OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG

VST FAKULTÄT FÜR VERFAHRENS- UND SYSTEMTECHNIK

Module Catalogue

Master Program

Process Safety and Environmental Engineering

Date: 05 April 2023

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1 Description of our Process Engineering Program

1.1 The Process Engineering Discipline

Process engineering focuses on developing, operating, and optimizing

- efficient,
- sustainable,
- safe,
- and economic

processes that convert raw materials into valuable products using physical, biological, and chemical processes. Process engineering is used to synthesize pharmaceuticals from fine chemicals, extract advanced materials such as fuels and plastics from oil, forge construction materials and ceramics from stone, purify metal from ore, recover recyclables and energy from waste, obtain silicon and glass from sand, and derive food from agricultural resources. Process engineering is everywhere, even when it is not apparent at first sight—and it is essential for the economy and society. It is especially indispensable in balancing societal demands for prosperity with efficient processes that sustainably preserve life and the environment.

Core topics covered in the process engineering program include:

- environmental analysis
- molecular modeling
- recycling
- material transport and storage
- modeling and analysis of energetic processes
- hazard assessment, risk analysis, and safety technology

1.2 Requirements for Admission

The Process Safety and Environmental Engineering master program is taught in the English language.

Applicants must have obtained a bachelor degree (210 Credit Points, EQF 6) in:

- Chemical engineering,
- Process engineering,
- Energy engineering,
- or a related field.

Adequate English language skills must be demonstrated through:

- TOEFL-test (550 points paper based, 213 points computer based, or 80 points internet based),
- Cambridge Certificate of Proficiency in English (CPE) – minimum score: C,
- Cambridge Certificate of Advanced English (CAE) – minimum score: B,
  or IELTS-test overall band score 6.0.

2 Objectives

2.1 Goals of the Process Safety and Environmental Engineering master program

The economical usage of energy resources, safe production and handling of materials, and the protection of the environment are gaining importance worldwide. Safety and environmental protection are indispensable elements of any industrial activity. In a modern society technical processes will only be accepted if the emerging hazards are identified and kept under control and if the environmental impact is reduced to an acceptable minimum. To achieve these aims, experts are needed which possess both an in-depth understanding of process engineering as well as specific knowledge of safety and environmental technologies. The master program **Process Safety and Environmental Engineering** aims to educate experts for industry as well as for authorities, research organizations, and higher education.

Graduates from the program are versed in the natural scientific fundamentals of technical processes, especially those related to safety and environment and think and act holistically in the assessment of safety and environmental concerns and their prevention and mitigation. They are capable to apply their engineering know-how to safety and environmental problems and appropriate solutions.

Graduates analyze processes based on advanced methods and models and develop new products, methods and system solutions to for safety and environment-related challenges.

They are able to identify gaps of knowledge in their field and plan and conduct theoretical and experimental studies to bridge these gaps, including a critical evaluation of the obtained data. They support and develop further a consciousness for safety and environmental protection in their professional affiliations.

Potential areas of employment include:
chemical and pharmaceutical industry, petro-chemical industry, oil and gas industry, power generation, waste management, animal feed and food industries, materials science, apparatus, machine and plant engineering, research organizations, etc.

2.2 Curriculum

The **Process Safety and Environmental Engineering** master program consists of modules. In addition to the compulsory modules on the topics of process engineering, safety and environmental technology, heat and mass transfer, and legal and management issues related to safety and environment, the students are required to compose their own study program with elective courses from the module catalogue. Completion of the Master thesis demonstrates that the student is qualified to work independently on academic topics.

After a standard study period of 3 semesters, the students can acquire 90 credit points (CP). The **Process Safety and Environmental Engineering** master program provides students with the opportunity to perform further research, particularly in areas such as process technology, environmental technology, energy technology and safety technology. The graduates are able to independently develop products, processes, technologies and, engineering solutions, making them into nationally and internationally respected experts in the field.

3 Program Overview

	1. Semester			2. Semester			3. Semester		
	CP	SWS	PA	CP	SWS	PA	CP	SWS	PA
Required Coursework	∑ = 50 CP								
Module 1 – Thermal Process Engineering	5	2-2-0	K120						
Module 2 –Advanced Heat and Mass Transfer				5	2-2-0	K120			
Module 3 – Chemical Reaction Engineering				5	2-2-0	K120			
Module 4 - Hazardous Properties of Materials			K240						
Hazardous Materials and Safety Characteristics	3	2-0-0							
Dispersion of Hazardous Materials	4	2-1-0							
Industrial Explosion Protection	3	2-0-0							
Module 5 - Technical Risks and Risk Assessment						K240			
Methods of Risk Analysis				4	2-1-0				
Fire Safety in Industrial Facilities				4	2-1-0				
Simulation Lab	2	0-0-2	P/F						
Module 6 - Environmental Engineering						K240			
Air Pollution Control				4	2-1-0				
Waste Water and Sludge Treatment	4	2-1-0							
Environmental Science Research Project	2	0-0-2	P/F						
Module 7 – Process Safety									
Legal Issues in Plant Operation and Process Safety				3	2-0-0	G			
Excursion				2	0-0-2	G			
Elective Coursework	∑ = 10 CP								
Module 8 - Elective Courses	7	5		3	2				
Module 9 - Master Thesis							30		KO
Sum	30			30			30		

