AC Angewandte Chemie

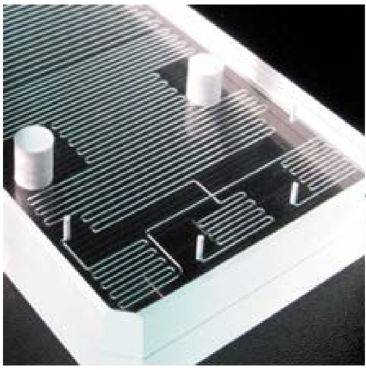
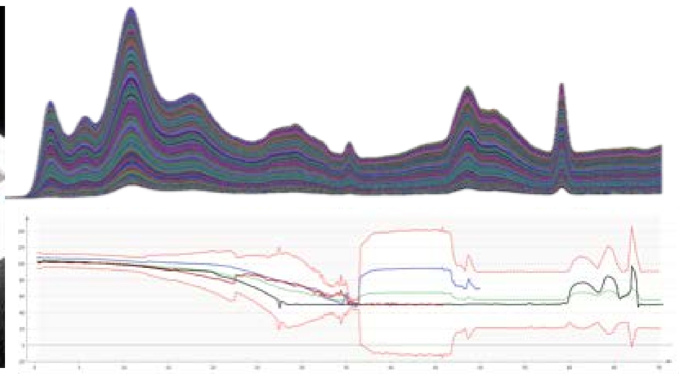
Module Compendium

for the Master's Degree Program

Master of Science

Process Analysis & Technology Management

Valid as of December 2018
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	4	5

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 professional qualifications that should be achieved with this module. The desired outcome describes which knowledge, skills and competences are to be acquired through study. Bloom's taxonomy serves as a tool in formulating learning outcomes statements and facilitate the writing of module descriptions. The particular cognitive levels (competence levels) are indicated with stages K1 up to K6 in the module descriptions. In particular the following levels are used: K1: remembering, K2: understanding, K3: applying, K4: analyzing, K5: evaluating, K6: creating.

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

<table>
<tr><td>Course of studies</td><td colspan="5">Process Analysis and Technology Management (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Technology Management</td></tr>
<tr><td>Abbreviation</td><td colspan="5">PAM01</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Quality Management
• Innovation Management
• Project management</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. Alexander Schuhmacher</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Alexander Schuhmacher, Dr. Held, Dr. Alexander Schulz</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="3">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Innovation and Project Management</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>Quality Management</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Innovation and Project Management</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Quality Management</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Total</td><td>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">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Basic understanding of good laboratory practice and project management principles, no further special prerequisites</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module:
• Students understand basic principles of innovation strategies and innovation processes. (K2)
• Students understand the significance of the context of innovation strategy for the daily business of researchers in an R&D organization. (K2)
• Students are able to evaluate how a portfolio of projects is managed efficiently and effectively. (K5)
• Students can estimate the principles of project life-cycle-management and the concepts of quality management. (K3)
• Students are able to analyze the responsibilities and tasks of QM in daily business. (K4)</td></tr>
<tr><td>Content</td><td colspan="5">Innovation Management</td></tr>
</table>

	• 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	1. Gassmann O. et al. (2004) Leading Pharmaceutical Innovation. Springer Verlag 2. Schein EH (1997) Organizational Culture and Leadership. Jossey-Bass Publishers 3. S. Nokes and S. Kelly. Guide to Project Management. FT Press (2003) 4. L. Brown and T. Grundy (2011) Project Management for the Pharmaceutical Industry. Gower Publishing Company 5. R.D. Austin (2004) Managing projects large and small. Harvard Business Essentials 6. PMI (2008) The Standard for Portfolio Management. 2nd edition. Project Management Institute 7. 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

<table>
<tr><td>Course of studies</td><td>Process Analysis and Technology Management (MSc)</td></tr>
<tr><td>Module</td><td>Scientific Methods 1 : Design of Experiment (DoE)</td></tr>
<tr><td>Abbreviation</td><td>PAM02
(identical with Module ACM05 in Master study programme Applied Chemistry)</td></tr>
<tr><td>Course(s)</td><td>• Design of Experiment, lecture classes
• Design of Experiment, class exercises</td></tr>
<tr><td>Semester</td><td>1</td></tr>
<tr><td>Person responsible for the module</td><td>Prof. Dr.-Ing. habil. Andreas Kandelbauer</td></tr>
<tr><td>Instructor</td><td>Prof. Dr. Andreas Kandelbauer
Prof. Dr. Ralph Lehnert</td></tr>
<tr><td>Language</td><td>English</td></tr>
<tr><td>Status within the curriculum</td><td>Mandatory</td></tr>
<tr><td>Type of course / WH</td><td><table><tr><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr><tr><td>Design of Experiment</td><td>2</td><td>2</td><td></td><td></td></tr></table></td></tr>
<tr><td>Workload in hours</td><td><table><tr><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr><tr><td>Design of Experiment</td><td>60</td><td>90</td><td>150</td><td>5</td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Total</td><td>60</td><td>90</td><td>150</td><td>5</td></tr></table></td></tr>
<tr><td>Credit points</td><td>5</td></tr>
<tr><td>Prerequisites for attending this course</td><td>none</td></tr>
<tr><td>Recommended knowledge / course work</td><td>Knowledge of statistics and chemometrics</td></tr>
<tr><td>Module goals / desired outcome</td><td>After successful completion of this module:

• Students will obtain a profound overview of basic approaches and standard methods of current DoE. (K1)
• Students profoundly understand the applicability and limitations of statistical experimental designs. (K2)
• Students have gained hands-on experience in using commercial software packages for planning, evaluating, and visualizing experiments. (K3)
• Students are able to plan experiments using scientifically sound approaches and conduct statistically correct analyses. (K4)
• Students can select, use and understand mathematical operations for data analysis (inferring statistics, response surface methodology, regression analysis etc.). (K4)
• Students can transform scientific or technical problem in a form suitable for statistical analysis (selection of appropriate factors and response quantities). (K5)</td></tr>
</table>

	• Students understand, evaluate, summarize, and visualize complex statistical results and can identify experimental key factors. (K6) • Students are able to exploit optimization potential of chemical and technical processes using DoE. (K5) • Students work in a self-organized manner and as a member of a team and do their work target-oriented and systematically. (K6)
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 examination (2h)
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

<table>
<tr><td>Course of studies</td><td>Process Analysis and Technology Management (MSc)</td></tr>
<tr><td>Module</td><td>Project Oriented Learning 1</td></tr>
<tr><td>Abbreviation</td><td>PAM03
(identical with Module ACM06 in Master study programme Applied Chemistry)</td></tr>
<tr><td>Course(s)</td><td>• Research Seminar
• Team Project</td></tr>
<tr><td>Semester</td><td>1</td></tr>
<tr><td>Person responsible for the module</td><td>Prof. Dr. Andreas Kandelbauer</td></tr>
<tr><td>Instructor</td><td>Prof. Dr. Kandelbauer, Prof. Dr. Rebner, Prof. Dr. Lehnert, Prof. Dr. Lorenz, Prof. Dr. Brecht, Dr. Kutuzowa, Dr. Ostertag, Prof. Dr. Carl-Martin Bell</td></tr>
<tr><td>Language</td><td>German, English</td></tr>
<tr><td>Status within the curriculum</td><td>Mandatory in ACM, PATM</td></tr>
<tr><td>Type of course / WH</td><td><table>
<tr><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Research Seminar</td><td></td><td></td><td></td><td>2</td></tr>
<tr><td>Team Project</td><td></td><td></td><td>4</td><td></td></tr>
</table></td></tr>
<tr><td>Workload in hours</td><td><table>
<tr><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Research Seminar</td><td>25</td><td>25</td><td>50</td><td></td></tr>
<tr><td>Team Project</td><td></td><td>100</td><td>100</td><td></td></tr>
<tr><td>Total</td><td>25</td><td>125</td><td>150</td><td>5</td></tr>
</table></td></tr>
<tr><td>Credit points</td><td>5</td></tr>
<tr><td>Prerequisites for attending this course</td><td>For reasons of occupational safety, the students have to prepare the theoretical and practical contents of the module prior to starting practical work in the laboratory. Proof of this is provided by successful participation in a safety and / or introductory colloquium (written or oral).</td></tr>
<tr><td>Recommended knowledge / course work</td><td>Physics, chemistry, mathematics</td></tr>
<tr><td>Module goals / desired outcome</td><td>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)

