrix components and their properties as well as the clinical applications of different matrices* • *the regulatory framework* • *key facts concerning the global regenerative medicine market* • *the state of the art in selected applications and the challenges* *students improve their ability in:* • *understanding and use new vocabulary* • *read, summarize and discuss about scientific topics prepare and present these results and short presentation in teams*
Content	**Biomedical Technologies - Biofabrication** • Introduction Biofabrication • Overview of different biofabrication technologies • Lab automation for cell and tissue cultures • Bioinks for scaffold and tissue fabrication **Regenerative Medicine** • Definition and short summary of fundamentals • Stem cells (basics and clinical applications) • Matrix (basics and clinical applications) • State-of-the-art clinical applications • Regulatory affairs and market

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Study and exam requirements	One written exam for the module (120 min)
Media used	Lecture, interactive discussions, group work, flip chart, PCs
Literature	• Gustav Steinhoff, Regenerative Medicine: From Protocol to Patient, Springer 2013 • Anthony Atala, Robert Lanza, James A., Thomson, and Robert M. Nerem, Principles of Regenerative Medicine, Elsevier, 2008 • Ratner, B. D., Hoffman A.S. et al. (eds.): Biomaterials Science - An Introduction to Materials in Medicine, Elsevier Academic Press, 2004 • Joseph Bronzino and Donald R. Peterson : The Biomedical Engineering Handbook, Fourth Edition: Four Volume Set, Crc Pr Inc; 2015

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BMS8 – Advanced Pharmacology

Course of studies	Biomedical Sciences (MSc)				
Module	Advanced Pharmacology				
Abbreviation	BMS8				
Course(s)	• *Biomedical* Pharmacology • Advanced Bioanalysis				
Semester	2				
Person responsible for the module	Prof. Dr. Reinhard Kuhn				
Instructor	Prof. Dr. Reinhard Kuhn				
Language	English				
Status within the curriculum	Mandatory				
Type of course / WH	Course	L	E	LW	S
	Biomedical Pharmacology	1			1
	Advanced Bioanalysis	2			
Workload in hours	Course	Class attendance	Study outside of class	Total	CP
	Pharmacology	30	45	75	
	Advanced Bioanalysis	30	45	75	
	Total	**60**	**90**	**150**	**5**
Credit points	5				
Prerequisites for attending this course	See examination regulations				
Recommended knowledge / course work	Knowledge of biochemistry, bioanalytics and instrumental analytics, biology, fundamentals of pharmacology				

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Module goals / desired outcome	General knowledge: • Profound overview of current bioanalytical techniques relevant for biomedical as well as pharmaceutical research • Understanding of mode of action of drugs Skills: • Understanding of drug interaction in the human organism • In-depth knowledge of Pharmaco-kinetics and Pharmaco-dynamics • Understanding of the use of modern analysis systems in personalized medicine • Understanding of the functioning of microarray- and gene-chip-systems • Ability to read and understand scientific publications Social competences: • Preparation and presentation of a scientific presentation for a seminar • Ability to do scientific research and present scientific findings
Content	**Analytical Methods in Biomedical Sciences** • DNA structure and isolation • Cloning and sequencing • Advanced polymerase chain reaction • DNA/RNA microarray technology • Karyotype analysis • Personalized medicine • Examples of personalized medicine **Biomedical Pharmacology** • Introduction to pharmaco-kinetics • Introduction to pharmaco-dynamics • Drug interaction • Drug impact on - stomach & gut - blood - blood vessels, kidney - heart - hormones • Neuropharmacology (ataractics, Parkinson's, analgesics)
Study and exam requirements	Written exam (2h)

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Media used	Lecture, script for download, board, student presentations, digital projector, handouts
Literature	• J Licino, ML Wong, Pharmacogenomics, Wiley-VCH (2003) • RS Matson, Applying Genomic and Proteomic Microarray Technology in Drug Discovery, CRC Press (2013) • C Mühlhardt, Der Experimentator: Molekularbiologie/Genomics, Spektrum Akad. Verlag (2002) • H Rehm, Der Experimentator: Proteinbiochemie/Proteomics, Spektrum Akad. Verlag (2002) • AM Lesk, Introduction to Genomics, Oxford University Press 2nd Ed. (2012) • NC Mishra, Introduction to Proteomics, Wiley (2010) • M Lämmerhofer, W Weckwerth, Metabolomics in Practice, Wiley-VCH (2013) • S Russel, LA Meadows, RR Russel, Microarray Technology in Practice, Elsevier Academic Press (2009) • Wissenschaftliche Publikationen

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PAM15 – Module from other schools or universities

Course of studies	Process Analysis and Technology-Management (MSc)					
Module	Module from other schools or universities					
Abbreviation	PAM-15					
Course(s)	Modules from other schools or universities with at least 4 SWS and 5 ECTS-credits to be approved by examination commission					
Semester	1 or 2					
Person responsible for the module	Prof. Dr. Wolfgang Honnen					
Instructor						
Language	English or German					
Status within the curriculum	Elective in PA&TM					
Type of course / WH	Course	L	E	LW	S	
	Internship semester	-	-	-	-	
Workload in hours	Course	Class attendance		Study outside of class	Total	CP
	Module from other schools or universities	60		90	150	5
	Total			**90**	**150**	**5**
Credit points	5					
Prerequisites for attending this course	See examination regulations					
Recommended knowledge / course work						

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Module goals / desired outcome	depending on the selected module
Content	depending on the selected module
Study and exam requirements	depending on the selected module
Media used	depending on the selected module
Literature	depending on the selected module

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