CP – Credit points
G – Graded assessment
K – Final examination (duration given in minutes)
KO – Colloquium
PA – Final examination
P/F – Pass-Fail
SWS – Semester week hourly workload (Lecture-Tutorial-Lab)

4 Required Modules

4.1 Module 1: Thermal Process Engineering

Required Module for the **Process Safety and Environmental Engineering** Master Program
Module 1: Thermal Process Engineering
Module Objectives (Competences): The students attain basic understanding of the fundamentals of thermal separation processes on selected unit operations (distillation/rectification, absorption, extraction, convective drying). They develop the skills necessary to transfer these fundamentals, to the numerous further existing thermal separation processes and can solve problems of practical relevance.
Contents: Equilibrium separation processes: ▪ Thermodynamics of vapor-liquid equilibrium ▪ Batch and continuous distillation ▪ Theory of separation cascades, rectification in try and packed columns ▪ Separation of azeotropic mixtures ▪ Practical design and hydraulic dimensioning of tray and packed columns ▪ Gas-liquid equilibrium ▪ Absorption in tray and packed columns ▪ Practical design of absorption apparatuses ▪ Thermodynamics of liquid-liquid equilibrium ▪ Separation of liquid mixtures by extraction ▪ Practical design of extraction equipment Kinetically controlled separation processes: ▪ Fundamentals of convective drying ▪ Adsorption equilibrium and standardized drying curve of the single particle ▪ Dimensioning of convective dryers ▪ Evaporations of liquid mixtures in inert gas ▪ Diffusion distillation and pseudo-azeotropic points
Forms of Instruction / Course Language: Lecture with tutorial / English
Prerequisites:
Workload: 2-2-0, classroom = 56 hours and self-studies = 94 hours
Assessments/Exams/Credits: K120 (written exam 120 min)/ 5 CP
Responsible lecturer: Prof. Dr.-Ing. Evangelos Tsotsas, IVT-TVT/FVST
Text/References: - Own notes for download - Seader, J.D., Henley, E.J.: Separation process principles, Wiley, New York, 1998 - Thurner, F., Schlünder, E.-U.: Destillation, Absorption, Extraktion, Thieme, Stuttgart, 1986

4.2 Module 2: Advanced Heat and Mass Transfer

Required Module for the **Process Safety and Environmental Engineering** Master Program

Module 2: Advanced Heat and Mass Transfer

Module Objectives (Competences):

Students will be able calculate important parameters of the heating and cooling processes for different solid bodies i.e. building walls, doors and windows. At the same time they will learn radiation heat transfer mechanism, radiation shields, secondary radiation heat transfer effects as well as determination of heat radiation from flames and finally the methods of intensive cooling with liquids. Moreover students will learn the calculation of coupled heat and mass transport processes using equilibrium relationships. This knowledge will enable them to identify the criteria for ignition, extinguishing system and other safety related issues during a process plant design.

Contents:

- Fourier's differential equation with boundary conditions and temperature gradients
- Simplified analytical solution for one-dimensional and dimensionless heat conduction in different conditions i.e. multi-dimensional heat conduction, heat transfer in semi-infinite bodies and short times, contact temperature, critical heat flux densities for pain sensing
- Heat transfer by radiation - mechanism, intensity, emissivity for solid, liquid and gaseous substances as well as dust and soot.
- View factors, radiative exchange, radiation shielding, greenhouse effect
- Secondary radiation effect of emergency blankets
- Solidification and melting processes
- Intensive cooling operations, diving, film and spray cooling influence of fluids, critical heat flux densities, Leidenfrost Effect.
- Coupled heat and mass transport processes, equilibrium conditions at phase boundaries, coal combustion

Forms of Instruction / Course Language:

Lecture with tutorial / English

Prerequisites:

Workload:

2-2-0, classroom = 56 hours and self-studies = 94 hours

Assessments/Exams/Credits:

K120 (written exam 120 min)/ 5 CP

Responsible lecturer:

Prof. Dr.-Ing. Eckehard Specht, ISUT/FVST

Text/References:

- A.F. Mills: Basic Heat and Mass Transfer, Prentice Hall
- Handouts can be downloaded. Downloading link will be provided during lecture.