After successful completion of this module:

• Students can define a research project: how to structure complex scientific questions and break them down into single steps like formulating state of the art and formulating scientific hypotheses. (K6)
• Students successfully apply tools for practical project planning and coordination (Gantt-diagrams, decision gates, milestones, deliverables, etc.). (K5)</td></tr>
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	• Students effectively extract information from technical and scientific databases and evaluate it with regard to a specific research question. (K4) • Students gain in-depth knowledge about a specific topic depending on the specified research question. (K3) • Students select the appropriate scientific methodology depending on the specific research question. (K4) • Students are able to think conceptually, work beneficial together in project teams and have developed and strengthened their team and communication skills. (K5)
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 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	Study requirements: oral presentation of project plan during semester Exam requirements: Written seminar paper (= state of the art) (100%)
Media used	Lecture, board, digital projector, handouts
Literature	1. Chalmers AF (2007) Wege der Wissenschaft. Einführung in die Wissenschaftstheorie, 6. Auflage, Nachdruck, Springer 2. Patzak G, Rattay G (2004) Projektmanagement, 4. Auflage, Linde International 3. Baguley P (1999) Optimales Projektmanagement, Falken 4. Scientific Original papers, depending on the specific research question 5. H.F. Ebel et al. (2006) Schreiben und Publizieren in den Naturwissenschaften, Wiley-VCH Weinheim.

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<table>
<tr><td>Course of studies</td><td colspan="5">Process Analysis and Technology Management (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Process Analytical Technology I</td></tr>
<tr><td>Abbreviation</td><td colspan="5">PAM04</td></tr>
<tr><td>Course(s)</td><td colspan="5">Process Spectroscopy and Spectrometry</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. Karsten Rebner</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Karsten Rebner</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="2">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Process Spectroscopy and Spectrometry</td><td>4</td><td></td><td></td><td></td></tr>
<tr><td rowspan="5">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Process Spectroscopy and Spectrometry</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Optofluidic System Technologies</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Total</td><td>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">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Knowledge of instrumental analysis</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module, students are able to:
• explain theoretical and instrumental concepts of process analyzers (K2).
• apply process spectroscopic methods for different industry branches and requirements (K3).
• compare the application of process analyzers in combination with microfluidic systems for medical and biomedical sensing and manipulation (K4)
• evaluate analyzer benefits and the trade-off between initial capital costs and ongoing cost-of ownership (K5)
• design process analyzer systems for monitoring and control of productions plants (K6).</td></tr>
<tr><td>Content</td><td colspan="5">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.
• Understanding Processes and How to Improve Them
• Optofluidics System Technology
• Implementation of Process Analytical Technologies</td></tr>
</table>

	• UV-Visible Spectroscopy for On-line Analysis • Vibrational Spectroscopy for Process Analytical Applications • Process Mass Spectrometry
Study and exam requirements	Written examination (2h) 70% and presentation 30%
Media used	Lecture, board, overheads, lecture notes, handouts, exercise sheets
Literature	1. Rabus, Rebner, Sada: Optofluidics, Process Analytical Technology, De Gruyter, 2018 2. Kessler RW (Ed.): Prozessanalytik Strategien und Fallbeispiele aus der industriellen Praxis, Wiley-VCH, 2006 3. Bakeev: Process Analytical Technology: Spectroscopic Tools and Implementation Strategies for the Chemical and Pharmaceutical Industries, Wily-VCH, 2010. 4. Undey, Low, Menezes, Koch: PAT Applied in Biopharmaceutical Process Development and Manufacturing, CRC Press 2012

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<table>
<tr><td>Course of studies</td><td>Process Analysis and Technology Management (MSc)</td></tr>
<tr><td>Module</td><td>Industry-Related Topics</td></tr>
<tr><td>Abbreviation</td><td>PAM5</td></tr>
<tr><td>Course(s)</td><td>• Regulatory Affairs
• IP Management</td></tr>
<tr><td>Semester</td><td>1</td></tr>
<tr><td>Person responsible for the module</td><td>Prof. Dr. Alexander Schuhmacher</td></tr>
<tr><td>Instructor</td><td>Dr. Xin Xiong
Prof. Dr. Alexander Schuhmacher</td></tr>
<tr><td>Language</td><td>English</td></tr>
<tr><td>Status within the curriculum</td><td>Mandatory</td></tr>
<tr><td>Type of course / WH</td><td><table>
<tr><td>Course</td><td>L</td><td>E</td><td></td><td></td></tr>
<tr><td>Regulatory Affairs</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>IP Management</td><td>2</td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Workload in hours</td><td><table>
<tr><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Regulatory Affairs</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>IP Management</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Sum</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
</table></td></tr>
<tr><td>Credit points</td><td>5</td></tr>
<tr><td>Prerequisites for attending this course</td><td>none</td></tr>
<tr><td>Recommended knowledge / course work</td><td>No specific knowledge required</td></tr>
<tr><td>Module goals / desired outcome</td><td>After successful completion of this module:
• Students understand 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. (K2)
• Students understand the specific 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. (K2)
• Students understand how to establish and implement a functional quality management-, quality control- and risk management-procedure/system in the life cycle of a regulated product (K3)
• Students are able to roughly evaluate a product and the manufacturing process based on the relevant national/international laws/directives/regulations and standards (K2)
• Students understand the international and European patent laws, patentability requirements, how to file a patent application and the writing of patent claims. (K2)</td></tr>
<tr><td>Content:</td><td>Regulatory affairs
• Medical device approval in EU, US and Germany</td></tr>
</table>

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	• Medicinal product/ pharmaceutical products approval in EU, USA and Germany • National and centralized registration of drugs in EU • Quality management, Risk analysis/management and GLP/GMP-regulations • Directives, regulations and guidance • Classification of the regulated products • Technical route for approval of medical devices in EU • ICH and harmonization of standards, guidance and directives 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 (2h)
Media used	Lecture, group work, interactive discussions, handouts, flip charts
Literature	1. The European Patent Convention (http://documents.epo.org/projects/babylon/eponet.nsf/0/00E0CD7FD461C0D5C1257C060050C376/$File/EPC_15th_edition_2013_de_bookmarks.pdf) 2. FDA-approvals: FDA regulated products https://www.fda.gov/NewsEvents/ProductsApprovals/ 3. EMA- EU authorization of medicines http://www.ema.europa.eu/ema/index.jsp?curl=pages/about_us/general/general_content_000109.jsp 4. EU Guidance for approval of medical devices https://ec.europa.eu/growth/sectors/medical-devices/guidance_nl

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PAM6 – Process Control (Sensors Fundamentals and Application)

<table>
<tr><td>Course of studies</td><td colspan="5">Process Analysis and Technology Management (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Process Control (Sensor Fundamentals and Applications)</td></tr>
<tr><td>Abbreviation</td><td colspan="5">PAM06</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Sensor Fundamentals and Applications</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. Ralph Lehnert</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Ralph Lehnert</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="2">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Design of Experiment</td><td>2</td><td>1</td><td>1</td><td></td></tr>
<tr><td rowspan="4">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Sensor Fundamentals and Applications</td><td>45</td><td>105</td><td>150</td><td>5</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td>Total</td><td>45</td><td>105</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">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Knowledge of physics, physical chemistry, instrumental analytics</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module students can …

• … overview the basic electrical and optical measuring methods as well as signal processing approaches. (K1)
• … understand the functional principles, designs and performance factors of physical and bio/chemical sensors. (K2)
• … analyze and perform concrete measuring tasks including designing and building simple customized sensors. (K4)
• … select, put into operation, implement and operate commercial sensors and sensor systems in laboratory and production contexts. (K5)
• … structure and execute adequate basic post-acquisition signal processing and data evaluation. (K4)
• … work in a systematic, self-organized and target-oriented manner, alone as well as part of a team. (K6)</td></tr>
<tr><td>Content</td><td colspan="5">The course consists of lectures 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</td></tr>
</table>

Study and exam requirements	Written examination (2h) and term paper (submitting solutions to given theoretical and/or practical problem/s), term paper contributes at most 30% to overall module grade, depending on extent and degree of difficulty
Media used	Lecture, board, overheads, lecture notes, handouts, exercise sheets
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

<table>
<tr><td>Course of studies</td><td colspan="5">Process Analysis and Technology-Management (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Scientific Methods 2: Multimodal Data Generation and Analysis (MDGSA)</td></tr>
<tr><td>Abbreviation</td><td colspan="5">PAM07
(identical with Module ACM10 in Master study programme Applied Chemistry)</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Multimodal Data Generation and Analysis I
• Multimodal Data Generation and Analysis II</td></tr>
<tr><td>Semester</td><td colspan="5">2</td></tr>
<tr><td>Person responsible for the module</td><td colspan="5">Prof. Dr. Karsten Rebner</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Karsten Rebner</td></tr>
<tr><td>Language</td><td colspan="5">English and German</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">Mandatory</td></tr>
<tr><td rowspan="3">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Multimodal Data Generation and Analysis I</td><td>1</td><td>1</td><td></td><td></td></tr>
<tr><td>Multimodal Data Generation and Analysis II</td><td>1</td><td>1</td><td></td><td></td></tr>
<tr><td rowspan="4">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Multimodal Data Generation and Analysis I</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Multimodal Data Generation and Analysis II</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Total</td><td>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">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Basic data handling procedures, data base structures</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module students:
• are able to explain why multimodal effects impact the collection, monitoring, storage, analysis and reporting of data. (K2)
• applying the combination of different measuring methods and how information can be generated with respect to chemical, pharmaceutical and biotechnological processes (K3)</td></tr>
</table>

	• checking errors and how to consider errors in decision strategies including interpretation, classification and comparison of the results obtained using different analytical and mathematical methods. (K4) • evaluate combined methods including multi-bloc methods and parallel factor analysis in contrast to the strategy of multivariate data analysis investigating many variables of one method. (K5) • are able to work in a self-organized manner and as a member of a team and do their work target-oriented and systematically. (K5) • design solutions and identify big data problems and are able to recast problems as data science questions. (K6)
Content	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 processes. Besides temperature, pressure, flow, density and filling level specific data arising from spectroscopic techniques. 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. <u>Multimodal Data Generation and Analysis I:</u> • Data handling, big data and smart data • Machine Learning Concepts - *Applying Unsupervised Learning*: Hierarchical Clustering, Soft Clustering Algorithms; Dimensionality Reduction Techniques • Machine Learning Concepts - *Applying Supervised Learning*: Support Vector Machine (SVM), Neural Network, Discriminant Analysis <u>Multimodal Data Generation and Analysis II:</u> • Data pre-processing, feature selection and transformation of three-dimensional fluorescence spectra (excitation, emission, intensity) • Three-Way Component and Regression Modelling: Parallel factor analysis (PARAFAC) • Hyperspectral imaging data collection and data analysis of three-dimensional hypercube • Analysis of data from combination of fluorescence spectroscopy, NMR (Nuclear Magnetic Resonance)

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	spectroscopy and LC-MS (Liquid Chromatography - Mass Spectrometry
Study and exam requirements	Analysis and evaluation of an external data set on the computer (2h)
Media used	Software: Matlab PLS Toolbox, Unscrambler (Camo)
Literature	1. An Introduction to Machine Learning, Miroslav Kubat, Springer 2. Multi-way Analysis: Applications in the Chemical Sciences, Rasmus Bro, ISBN-13: 978-0471986911; Wiley 3. Applied Multiway Data Analysis; Pieter M. Kroonenberg, Wiley

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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	none					
Recommended knowledge / course work						
Module goals / desired outcome	After successful completion of this module, students are able to: • understand how search engines and citation management programs function and can be used (K2). • use relevant literature data bases with respect to scientific publications, patents, reviews, and monographs (K3). • conduct systematic and efficient scientific literature searches (source identification and exploitation) (K3). • cary out complete multivariate analyses of complex data sets (K3).					

	• cite and organize literature correctly according to respective scientific standards and to save citations using citation managers (K4) • work in a self-organized manner and as a member of a team and do their work target-oriented and systematically (K4) • evaluate and efficiently document relevant publications and text/content therein (K5). • design new multivariate models for a given data set (K6)
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 component analysis (PCA), partial least squares regression (PLS) and cluster analysis
Study and exam requirements	Written examination (2h) and presentation (Presentation contributes with a weight of maximal 30% to overall module grade, depending on extent and difficulty).
Media used	Lecture, board, overheads, lecture notes, handouts, exercise sheets, software practicals in CIP-pool
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. Andreas Kandelbauer
Instructor	Prof. Dr. Kandelbauer, Prof. Dr. Rebner, Prof. Dr. Lehnert, Prof. Dr. Lorenz, Prof. Dr. Brecht, Dr. Kutuzowa, 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	For reasons of occupational safety, the students have to prepare the theoretical and practical contents of the module prior to starting practical work in the laboratory. Proof of this is provided by successful participation in a safety and / or introductory colloquium (written or oral).
Recommended knowledge / course work	Physics, chemistry, mathematics
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 specific research question. POL-2 is a continuation of POL-1 (PAM-03) After successful completion of this module: • Students understand the scientific methodology and can define, perform and control a research project. (K2) • Students professionally apply tools for practical project management (action items, meeting organization, work documentation, efficient use of resources, coordination, etc.). (K4) • Students are familiar with specific scientific and technological methods as well as materials depending on the specific actual research question. (K2)

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	• Students use technical and scientific databases effectively. (K3) • Students formulate scientific hypotheses, plan and performing experiments, adapt and apply appropriate scientific equipment, perform accurate measurements and formulate project reports. (K5) • Students properly present and scientifically sound defense their own findings in front of a panel of experts (= council of supervisors) (K5) • Students discuss competently experimental results in the light of the state of the art and comparing own findings to the scientific literature. (K4) • Students assimilate to novel research questions, adapt to / orientate in a new field. (K5) • Students are able to work in a self-organized manner and as a member of a team and do their work target-oriented and systematically. (K6)
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	Final project report (70%) Final project defense (30%), including oral presentation and poster presentation
Media used	Lecture, board, digital projector, handouts
Literature	1. Chalmers AF (2007) Wege der Wissenschaft. Einführung in die Wissenschaftstheorie, 6. Auflage, Nachdruck, Springer 2. Patzak G, Rattay G (2004) Projektmanagement, 4. Auflage, Linde International 3. Baguley P (1999) Optimales Projektmanagement, Falken 4. Scientific Original papers, depending on the specific research question 5. H.F. Ebel et al. (2006) Schreiben und Publizieren in den Naturwissenschaften, Wiley-VCH Weinheim.