4.3 Module 3: Chemical Reaction Engineering

Required Module for the **Process Safety and Environmental Engineering** Master Program
Module 3: Chemical Reaction Engineering
Module Objectives (Competences): In the lecture Chemical Reaction Engineering, students will learn to quantitatively assess chemical reactions such that they are able to select suitable reactor types for a given reaction and specify critical design features.
Contents: 1. Stoichiometry of chemical reactions ▪ Key components and key reactions ▪ Extent of reaction, conversion, selectivity, and yield 2. Chemical thermodynamics ▪ Reaction enthalpy ▪ Temperature and pressure dependency ▪ Chemical equilibrium ▪ Free Gibbs enthalpy ▪ Equilibrium constant K_p and temperature dependency ▪ Pressure influence on chemical equilibrium 3. Kinetics ▪ Reaction rate ▪ Rate laws of simple reactions ▪ Decomposition, parallel and series reactions ▪ Equilibrium limited reactions ▪ Estimation of kinetic parameters ▪ Differential method ▪ Integral method ▪ Kinetics of heterogeneously catalyzed reactions ▪ Adsorption and Chemisorption ▪ Langmuir-Hinshelwood kinetics ▪ Temperature dependency of heterogeneously catalyzed reactions 4. Mass transfer in heterogeneous catalysis ▪ Basics ▪ Diffusion in porous systems ▪ Pore diffusion and reaction ▪ Film diffusion und reaction ▪ Thiele module and pore efficiency factor 5. Design of chemical reactors ▪ Reaction engineering principles ▪ General mass balance ▪ Isothermal reactors ▪ Ideal batch reactor (BR) ▪ Ideal plug flow reactor (PFR) ▪ Ideal continuous stirred tank reactor (CSTR) ▪ Real technical reactors ▪ Cascade of stirred tanks 6. Heat balance of chemical reactors

- General heat balance
- Cooled CSTR
- Stability problems in chemical reactors
- Residence time behavior
- Calculation of conversion in real reactor systems
- Cascade model, Dispersions model, Segregation model
- Modeling of conventional fixed-bed reactors
- Selectivity problems
- Increase of selectivity in membrane reactors

7. Material aspects in chemical process engineering
   - Importance of the chemical industry and feedstock
   - Steam cracking of hydrocarbons
   - Chemical products

Forms of Instruction / Course Language:
Lecture with tutorial / English

Prerequisites:

Workload:
2-2-0, classroom = 56 hours and self-studies = 94 hours

Assessments/Exams/Credits:
K120 (written exam 120 min)/ 5 CP

Responsible lecturer:
Prof. Dr.-Ing. Andreas Seidel-Morgenstern, IVT-CVT/FVST
Prof. Dr.-Ing. Christof Hamel, IVT-CVT/FVST

Text/References:
O. Levenspiel, Chemical Reaction Engineering, John Wiley & Sons, 1972

4.4 Module 4: Hazardous Properties of Materials

<table>
<tr><td colspan="2">Required Module for the Process Safety and Environmental Engineering Master Program</td></tr>
<tr><td>Module 4:</td><td>Hazardous Properties of Materials
Section I: Hazardous Materials and Safety Characteristics
Section II: Dispersion of Hazardous Materials
Section III: Industrial Explosion Protection</td></tr>
<tr><td colspan="2">Module objectives (competences):
Section I: Hazardous Materials and Safety Characteristics
Students will learn important properties of different material to calculate safety and fire protection measures and assess the effects of changes in external conditions. Therefore they will develop the skills to calculate preventive measures in advance and also in case of real fire and explosion.

Section II: Dispersion of hazardous materials
Course participants deal with the problem of accidental releases of hazardous substances from industrial installations. They learn the principles of passive and jet dispersion in gas or particle phase and in relation to the atmospheric stability conditions. They are capable to apply mathematical tools to calculate concentration profiles for emitted substances in the x-y-z space and depending on time. They can assess the hazard for organisms present in the radius of action of the release by comparing the calculated concentrations with relevant hazard threshold values.

Section III: Industrial explosion protection
Students learn to know the explosion hazards in different branches of industry, the phenomenology of initiation and propagation of explosions and the key influencing factors. They are qualified to calculate the expected explosion pressure and other safety characteristics.</td></tr>
<tr><td colspan="2">Contents:
Section I: Hazardous Materials and Safety Characteristics
▪ Overview of groups of hazardous materials (toxicity, ignition sensitivity, fire and explosion hazards)
▪ safety indicators of hazardous materials
▪ experimental testing procedures for safety data
▪ computational methods for safety data
▪ application of safety indicators in protective measures

Section II: Dispersion of hazardous materials
▪ Emission and passive dispersion of neutral and heavy gases, atmospheric stability conditions,
▪ Gaussian distribution based dispersion models,
▪ Particle trajectories-based simulation models,
▪ Jet dispersion,
▪ Partitioning and fate of chemicals in the environment
▪ Toxicity of substances, the Acute Exposure Guideline Level concept,
▪ Release of liquids and gases from leakages,
▪ Dispersion of radionuclides

Section III: Industrial explosion protection
▪ Gas, dust and hybrid mixture explosions, phenomenology
▪ Ignition sources and processes
▪ Properties of reactive gases, vapors of flammable liquids, dusts, mists and aerosols and foams</td></tr>
</table>

▪ Assessment of explosion hazards ▪ Explosion protection measures, design and application principles
Forms of Instruction / Course Language: Lecture with tutorial / English
Prerequisites:
Workload: Section I: 2-0-0, classroom = 28 hours and self-studies = 62 hours Section II: 2-1-0, classroom = 42 hours and self-studies = 78 hours Section III: 2-0-0, classroom = 28 hours and self-studies = 62 hours
Assessments/Exams/Credits: K240 (written exam 240 min) / 10 CP
Responsible lecturer: Section I: Prof. Dr.-Ing. Ulrich Krause, IAUT/FVST Section II: Dr. rer. Nat. Ronald Zinke, IAUT/FVST Section III: Prof. Dr.-Ing. Ulrich Krause, IAUT/FVST
Text/References: - Steinbach: Safety Assessment for Chemical Processes - Steen/Hattwig: Handbook of Explosion protection - Eckhoff: Dust explosions in the process industries - Mannan: Lee’s Loss prevention in the Process Industries - Stoessel: Thermal Safety of Chemical Processes - UN Handbook for Tranportation of Dangerous Goods (“Orange Book”) - TNO Coloured Books Series

4.5 Module 5: Technical Risks and Risk Assessment

Required Module for the **Process Safety and Environmental Engineering** Master Program	
Module 5:	**Technical Risks and Risk Assessment** Section I: Methods of Risk Analysis Section II: Fire Safety in Industrial Facilities Section III: Simulation Lab
Objectives: Section I: Methods of Risk Analysis The students acquire knowledge in the field of probabilistic safety analysis and quantitative risk assessment for technical systems and processes. In addition they will learn several qualitative, semi-quantitative and quantitative risk analysis methods including Hazard and Operability Studies (HAZOP), Layer of Protection Analysis (LOPA), Failure Mode and Effect Analysis (FMEA), Fault and Event Tree analysis. Moreover, students develop the ability to conduct both qualitative and quantitative risk analysis and learn reliability analysis methods for technical systems. As an exercise, students perform a complete quantitative risk assessment including event tree and fault tree analysis, consequence assessment and risk integration techniques for the example of a fuel storage and processing unit. Assessment of individual and group risk from industrial accidents using the probit method is also included. Section II: Fire Safety in Industrial Facilities The students are capable to identify, assess and evaluate the major fire hazards in the process industries, based on fire-related properties of materials produced or handled, presence of ignition sources and fire effects like flame radius and height, radiative heat and smoke dispersion. Students derive and apply mathematical tools and simulation methods for fire and smoke propagation through industrial installations including computational fluid dynamics methods. Section III: Simulation Lab Students learn to perform simulations for pollutant dispersion, fires and explosions based on state-of-the-art software tools (e.g. PHAST, AUSTAL, ANSYS suite, OpenFOAM). They are able to structure a simulation problem such to make it accessible to software use. Students get skills on qualified plausibility checks of computed results and assessment of uncertainties in simulations. Students will be prepared to apply simulation software for hazard assessment.	
Contents: Section I: ▪ Probability distributions and functions (Kolmogorov Axioms), conditional probability, Bayes theorem, maximum likelihood function. ▪ Terminologies related to risk analysis and evaluation, event probabilities, evaluate the extent of damage, individual risk and group risk. ▪ In detail Qualitative Risk Analysis (QRA) method learning including content, structure and implementation of a HAZOP study. ▪ Conducting a quantitative risk analysis which includes a Master Logic Diagram preparation, selection of the analysis area, development of an Event Tree for a technical disaster and a Fault Tree for the failure of a technical facilities as well as the error probability calculation. ▪ Methods to determine the magnitude of damage for industrial accidents, damage effects on individuals, and Probit functions distributions. ▪ Calculation methods for individual and group risk and development of risk graph.	

- Analysis of data uncertainty in probabilistic models, maximum likelihood distributions of event probabilities and Monte Carlo simulation.
- Study Reliability models - determination of failure rates, default probabilities, calculation of the availability of technical systems.
- Safety concepts on the basis of Safety Integrity levels (SIL).
- Probabilistic risk analysis for fire protection.

Section II:
- Behavior of materials in fire, thermal and chemical stability, physical and chemical properties of combustible materials,
- calculation of fire loads, determination of combustion efficiency
- Fire and smoke propagation, simulation models
- Fires of solids and liquid materials, pool fires, jet fires
- Computation of fire scenarios with numerical methods
- Fire detection in industrial facilities
- Layout and application modes of automatic extinction systems
- Firefighting in industrial facilities

Section III:
- Dispersion scenario for a light gas from an emission source,
- Radiation heat transfer from fires between process installations,
- Explosion propagation from a process vessel into a pipe,
- Computation of external effects of explosions.

Forms of Instruction / Course Language:
Lecture, tutorial, and lab / English

Prerequisites:
Mathematics, Statistics, Chemistry, Thermodynamics, Fluid Dynamics

Workload:
Section I: 2-1-0, classroom = 42 hours and self-studies = 78 hours
Section II: 2-1-0, classroom = 42 hours and self-studies = 78 hours
Section III: 0-0-2, computer lab = 28 hours and self-studies = 32 hours

Assessments/Exams/Credits:
K240 (written exam 240 min) / 10 CP

Responsible lecturer:
Section I: Prof. Dr.-Ing. Ulrich Krause, IAUT/FVST
Section II: Dr.-Ing. Andrea Klippel, IAUT/FVST
Section III: Dr. rer. nat. Ronald Zinke, IAUT/FVST

Text/References:
- Steinbach: Safety Assessment for Chemical Processes
- Bedford/Cooke: Probabilistic Risk Analysis - Foundations and Methods
- Mannan: Lee's Loss prevention in the Process Industries
- SFPE Handbook Fire protection Engineering
- Visscher: Air Dispersion Modeling: Foundations and Applications
- Drysdale D: An introduction to fire dynamics