<table>
<tr><td>Course of studies</td><td>Process Analysis and Technology-Management (MSc)</td></tr>
<tr><td>Module</td><td>Process Analytical Technology II</td></tr>
<tr><td>Abbreviation</td><td>PAM10</td></tr>
<tr><td>Course(s)</td><td>Sampling and Sample Preparation SSP
Measuring and Control Technology MCT</td></tr>
<tr><td>Semester</td><td>2</td></tr>
<tr><td>Person responsible for the module</td><td>Prof. Dr. Karsten Rebner</td></tr>
<tr><td>Instructor</td><td>Prof. Dr. Karsten Rebner</td></tr>
<tr><td>Language</td><td>English</td></tr>
<tr><td>Status within the curriculum</td><td>Mandatory</td></tr>
<tr><td>Type of course / WH</td><td><table>
<tr><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Sampling and sample preparation</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>Measuring and Control Technology</td><td>2</td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Workload in hours</td><td><table>
<tr><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Sampling and sample preparation</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Measuring and Control Technology</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Total</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
</table></td></tr>
<tr><td>Credit points</td><td>5</td></tr>
<tr><td>Prerequisites for attending this course</td><td>none</td></tr>
<tr><td>Recommended knowledge / course work</td><td>basic knowledge of measurement of physical and chemical analytical methods</td></tr>
<tr><td>Module goals / desired outcome</td><td>After successful completion of this module, students are able to:
identify state of the art extraction techniques for organic and inorganic analytes (K1).
explain sampling preparation techniques in biological measurements (K2).
understand the reasons why sampling is often unreliable and apply ways to improve it (K2).
compare laboratory and process analytical methods and results of applications in the field and in the lab (K2).
apply sampling strategies and measurement and control techniques together within industrial and non-industrial monitoring systems (K3).
apply strategies to make samples compatible to the analyzers they serve (K3).</td></tr>
</table>

	• compare a wide range of rather simple sensors as used to measure temperature, pressure, humidity, acceleration and density (K4) • outlining online process analytical methods with chemical background like FTIR, NIR, MIR, MS, GC/MS, MCC/IMS, LC/MS (K4) • analyze sensor, spectrometric and spectroscopic data with respect to remote process control (K4). • differentiate on-line, in-line, at-line and off-line methods including sampling strategies and control technologies (K4). • evaluate time delay effects in process segments of sample transport lines (K5). • evaluate existing or proposed locations for the sampling nozzle and make a decision (K5). • design and construct complete analyzer sampling systems (K6).
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, … • 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) 70%, presentation 30%
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

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
Semester	2
Person responsible for the module	Prof. Dr. Marc Brecht
Instructor	Prof. Dr. Marc Brecht
Language	English
Status within the curriculum	Mandatory

Type of course / WH

Course	L	E	LW	S
Microscopy and Optics	4			

Workload in hours

Course	Class attendance	Study outside of class	Total	CP
Microscopy and Optics	60	90	150	
Total	60	90	150	5

Credit points	5
Prerequisites for attending this course	none
Recommended knowledge / course work	Fundamental knowledge of optics, sensors and spectrometers, basic physics
Module goals / desired outcome	After successful completion of this module students: • have a detailed knowledge of geometrical and ray optics (K1) • understand the formation of images by mirrors and lenses (K2) • understand the difference between geometrical and wave optics (K2) • are able to solve problems of intermediate complexity (K3) • are able to construct images formed by a simple lens system (e.g. a microscope) (K3) • have a profound knowledge of the most relevant microscopic techniques (K1) • are able to assign a problem to the most relevant microscopy techniques (K4) • are able to analyze a given microscopy technique and find out the most relevant relations (K4) • create and give an oral presentation about a microscopic technique for other students (K6)
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

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	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 given.
Study and exam requirements	Study requirements without marks: • 2-3 group presentations of articles/papers/reviews • 1 presentation about a topic announced in the first week • 1-2 mandatory exercises Exam requirement: Written examination 100 % (2h)
Media used	PowerPoint slides, flip charts, board, experiments
Literature	1. Hecht, E.: Optics, Addison-Wesley, 2001 2. Demtröder, W.: Laser spectroscopy I & II, Springer; 5th ed. 2014 3. Murphy, D.B.: Fundamentals of Light Microscopy and Electronic Imaging, Wiley-Blackwell; 2nd ed. 2012 4. 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	An elective module may be selected from the “catalogue elective modules” in the study and examination regulation. After approval by the Examination Board, courses from other faculties, colleges or universities may be selected. The elective module catalogue can be extended by decision of the examination board.
Recommended knowledge / course work	Depends on elective
Module goals / desired outcome	Depends on elective
Content	Depends on elective

Study and exam requirements	Student must document successful participation in a university course
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's 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	The master's thesis module may only be started if at least 45 ECTS credits have been earned from the modules of semesters 1 and 2. The modules PAM2, PAM3, PAM7, PAM8 and PAM9 must be completed.
Recommended knowledge / course work	Successful completion of research project
Module goals / desired outcome	After successful completion of this module: • Students perform detailed and in-depth research on a defined scientific field of study.(K6) • Students work independently in a team on a defined research project.(K4) • Students evaluate and implement insights / findings of scientific literature.(K5) • Students prepare and present scientific results.(K3) • Students apply modern adequate strategies for finding scientific solutions.(K4) • Students promote team work in a research group.(K4)
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 supervision of a professor of our faculty. Their work will culminate in a master's thesis, to be written by each student individually and

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	independently. The thesis work may also be done in an industrial R &/or D 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's Thesis: The processing time for the master's thesis is six months. 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 (Add. Module only for stud. with 180 ECTS BSc'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	If the first academic degree required for this Master's degree program is less than 210 ECTS credits, any missing ECTS credits, as determined by the Examination Board, can be made up through an internship semester. The internship semester must be completed at the latest before the beginning of the master's thesis.
Recommended knowledge / course work	Successful completion of semesters 1 and 2
Module goals / desired outcome	After successful completion of this module: • Students have a profound insight into the structure, organization and operations of an industrial company or a research institution. (K2) • Students are aware of the independent processing of specific tasks within projects. (K2) • Students are able to determine the status of development / research by literature search. (K4) • Students have acquired the skills for independent implementation of projects. (K4) • Students have gained the competence for a systematic and a structured approach. (K5) • Students have gained the competence to work scientifically. (K6) • Students have experienced the manners and practices in the work environment. (K2) • Students have improved their team and communication skills through participation in the working group.(K3) • Students interact successfully in intercultural surroundings.(K4)

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	The internship semester is supervised and regulated by the School of Applied Chemistry which awards 30 ECTS credits for the successful completion of the internship. Exam components are: Continuos assessment, regular reporting, preparation of a project report manuscript, certificate of the internship site. Further details are regulated by a guideline of the examination board.
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

<table>
<tr><td>Course of studies</td><td colspan="5">Angewandte Chemie (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Specialized polymer analytical methods</td></tr>
<tr><td>Abbreviation</td><td colspan="5">ACM01</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Thermal Analysis and Process Safety
• Rheology</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. Andreas Kandelbauer</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Andreas Kandelbauer
Prof. Dr. Roy Hornig</td></tr>
<tr><td>Language</td><td colspan="5">German</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">Mandatory in ACM / elective in others</td></tr>
<tr><td rowspan="3">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Thermal Analysis and Process Safety</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>Rheology</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Thermal Analysis and Process Safety</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Rheology</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Total</td><td>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">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Physics, chemistry, mathematics</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module:

• Students understand 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. (K2)
• Students understand the determination of basic characteristic values of material constants (melting points, glass transition temperatures, reaction enthalpies, etc.). (K2)
• Students derive complex information from calorimetric and rheometric measurements (reaction kinetics, activation energy barriers, thermal stability parameters, etc.). (K3)
• Students derive relevant data in the context of thermal process safety. (K3)
• Students derive and predict technologically important information regarding process windows, process optimization and process safety. (K4)</td></tr>
</table>

	• Students set-up complex experiments in order to study the physical / chemical systems (guidelines for thermal and rheological analysis). (K5) • Students apply specialized data treatment methods. (3) • Students apply mathematical methods for Data treatment (kinetic modelling). (K3) • Students apply commercial software packages. (K3) • Students select appropriate thermal and rheological analysis protocols depending on the problem. (K3) • Students critically examine experimental results. (K4) • Students correctly apply thermal and rheological material data and application of these data for process understanding and optimization. (K4) • Students interpret such technical systems in the students' future careers or to virtually understand, operate and master complete processes based on the acquired knowledge. (K5) • Students assess critically conventional solutions to improve or to replace them with new solutions. (K6)
Content	1. Thermal Analysis and Process Safety • Basics and application of standard and advanced thermal analytical and calorimetric methods in the 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

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	• Recognize faulty measurements • Determinationof viscoelastic properties of liquids and solids • Systematics of rheological analysis
Study and exam requirements	Written examination (2h)
Media used	Lecture, board, digital projector, handouts
Literature	1. Ehrenstein GW, Riedel G, Trawiel, Thermal Analysis of Plastics: Theory and Practice, Hanser, 2004 2. Frick A, Stern C, DSC-Prüfung in der Anwendung, Hanser, 2013 3. Sarge SM, Höhne GWH, Hemminger W, Calorimetry. Fundamentals, Instrumentation, and Applications, Wiley, 2014 4. Stoessel F, Thermal Safety of Chemical Processes. Risk Assessment and Process Design, Wiley, 2008 5. Vyazovkin S, Isoconversional Kinetics of Thermally Stimulated Processes, Springer, 2015 6. Wissenschaftliche Originalliteratur (Aufgaben-bezogene Artikel aus peer-reviewed Zeitschriften) 7. Brummer R, Rheology Esseentials of Cosmetic and Food Emulsions, Springer Berlin, 2005 8. Mezger Th, The Rheology Handbook, Vincentz, 2006 9. Schramm G, Einführung in die Rheologie und Rheometrie, Gebr. Haake, Karlsruhe

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<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. Krastev, Prof. Dr. Kuhn, Prof. Dr. Lorenz, Prof. Dr. Kandelbauer, Prof. Dr. Bell</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="3">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 rowspan="4">Workload in hours</td><td>Course</td><td>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>60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td>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">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Physics, chemistry, mathematics</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module:

• Students understand the important fundamentals in chemical engineering.(K2)
• Students understand the importance of mechanical and thermal unit operations.(K2)
• Students apply the mechanical and thermal unit operations, which are important in the assessment of devices or equipment in the process engineering industries.(K4)
• Students discuss important examples of industrial chemical and bio chemical plants.(K4)
• Students apply principles of reaction safety in calculations for technical processes.(K3)
• Students understand the importance of membrane technology in chemical engineering and govern methods based on it.(K4)</td></tr>
</table>

	• Students understand the principles and different aspects of polymer engineering processes.(K2) • Students understand the principles and different aspects of biotechnological processes.(K2) • Students understand the principles and different aspects of downstream processes.(K2) • Students interpret such technical systems in the students' future careers or virtually understand, operate and master complete processes based on the acquired knowledge. (K5) • Students assess critically conventional solutions, to improve or to replace them with new solutions. (K4) • Students have developed and strengthened their team and communication skills.(K4)
Content	**1. Practical fundamentals in process engineering (Honnen) / 6 blocks á 90 Min.** a. Definition of process engineering b. Similarities and differences of processes (example: cement production and reforming process) c. Definition of unit operations d. Flow diagrams as the important communication tool in process engineering e. Discussion of practical Examples of characteristic industrial processes by means of Worksheets **2. Thermal Reaction Safety (Kandelbauer) / 4 blocks á 90 Min.** a. Thermal Reaction Safety b. Technical Aspects of Reactor Safety c. Assessment of Thermal Process Safety d. Selected Inorganic Technological Processes (optional) **3. Membrane Technology in Chemical Engineering (Bell) / 2 blocks á 90 Min.** a. Introduction to Membrane Technology b. Applications c. Separation Mechanism d. Membrane Structures e. Membrane Preparation f. Membrane Processes g. Membrane Modules h. Applications, Segments and Markets i. Membranes for Medical Applications **4. Polymer Engineering (Lorenz) / 6 blocks á 90 Min.** a. Polymer Melts b. Extrusion c. Molding Processes d. Production of sheets and films

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	e. Fibres and Filaments **5. Biotechnology and bioprocess engineering (Krastev) / 6 blocks á 90 min.** a. Biotechnology b. Bio catalytic process engineering c. Bio catalytic processes - examples **6. Downstream Processing (Kuhn) / 6 blocks á 90 Min.** a. Preparative chromatography b. Extraction (liquid-liquid E.; supercritical fluid E.; solid-phase E.) c. Analytical and preparative centrifugation
Study and exam requirements	Written examination (2h)
Media used	Lecture, board, digital projector, handouts
Literature	1. Jess, Andreas; Wasserscheid, Peter: Chemical Technology, An Integral Textbook, Wiley-VCH (2013) 2. McCabe, Warren L.; Smith, Julian C.;Harriott, Peter: Unit Operations of Chemical Engineering, International Edition, McGraw-Hill Higher Education, 7th ed. (2005) 3. Doran, Pauline M.: Bioprocess Engineering Principles, Academic Press, 2. ed. (2012) 4. Katoh, Shigeo; Horiuchi, Jun-ichi; Yoshida, Fumitake: Biochemical Engineering, A Textbook for Engineers, Chemists and Biologists, Wiley-VCH , 2nd, rev. and enl. ed. (2015)

ACM7 – Polymer Based Materials 2 (in German language)

<table>
<tr><td>Course of studies</td><td colspan="5">Angewandte Chemie (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Polymer-basierte Materialien 2</td></tr>
<tr><td>Abbreviation</td><td colspan="5">ACM-07</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Polymere und Flüssigkristalle / Selected Soft Materials
• Hybridwerkstoffe / Hybrid Materials</td></tr>
<tr><td>Semester</td><td colspan="5">2</td></tr>
<tr><td>Person responsible for the module</td><td colspan="5">Prof. Dr. Ralph Lehnert</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Ralph Lehnert (Polymere und Flüssigkristalle)
Prof. Dr. Roy Hornig (Hybridwerkstoffe)</td></tr>
<tr><td>Language</td><td colspan="5">Deutsch</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">Pflichtmodul in ACM / elective in others</td></tr>
<tr><td rowspan="3">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Polymere und Flüssigkristalle</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>Hybridwerkstoffe</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Polymere und Flüssigkristalle</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Hybridwerkstoffe</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Total</td><td>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">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Physik, Chemie, Mathematik</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">Nach erfolgreicher Teilnahme an diesem Modul können die Studierenden...