4.6 Module 6: Environmental Engineering

Required Module for the **Process Safety and Environmental Engineering** Master Program
Module 6: **Environmental Engineering** Section I: Air Pollution Control Section II: Waste Water and Sludge Treatment Section III: Environmental Science Research Project
Module Objectives (technical, methodological, key skills): Section I: Air Pollution Control Students will learn to recognize and analyze the framework of environmental engineering as well as the sources and consequences of air pollution. They will understand the principles of mechanical, thermal, chemical, and biological processes of exhaust gas treatment, learn to design such processes and the respective equipment. They will be able to develop solutions for the prevention of air pollution through the efficient combination of mechanical, thermal, chemical, and biological processes. Section II: Waste Water and Sludge Treatment The students are able to identify the relevant physical, chemical and biological properties of wastewater and understand the fundamentals of wastewater treatment technologies. They can identify the relevant physical, chemical and biological properties of biosolids from wastewater treatment and develop creative solutions for the treatment of wastewater. Students are skilled to handle advanced technologies to control the emissions to surface water. Section III: Environmental Science Research Project The students gain skills for structuring and writing scientific articles on selected fields of safety or environmental technology. They are able to evaluate published work of other authors and to describe the scientific motivation for their own efforts. They learn appropriate reporting of own scientific achievements and handling of references. Based on the results obtained students are able to derive and express meaningful conclusions.
Contents: Section I: Air Pollution Control ▪ Sources of air pollution ▪ Basic meteorological processes ▪ Health risks of air pollution exposure ▪ Environmental impact of air pollution ▪ Gas-phase chemistry and measurements ▪ Pollution emission controls and regulations ▪ Technologies for air pollution control Section II: Waste Water and Sludge Treatment ▪ Constituents and analysis of waste water ▪ Principles of mechanical treatment processes ▪ Principles of biological treatment processes ▪ Principles of chemical treatment processes ▪ Activated sludge processes ▪ Biofilm processes ▪ Process selection ▪ Wastewater sludge treatment processes ▪ Disinfection processes

- Water reuse

Section III: Environmental Science Research Project

- Selection of a (small-scale, preferably theoretical) research topic, identifying the gap of knowledge,
- Literature review on the topic,
- Structuring of a scientific article
- Drafting a scientific paper on the topic selected
- Preparing a group presentation on the paper

Forms of Instruction / Course Language:
Section I: Lecture and tutorial / English
Section II: Lecture and tutorial / English
Section III: Group project, scientific essay, oral presentation / English

Prerequisites:

Workload:
Section I: 2-1-0, classroom = 42 hours and self-studies = 78 hours
Section II: 2-1-0, classroom = 42 hours and self-studies = 78 hours
Section III: 0-0-2, classroom = 28 hours and self-studies = 32 hours

Assessments/Exams/Credits:
K240 (written exam 240 min) / 10 CP

Responsible lecturer:
Section I: Dr.-Ing. Kristin Hecht, IAUT/FVST
Section II: Prof. Dr.-Ing. Heinz Köser, IAUT/FVST
Section III: Dr.-Ing. D. Gabel/Prof. Dr.-Ing. U. Krause/Dr. rer. nat. R. Zinke/Dr.-Ing. K. Hecht, IAUT/FVST

Text/References:

- DJ Jacob, Introduction to Atmospheric Chemistry, Princeton University Press 1999
- CD Cooper, FC Alley, Air Pollution Control: A Design Approach, Waveland Press 2002
- DA Vallero, Fundamentals of Air Pollution, Academic Press 2014
- N.F. Gray "Water Technology", Elsevier 2005;
- Metcalf a. Eddy "Wastewater Engineering" MacGrawHill 2003,
- P. A. Vesilind "Wastewater treatment plant design"
- "Student Workbook" IWA Publishing, 2003
- Handouts will be given during lecture

4.7 Module 7: Process Safety

<table>
<tr><td colspan="2">Required Module for the Process Safety and Environmental Engineering Master Program</td></tr>
<tr><td>Module 7:</td><td>Process Safety
Section I: Legal Issues in Plant Operation and Process Safety
Section II: Excursion</td></tr>
<tr><td colspan="2">Objectives:
Section I: Legal issues in plant and process safety
The students will
▪ acquire knowledge of the legal requirement regarding safety of an operating industrial facility according to different national and international directives
▪ learn about important responsibilities of a Safety Engineer in a process plant
▪ develop skills to evaluate different materials with respect to associated hazards, which also meet the requirements of Dangerous Substances Regulation
▪ acquire hazard assessment knowledge from the operation of technical facilities and systems according to relevant regulation
▪ learn about the classification systems for hazardous substances (REACH) and hazardous materials (GHS).