• ... die Eigenschaften, Ordnungszustände, Strukturbildung und Phasenübergänge verschiedener Arten weicher Materie verstehen.(K2)
• ... die Zusammenhänge zwischen mikroskopischen Eigenschaften, mesoskopischer Ordnung und makroskopischen Materialeigenschaften mit Schwerpunkt auf Struktur-Funktionalitätsbeziehungen und Grenzflächen verstehen und analysieren. (K4)
• ... die Kompatibilität zwischen verschiedenen Materialien (organisch, polymer, elastomer, anorganisch, metallisch) verstehen, bewerten und Voraussagen hierzu entwickeln.(K5)</td></tr>
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<table>
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… technologische Verfahren zur Herstellung von Hybrid- und Verbundmaterialien (Formulierung, Compoundierung, etc.) beschreiben und deren Einsetzbarkeit in konkreten Problemen beurteilen.(K4)
… geeignete Materialien für vorgegebene Anwendungen / Eigenschaftsprofile (z.B. Polymere, Lösemittel, Elastomere, Haftvermittler) evaluieren und auswählen.(K5)
… die Anwendungsbreite und Limitation bestehender Materialien und Technologien einschätzen.(K5)
… Vorgehensweisen zur Werkstoffkompatibilisierung entwickeln.(K6)

</td></tr>
<tr><td>Content</td><td>
1. 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 Adhäsion und Klebstoffe
Kompatibilität zwischen Polymeren, Anorganika und Metallen
Reinigung und Aktivierung von Substratoberflächen
Chemie und Technologie der Haftvermittler
Technologie ausgewählter Polymer-Metallverbunde
Prüfverfahren und Qualitätskontrolle

</td></tr>
<tr><td>Study and exam requirements</td><td>Klausur 2h und Präsentation (Beitrag der Präsentation zur Modulnote maximal 20%, abhängig von Umfang und Schwierigkeitsgrad)</td></tr>
<tr><td>Media used</td><td>Tafelanschrieb, Overheads, Skriptum, Tischvorlagen</td></tr>
<tr><td>Literature</td><td>
1. Gedde, UW, Polymer Physics, Kluwer Academic Publishers, 2001
2. Jones, R. A. L.: Soft Condensed Matter, Oxford University Press, 2002
3. Hamley, I, Introduction to Soft Matter. Synthetic and Biolological Self-assembling Materials, Wiley, 2000
4. Kickelbick G, Hybrid Materials, Wiley-VCH, 2008
5. Stokes RJ, Evans DF, Fundamentals of Interfacial Engineering, Wiley-VCH, 1997
6. Plüddemann EP, Silane Coupling Agents, 2nd edition, Kluwer, 1991
7. Mittal KL, Pizzi A, Adhesion Promotion Techniques. Technological Applications, Marcel Dekker, 2002
8. Ausgewählte wissenschaftliche Originalarbeiten und Review-Artikel
</td></tr>
</table>

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ACM8 – Polymer Based Materials 1 (in German language)

<table>
<tr><td>Course of studies</td><td colspan="5">Angewandte Chemie MSc</td></tr>
<tr><td>Module</td><td colspan="5">Polymer-basierte Materialien 1</td></tr>
<tr><td>Abbreviation</td><td colspan="5">ACM-08</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Advanced Materials
• Product Functionality Design</td></tr>
<tr><td>Semester</td><td colspan="5">2</td></tr>
<tr><td>Person responsible for the module</td><td colspan="5">Prof. Dr. Andreas Kandelbauer</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Andreas Kandelbauer (Advanced Materials)
Prof. Dr. Richard Schilling (Product Functionality Design)</td></tr>
<tr><td>Language</td><td colspan="5">Deutsch</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">Pflichtmodul in ACM / elective in others</td></tr>
<tr><td rowspan="3">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Advanced Materials</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>Product Functionality Design</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Advanced Materials</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Product Functionality Design</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Total</td><td>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">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Physik, Chemie, Mathematik</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">Nach erfolgreichem Abschluss dieses Moduls:
• Studierende verfügen über ein vertieftes Grundlagenwissen ausgewählter materialwissenschaftlicher Inhalte mit Schwerpunkt auf Struktur-Funktionalitätsbeziehungen. (K1)
• Studierende können anwendungsorientierte Fragestellungen der wechselseitigen Abhängigkeit zwischen Materialfunktionalität und Produkteigenschaften diskutieren. (K3)
• Studierende verstehen die Eigenschaften und Strukturen von Hochleistungspolymeren und deren Anwendungen. (K2)
• Studierende verstehen die Architekturen und den Chemismus verschiedener Nanomaterialien, Hochleistungspolymere und Polymerverbundwerkstoffe. (K2)</td></tr>
</table>

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	• Studierende kennen die speziellen Strategien zur Performanceverbesserung von Werkstoffen. (K1) • Studierende verstehen die Prinzipien der Verbundwerkstofftechnologie, Herstellungs- und Verarbeitungsverfahren. (K2) • Studierende verfügen über Methodenkompetenz für eine funktionsgerechte, designorientierte Materialauswahl und ein materialgerechtes Design. (K3) • Studierende verfügen über Problemlösungskompetenz zur Formulierung von Design- und Materialanforderungsprofilen. (K3) • Studierende verstehen materialwissenschaftliche Aspekte von Relevanz für Anwendung und F&E in Polymerindustrie, Medizinprodukte-Industrie und Werkstoffentwicklung. (K2) • Studierende verstehen, wie makroskopische Eigenschaften von mikroskopischen Eigenschaften abhängen. (K2) • Studierende sind fähig, über wissenschaftliche Literatur und Datenbanken relevante Materialien für bestimmte Anwendungen / Eigenschaftsprofile auszuforschen. (K4) • Studierende suchen und wählen analytisch-systematisch komplexe Materialsysteme anhand von Material- und Produktlastenheften aus. (K4) • Studierende beherrschen den Umgang mit Software zur Materialauswahl, Eigenschaftsvorhersage und Prototypenkonstruktion. (K4) • Studierende setzen funktionale Materialkonzepte von der Modellbildung bis zum Prototypen um. (K5) • Studierende können Anwendungsbreite und Limitation bestehender Materialien und Technologien benennen. (K4) • Studierende verfügen über Zusammenhangswissen zur Lösung materialwissenschaftlicher Problemstellungen. (K3) • Studierende wählen Materialien unter technologischen und Designgesichtspunkten aus. (K4)
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

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	• 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	Klausur 2h (85%), Hausarbeit mit Präsentation zum Bereich Advanced Materials (15%)
Media used	PPT, Tafelanschrieb, Overhead-Folien, Skriptum, Tischvorlagen, Formelsammlungen, Übungen
Literature	1. Ullmann´s Encyclopedia of Industrial Chemistry, Wiley 2012 2. Ghosh SK, Self-Healing Materials, Wiley, 2012 3. Krueger A, Carbon Materials and Nanotechnology, Wiley, 2012 4. Dodiuk H, Goodman S, Handbook of Thermosetting Plastics, CRC / Elsevier, 2014 5. KLumar C, Nanomaterials for the Life Sciences (Series) Vols. 1-10, Wiley, 2012 6. Current scientific original papers 7. Kickelbick G, Hybrid Materials, Wiley-VCH, 2008 8. Stokes RJ, Evans DF, Fundamentals of Interfacial Engineering, Wiley-VCH, 1997 9. Methodik der Werkstoffauswahl: Der systematische Weg zum richtigen Material, Carl Hanser Verlag GmbH & Co. KG; Auflage: 1 (2006), ISBN-10: 9783446406803 10. 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 11. Software: CES Edu Pack 2013, Grantadesign, Cambridge