Section II:
Theoretical knowledge will be supplemented with a first-hand view of an operating plant. Typical problems and approaches for dealing with them will be explained from a professional perspective. The students will acquire practical experience about industrial realities which will prepare them for their professional careers.</td></tr>
<tr><td colspan="2">Contents:
Section I:
▪ The content and purpose of the Federal Pollution Control Act and subordinate legal regulations, in particular the Major accident regulations. Also content of the SEVESO European Union directive (Chemical Accidents - Prevention, Preparedness and Response)
▪ Characteristics and sequence hazardous incidents in process plants, case studies (Seveso, Flixborough)
▪ Responsibilities for the operation of process plants, basic duties, extended duties, threshold quantities, safety clearances, safety report
▪ Content and purpose of Hazardous Substances Ordinance, Technical rules for Hazardous Substances
▪ Systems and methods for classifying hazardous substances, REACH system, and Material Safety Data Sheet (MSDS)
▪ Labeling systems for hazardous substances
▪ Legal obligations of operators for the safe operation of machinery, equipment and technical systems
▪ Systematic analysis of hazards in operating areas
▪ Structure and content of risk assessment according to EC ATEX Directives

Section II:
▪ Excursion to an industrial operation
▪ Discussion of industrial safety protocols and requirements
▪ Exposure to industrial fittings and equipment
▪ Professional perspectives on dealing with working hazards</td></tr>
</table>

Forms of Instruction / Course Language: Lecture with tutorial, excursion/ English
Prerequisites: Knowledge of basics in thermodynamics and fluid dynamics, chemical reactions and strength of materials
Workload: Section I: 2-0-0 classroom = 28 hours and self-studies = 62 hours Section II: 0-0-2 classroom = 28 hours and self-studies = 32 hours
Assessments/Exams/Credits: Section I: graded assessment of performance/ 3 CP Section II: graded assessment of performance/ 2 CP The module grade is the CP-weighted average of the section grades.
Responsible lecturer: Section I: Dr.-Ing. Dieter Gabel, IAUT/FVST Section II: Prof. Dr.-Ing. Heinz Köser, IAUT/FVST
Text/References: - Series of European Commission Seveso Directives - Mannan: Lee’s Loss prevention in the Process Industries - UN Handbook for Transportation of Dangerous Goods (Orange Book) - UN manuals for the handling of hazardous materials and dangerous goods (Yellow Book, Purple Book) - European Directives on Explosive Atmosphere More will be given during lecture

4.8 Module 8: Elective Courses

Required Module for the **Process Safety and Environmental Engineering** Master Program
Module 8: Elective Courses
Objectives: The elective courses enable to students to customize their educational experience while still getting a broad education foundation in environmental engineering and process safety. Students deepen their understanding of process engineering in the subjects of their choice. Students can develop sub-specialties in their area of interest or develop skills that they wish to use in their future careers.
Contents: A minimum of three and maximum of five elective courses are chosen from the list of elective courses in this handbook (Section 5). The courses cover a wide range of topics. Students may choose related courses to specialize in a certain area or may choose different topics to gain a broader perspective.
Forms of Instruction / Course Language: Course dependent, see Section 5
Prerequisites: Course dependent, see Section 5
Workload: Course dependent, see Section 5 At least 10 CP in sum
Assessments/Exams/Credits: Each elective course has its own final examination, listed in the course description in Section 5. The module grade is the average grade with equal weight given to each course. The module is worth a maximum of 10 CP.
Responsible lecturer: Prof. Dr.-Ing. Ulrich Krause, IAUT/FVST
Text/References:

4.9 Module 9: Master Thesis

Required Module for the **Process Safety and Environmental Engineering** Master Program
Module 9: Master Thesis
Objectives: The Master thesis serves to prove that the student is qualified to work independently on a given academic problem with scientific methods within a specific period of time. The student is able to analyze to assess potential solutions critically. The student is able to situate his work within the context of current research.
Contents: Subjects related to current research projects are published by the professors of the faculty. The students can chose a subject of their choice. The setting of the topic and the name of the examiner has to be documented at the examination office. In the colloquium the students have to prove, that they are able to defend the results of their independent scientific processing. Therefore the results have to be presented in a 15 minutes talk with subsequent questions.
Forms of Instruction / Course Language: Independent problem-solving with concluding assignment
Prerequisites: 50 CP
Workload: 20 weeks
Assessments/Exams/Credits: Master thesis with colloquium / 30 CP
Responsible lecturer: Chairman of the board of examiners
Text/References:

5 Elective Courses

5.1 Advanced Process Systems Engineering

Elective Course for the **Process Safety and Environmental Engineering** Master Program
Course: Advanced Process Systems Engineering
Objectives: The students should learn how to derive mathematical models for the analysis and design of complex chemical and biochemical production systems on different time and length scales (molecular level, particle level, continuum phase level, process unit level, plant level). The students will be able to model multiphase systems, including various phase combinations and interfacial transport phenomena. Furthermore students will learn to apply advanced model reduction techniques.
Contents: ▪ Multilevel modelling concepts ▪ Molecular fundamentals of kinetics and thermodynamics ▪ Modelling of complex continuum systems ▪ Advanced process optimization techniques
Forms of Instruction / Course Language: Lecture and exercises/tutorials; (winter semester)
Prerequisites: Bachelor in Process engineering or in a comparable course
Workload: 2-2-0, classroom = 56 hours and self-studies = 94 hours
Assessments/Exams/Credits: Oral exam / 5 CP
Responsible lecturer: Prof. Dr.-Ing. Kai Sundmacher, IVT-SVT/FVST
Text/References: - R.B. Bird, W.E. Stewart, E.N. Lightfoot Transport Phenomena, Wiley, Chichester, 1960 - O. Levenspiel, Chemical Reaction Engineering, Wiley, New York, 1972. - D. Kondepudi, I. Prigogine, Modern Thermodynamics, Wiley-VCH, Chichester, 1998 - S.V. Patankar, Numerical Heat Transfer and Fluid Flow, McGraw-Hill, New York, 1980