BMS1 – Analytical Methods in Biomedical Sciences

Course of studies	Biomedical Sciences (MSc)
Module	**Analytical Methods in Biomedical Sciences**
Abbreviation	BMS1
Course(s)	• Analytical Methods in Biomedical Sciences • Diagnostic Technologies
Semester	1
Person responsible for the module	Prof. Dr. Reinhard Kuhn
Instructor	Prof. Dr. Reinhard Kuhn Prof. Dr. Ralf Kemkemer
Language	English
Status within the curriculum	Mandatory in BMS / elective in others

Type of course / WH

Course	L	E	LW	S
Analytical Methods in Biomedical Sciences	1			1
Diagnostic Technologies	2			

Workload in hours

Course	Class attendance	Study outside of class	Total	CP
Analytical Methods in Biomedical Sciences	30	45	75	
Diagnostic Technologies	30	45	75	
Total	**60**	**90**	**150**	**5**

Credit points	5
Prerequisites for attending this course	none
Recommended knowledge / course work	Knowledge of biochemistry, bioanalysis, instrumental analytics, chemistry, biology
Module goals / desired outcome	After successful completion of this module: • Students have a profound overview of current bioanalytical and diagnostic techniques that are significant in biomedical and pharmaceutical research and routine applications.(K1) • Students profoundly understand technologies and functioning of laboratory diagnostics and applications.(K2) • Students are able to analyze and evaluate current research literature and elaborate scientific seminars.(K4) • Students understand complex relationships in bioanalysis.(K2)

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	• Students understand interrelations of current fundamental research fields, e.g. proteomics, protein-based assay systems etc., and are able to utilize public data banks.(K2) • Students understand the principles of structure of diagnostic systems and prerequisites for certain applications.(K2) • Students are able to understand the potential and limitations of existing technologies.(K2) • Students are able to evaluate various methods of modern cell culture techniques and laboratory diagnostics.(K5)
Content	**Analytical Methods in Biomedical Sciences** The course consists of a lecture and a seminar. Students must choose a research topic from a given list and present a scientific seminar. The following fields of study will be covered in the lecture and seminars: • Proteomics • Protein-based assays • Biomarkers • Selected topics of bioanalysis, e.g. Clinical laboratory diagnostics, blotting techniques, two-hybrid systems, FRET, CRISPR/Cas, etc. **Diagnostic Technologies** Structure, function and application of advanced laboratory diagnostic methods, in particular • micro-technologies and microfluidics, • lab-on-a-chip technology, • Cell counting and sorting, • advanced microscopy.
Study and exam requirements	Written examination (2h), presentation, term paper; final grade is calculated from written exam (70%) and seminar presentation (30%)
Media used	Lecture, script as download, board, student presentations, digital projector, handouts, research literature
Literature	1. Rehm, H., Letzel, T.: Der Experimentator – Proteinbiochemie/Proteomics, Spektrum Verlag 2. Vishal, S.: Biomarkers in Medicine, Drug Discovery and Environmental Health, Wiley 3. Matson, R.S.: Applying Genomic and Proteomic Microarray Technology in Drug Discovery, CRC Press 4. Lovric, J.: Introducing Proteomics, Wiley-Blackwell 5. Russel, S., Meadows, L.A., Russel, R.R.: Microarray Technology in Practice, Academic Press

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	6. Issaq, H.J.: Proteomic and Metabolomic Approaches in Biomarker Discovery, Academic Press 7. Lämmerhofer, M.: Metabolomics in Practice, Wiley-VCH 8. 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 9. Scientific publications

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<table>
<tr><td>Course of studies</td><td>Biomedical Sciences (MSc)</td></tr>
<tr><td>Module</td><td>Materials and Applications in Biomedical Sciences</td></tr>
<tr><td>Abbreviation</td><td>BMS2</td></tr>
<tr><td>Course(s)</td><td>• Functional Implants & Surface Technologies
• Drug Release and Delivery Systems</td></tr>
<tr><td>Semester</td><td>1</td></tr>
<tr><td>Person responsible for the module</td><td>Prof. Dr. Rumen Krastev</td></tr>
<tr><td>Instructor</td><td>Prof. Dr. Rumen Krastev
Prof. Dr. Ralf Kemkemer</td></tr>
<tr><td>Language</td><td>English</td></tr>
<tr><td>Status within the curriculum</td><td>Mandatory in BMS / elective in others</td></tr>
<tr><td>Type of course / WH</td><td><table>
<tr><td>Course</td><td>L</td><td>E</td><td>LW</td><td>S</td></tr>
<tr><td>Drug Release and Delivery Systems</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>Functional Implants & Surface Technologies</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table></td></tr>
<tr><td>Workload in hours</td><td><table>
<tr><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Drug Release and Delivery Systems</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Functional Implants & Surface Technologies</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Total</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
</table></td></tr>
<tr><td>Credit points</td><td>5</td></tr>
<tr><td>Prerequisites for attending this course</td><td>none</td></tr>
<tr><td>Recommended knowledge / course work</td><td>Basic understanding (BSc-level) of chemistry, biology and biomedical technology, material sciences</td></tr>
<tr><td>Module goals / desired outcome</td><td>After successful completion of this module:

- Students know the materials for biomedical application in in-vitro and in-vivo applications. (K1)</td></tr>
</table>

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	- Students understand the technologies for surface modifications for implants and related methods. (K2) - Students know biomedical implant technologies - application examples and challenges. (K1) - Students understand drug delivery concepts and application of polymers. (K2) - Students understand drug release methods, kinetics and applications. (K2) - Students will be able to understand surface and polymer chemistry technologies and transfer these to appropriate applications in the biomedical field. (K2) - Students will be able to identify technical working principles of complex implants. (K3) - Students will be able to understand the complexity of tissue-material interaction and relate this to material properties. (K2) - Students will be able to classify the suitability of different materials classes for specific applications. (K3) - Students will be able to analyse limitations of current technologies in the field. (K4) - Students develop skills in research, reading and interpretation of scientific texts. (K4) - Students gain an awareness of ethical aspects in the development of medical products. (K3)
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. Relation of diagnostic and delivery – theranostic. Approaches, formulations, technologies, and systems for transporting of active pharmaceutical compounds as needed to achieve the desired therapeutic effect. Release based on diffusion, degradation, swelling, and affinity-based mechanisms. Current approaches – site and time specific targeting, facilitated pharmacokinetics. Immobilisation and delivery of "biologicals" e.g. peptides, proteins, antibodies, vaccines and gene based drugs

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	Examples for release techniques – thin polymer film delivery. Acoustic, light, magnetic initiated targeted delivery. Liposomal delivery. Polyplexes and RNA delivery.
Study and exam requirements	Written examination (2h)
Media used	PowerPoint slides, flip charts, board
Literature	1. Zilberman, Meital (Eds.) Active Implants and Scaffolds for Tissue Regeneration, Springer 2011 2. A. Tripathi, J.S. Melo (Eds.) Advances in Biomaterials for Biomedical Applications, Springer 2017 3. T. Kawai, M. Hashizume (Eds.) Stimuli-Responsive Interfaces - Fabrication and Application, Springer 2017 4. Ritter A.B., et al.: Biomedical Engineering Principles, CRC Press, 2012 5. Wintermantel E., H. Suk-Woo Ha: Medizintechnik: Life Science Engineering, Springer 2009 6. F. Rossi, G. Perale, M. Masi Controlled Drug Delivery Systems - Towards New Frontiers in Patient Care, Springer 2016 7. Narayan R.: Biomedical Materials, Springer Publisher, 2009 8. Ratner B.D. et al.: Biomaterial Sciences, Elsevier Oxford, 2012 9. King M.R.: Principles of Cellular Engineering – Understanding the Biomolecular Interface, Academic Press, 2006