5.2 Analysis and Design of Experiments

Course: Selective module for the master course Process Safety and Environmental Engineering
Module: Analysis and Design of Experiments
Objectives: The students learn how to use statistical methods to evaluate experimental data, how to estimate parameters along with their confidence intervals for linear and nonlinear models using classical and modern regression techniques. They are able to use different methods to discriminate between possible process models and to design and evaluate classical experimental plans. Additionally, the students learn to use modern design of experiments for sampling design sites used in computer experiments or simulations. This allows the student to then perform various forms of analysis, such as system prediction, optimization, visualization, etc. for computationally based process models.
Contents: • Basic concepts: variables, parameters, models, design of experiments • Statistical foundations: probability, probability distributions, population, sample, estimators, confidence intervals • Parameter estimation: linear and nonlinear regression, simultaneous multiple regression, Bayesian regression, Maximum-Likelihood method, goodness/lack of fit, individual and joint confidence regions • Design of experiments: classical design methods for models of first and second order, factorial and blocked designs, modern methods for use with computational models • Interactive use of Matlab for illustrative purposes on important examples
Teaching: 3 SWS, Lectures, tutorials and Matlab tutorials
Prerequisites: Bachelor in chemical engineering or related fields. Basic knowledge of statistics and maths.

Workload: Regular Study: 42 h, Private Study: 78 h
Examination/Credits: Written exam / 90 min / 4 CP
Responsible lecturer: Dr.-Ing. Voigt, FVST

5.3 Biodegradations

Modulbezeichnung	Biodegradations
Englischer Titel	*Biodegradations*
Modulniveau nach DQR	Level 7 (master level)
Modulnummer	
Untertitel	Biodegradation of contaminations and anaerobic digestion for biogas production
Lehrveranstaltungen	Lecture Biodegradation of contaminations Lecture Biogas production and utilization
empfohlenes Studiensemester	2nd Semester
Häufigkeit des Angebots/ Angebotsturnus	Every SuSe, weekly
Modulverantwortliche:r	Dr.-Ing. Lucie Moeller, Helmholtz Centre for Environmental Research GmbH - UFZ (Department Centre for Environmental Biotechnology - UBZ)
Dozent:in	Dr.-Ing. Lucie Moeller, UFZ
Sprache	Englisch
Zuordnung zum Studiengang/ Curriculum / Verwendbarkeit des Moduls	► Master course „Process Safety and Environmental Engineering"
Lehrform und SWS	Lecture 2 SWS attendance time
Arbeitsaufwand	Lectures: 30 hours (2 SWS), private studies: 120 hours
Dauer des Moduls	1 Semester
Credit Points (CP)	5
Voraussetzung für die Vergabe von CP	Oral presentation of a case study, solution of a complex calculation task for the planning of a biogas plant, written examination on the knowledge from the lectures
Teilnahmevoraussetzungen	none
Empfehlungen für die Teilnahme	Basic knowledge of biotechnology, chemistry, (bio)process engineering and microbiology is desirable

Modulziele / angestrebte Lernergebnisse / Learning Outcomes	► The lecture provides the students with information on the biological degradation of organic substances. The basic principles of biodegradation are presented and it is shown how these principles relate to a) bioremediation and b) biogas production. The students learn about chemical and biological remediation processes and technologies. A number of contaminants are addressed: oil, microplastics, micropollutants, etc. In the second part, students receive information about biogas production and processing technologies. The lecture is supplemented by examples from current research, a tour of a large-scale biogas plant is planned. At the end, the students develop a case study based on a real environmental problem in their home countries.
Inhalt	► Biological principles of microbial degradation: catabolism, influence of chemical structure on biodegradation, cometabolism, persistent substances ► Biodegradation of contaminations: • Methods of Bioremediation • Micropollutants: Pharmaceuticals and pesticides in the environment • Biodegradation and bioremediation of hydrocarbons • Heavy metals: bioleaching • Microplastics ► Biogas production and utilization • Biological principles of anaerobic digestion • Anaerobic digestion plants • Substrates for the biogas production • Monitoring and optimization of the anaerobic process • Biogas purification and utilization
Studien- / Prüfungsleistungen / Prüfungsformen	Presentation, 15 minutes + 5 minutes discussion; written exam 30 min; (independent) calculation for planning a biogas plant.
Literatur	– M. Alexander: Biodegradation and Bioremediation, 1st Edition, Academic Press, 1994, ISBN 0-12-049860-X – S. Das: Microbial Biodegradation and Bioremediation, 1st Edition, Elsevier Inc., 2014, ISBN 978-0-12-800021-2. – M. Kaltschmitt, H. Hartmann, H. Hofbauer: Energie aus Biomasse, 2nd Edition, Springer-Verlag Berlin Heidelberg, 2009, ISBN: 978-3-540-85094-6 – W. Bischofsberger, N. Dichtl, K.-H. Rosenwinkel, C.F. Seyfried, B. Böhnke: Anaerobtechnik, 2nd Edition, Springer-Verlag Berlin Heidelberg, 2005, ISBN: 3-540-06850-3
Sonstige Informationen	