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

<table>
<tr><td>Course of studies</td><td colspan="5">Biomedical Sciences (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Industry-Related Topics 1</td></tr>
<tr><td>Abbreviation</td><td colspan="5">BMS3</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Drug Discovery & Development
• Introduction into Medical Technology</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. Alexander Schuhmacher</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Alexander Schuhmacher, Dr. Wiedmann
Prof. Dr. Günter Lorenz, Dr. Schüle</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">Mandatory in BMS / elective in others</td></tr>
<tr><td rowspan="3">Type of course / WH</td><td>Course</td><td>L</td><td>E</td><td></td><td></td></tr>
<tr><td>Drug Discovery & Development</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>Introduction into Medical Technology</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Drug Discovery & Development</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Introduction into Medical Technology</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Sum</td><td>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">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Basic understanding, knowledge of the principles of pharmaceutical and medical technology industries
Basic knowledge of natural sciences</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module:

• Students have a basic knowledge of the pharmaceutical and medical technology industries.(K1)
• Students understand the strategic and operational topics concerning drug discovery, drug development, medical and biomedical technologies.(K2)
• Students understand state-of-the-art developments, research, and expert opinions in the pharmaceutical industry.(K2)
• Students understand the key success factors in research and development (R&D) as well as value creators in pharmaceutical innovation.(K2)
• Students understand the innovation process, pharmaceutical R&D, research and innovation strategies. (K2)
• Students will gain an overview of the pharmaceutical industry and how pharmaceutical R&D works operationally.(K1)</td></tr>
</table>

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	• 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). (K2) • Students understand the definition of biomedical engineering and the basic principles and medical background of different technologies.(K2) • Students understand and use new vocabulary, read, summarize and discuss scientific topics and prepare and present scientific results in the form of short presentations in teams.(K4)
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 **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

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	• Stent • Heart valve • Cochlear • Retinal
Study and exam requirements	written examination (2h)
Media used	Lecture, group work, interactive discussions, handouts, flip charts
Literature	1. 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 2. Ratner, B. D., Hoffman A.S. et al. (eds.): Biomaterials Science - An Introduction to Materials in Medicine, Elsevier Academic Press, 2004 3. Joseph Bronzino and Donald R. Peterson : The Biomedical Engineering Handbook, Fourth Edition: Four Volume Set, Crc Pr Inc; 2015 4. Pierre Morgon (2014) Sustainable Development in the Healthcare System, Springer

<table>
<tr><td>Course of studies</td><td colspan="5">Biomedical Sciences (MSc)</td></tr>
<tr><td>Module</td><td colspan="5">Biomedical Technologies</td></tr>
<tr><td>Abbreviation</td><td colspan="5">BMS7</td></tr>
<tr><td>Course(s)</td><td colspan="5">• Regenerative Medicine
• Biomedical Technologies - Biofabrication</td></tr>
<tr><td>Semester</td><td colspan="5">2</td></tr>
<tr><td>Person responsible for the module</td><td colspan="5">Prof. Dr. Petra Kluger</td></tr>
<tr><td>Instructor</td><td colspan="5">Prof. Dr. Petra Kluger</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Status within the curriculum</td><td colspan="5">Mandatory in BMS / 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>Biomedical Technologies</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td>Regenerative Medicine</td><td>2</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Workload in hours</td><td>Course</td><td>Class attendance</td><td>Study outside of class</td><td>Total</td><td>CP</td></tr>
<tr><td>Biomedical Technologies</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Regenerative Medicine</td><td>30</td><td>45</td><td>75</td><td></td></tr>
<tr><td>Total</td><td>60</td><td>90</td><td>150</td><td>5</td></tr>
<tr><td>Credit points</td><td colspan="5"></td></tr>
<tr><td>Prerequisites for attending this course</td><td colspan="5">none</td></tr>
<tr><td>Recommended knowledge / course work</td><td colspan="5">Cell biology, physiology, biomaterials, tissue engineering, biomedical engineering</td></tr>
<tr><td>Module goals / desired outcome</td><td colspan="5">After successful completion of this module:
• Students can define the terms and the aims of biofabrication and Regenerative Medicine. (K1)
• Students can explain automation principles and different biofabrication technologies, their characteristics and pros & cons. (K2)
• Students can describe materials and techniques used in Regenerative Medicine and classify the state of the art in various clinical applications.(K2)
• Students can predict the usability of a material as a bioink. (K3)
• Students can judge whether a biomedical product is a medicinal product or and advanced therapeutic medicinal product. (K4)</td></tr>
</table>

	• Students can compare different stem cell products and analyze their niche at the global Regenerative medicine market (K4) • Students can evaluate and hypothesize the future biomedical perspectives of various biofabrication techniques. (K5) • Students can design a virtual workflow to use biofabrication technologies to generate a product for Regenerative Medicine (K6).
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
Study and exam requirements	Written examination (2h)
Media used	Lecture, interactive discussions, group work, flip chart, PCs
Literature	1. Gustav Steinhoff, Regenerative Medicine: From Protocol to Patient, Springer 2013 2. Anthony Atala, Robert Lanza, James A., Thomson, and Robert M. Nerem, Principles of Regenerative Medicine, Elsevier, 2008 3. Ratner, B. D., Hoffman A.S. et al. (eds.): Biomaterials Science - An Introduction to Materials in Medicine, Elsevier Academic Press, 2004 4. 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 in BMS / elective in others
Type of course / WH	see table below
Workload in hours	see table below
Credit points	5
Prerequisites for attending this course	none
Recommended knowledge / course work	Knowledge of biochemistry, bioanalysis and instrumental analytics, biology, fundamentals of pharmacology
Module goals / desired outcome	After successful completion of this module: • Students gain a profound overview of current bioanalytical techniques relevant for biomedical as well as pharmaceutical research. (K1) • Students understand the mode of action of drugs the importance of DNA/RNA in context of drug actions.(K2) • Students understand drug interaction in the human organism.(K2) • Students have in-depth knowledge of Pharmacokinetics and Pharmacodynamics.(K2) • Students understand the use of modern analysis systems in personalized medicine and are able to illustrate future trends thereof.(K2) • Students understand the functioning of microarray- and gene-chip-systems.(K2)

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**

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	• Students are able to do scientific research and present scientific findings.(K4)
Content	**Analytical Methods in Biomedical Sciences** • DNA structure and isolation • Cloning and sequencing • Advanced polymerase chain reaction • DNA/RNA microarray technology • Personalized medicine • Examples of personalized medicine • Karyotype analysis **Biomedical Pharmacology** • Introduction to pharmacokinetics • Introduction to pharmacodynamics • Drug interaction • Drug impact on - stomach & gut - blood - blood vessels, kidney - heart - hormones
Study and exam requirements	Written examination (2h)
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) • S Russel, LA Meadows, RR Russel, Microarray Technology in Practice, Elsevier Academic Press (2009) • H Lüllmann, K. Mohr, Pharmakologie und Toxikologie, Thieme Verlag • M Hacker, K Bachmann, W Messer (Eds.), Pharmacology: Principles and Practice, Academic Press (2009) • Scientific papers

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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	After approval by the Examination Board An elective module may be selected from the offer of other faculties, colleges or universities.
Recommended knowledge / course work	
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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