Freigabe / Version	Last editing of the module: 2020

5.4 Biofuels – Sustainable Production and Utilisation

Elective Course for the **Process Safety and Environmental Engineering** Master Program
Course: Biofuels – Sustainable Production and Utilisation
Objectives: The students will get an overview of the conversion processes of biomass to various fuels. The energetic, economic, and ecological aspects of the processes will be declared. The students will learn the differences between the thermochemical and biotechnological processes and they will understand the process limitations for various raw materials (e.g. starch vs. lignocellulosic raw materials). They will learn how to apply the common chemical reaction engineering modeling principles for biomass conversion processes and which are feasible model assumptions to describe the reactions and unit operations applicable for biofuel production processes. Beyond the process engineering aspects the students will learn the principles to carry out a life cycle assessment (well-to-wheel). Over case studies they will learn how to critically apply the life cycle assessment analysis for the production and utilization of biomass based fuels. The importance of system boundaries, the principles of allocation and the credit method applicability will be declared. Furthermore, the course brings the students the skills of searching and collecting scientific peer-reviewed information with the citation on-line database Scopus. They will learn to analyze and critically review the relevant scientific publications, and to report scientific published information appropriately.
Contents: 1. Renewable biomass sources in comparison to fossil sources 2. Biomass feedstock and intermediates, feedstock characterization 3. Biofuels (ethanol, FAME, FT-Fuels, biogas, methanol, hydrogen) ▪ Properties, utilization, comparison to fossil fuels 4. Production processes and applicable model description for the processes ▪ Ethanol production processes (starch and sugar based and lignocellulosic based) ▪ Biodiesel production: transesterification (base and acid catalyzed and hydrogenation processes) ▪ Thermochemical conversion: biomass gasification and pyrolysis ▪ Fischer-Tropsch process for biomass-to-liquid (BTL) conversion ▪ Algae biomass potential and utilization for biofuel production (hydrogen and liquid fuel) 5. Sustainability of biofuel production and utilization ▪ Principles of LCA and case studies for biofuel production
Forms of Instruction / Course Language: Lectures, guided scientific citation search, literature survey
Prerequisites: Basic courses of chemistry and chemical engineering (Bachelor level)
Workload: presence: 28 hours (2 SWS), survey: 14 h (1 SWS), self-studies = 78 hours
Assessments/Exams/Credits: written exam / 4 CP
Responsible lecturer: Dr. Techn. Liisa Rihko-Struckmann, IVT-SVT/FVST
Text/References: lecture notes (partially free to download)

5.4 Combustion Engineering

Elective Course for the **Process Safety and Environmental Engineering** Master Program

Course: Combustion Engineering

Objectives:

The students are able to conduct energy and mass balances for different stoichiometric conditions. They can calculate for a given energy the air demand and the composition of the flue gas. They can apply the criteria for stable ignition, flash back a blow off. They know the conditions for explosions and detonations. They are able to design firings. They can estimate energy consumption and safety mechanism.

Contents:

- Characterizing of gaseous, liquid and solid fuels, oxygen and air demand
- Composition of combustion gas, influence of excess air number, specific flue gas amount, equilibrium of gas, dissociated components, hypostoichiometric combustion
- Combustion gas temperatures, firing efficiency, influence of heat recovery with air preheating, oxygen enrichment, using of gross heating values for residential heating
- Premixed flames, reaction mechanism, ignition, flame speed, distinguish distance, minimum ignition energy, stability
- Diffusion flames, mixing mechanism, flame length, stability
- Explosions and detonations
- Combustion of liquid fuels, mechanism, atomization
- Combustion of solid fuels, grinding, pyrolysis, reaction mechanism, ash behavior
- Design of firings

Forms of Instruction / Course Language:

Lectures with tutorials, excursions and experiments; (winter semester);

Prerequisites:

Thermodynamics

Workload:

2-1-0, classroom = 42 hours and self-studies = 78 hours

Assessments/Exams/Credits:

Written exam 120 min / 4 CP

Responsible lecturer:

Prof. Beyrau, ISUT/FVST

Text/References:

- Handsout and own written papers can be downloaded
- S. Turns: An introduction to combustion, McGraw Hill

5.5 Computational Biology and Chemistry

Course:
Selective module for the master course Process Safety and Environmental Engineering

Module:
Computational Biology and Chemistry

Objectives:
In this module, students are getting to know different approaches to model questions from chemical and biological fields. The lecture conveys basis principles of modelling chemical and biological intermolecular interactions. Different approaches on different time and spatial scales will be discussed with particular emphasis on providing answers to scientific questions. Theoretical knowledge will be put in practice during exercises in the computer lab. Simple problems will be dealt with independently and typical approaches from a professional perspective from biotechnology and chemical industry will be treated. The students are to acquire competences and practical experience for their professional life. They are getting to know how to apply and evaluate molecular simulations and computational approaches as independent tools to solve problems.

Contents:
- Introduction, time and size scales of interactions
- Intermolecular interactions (hydrogen bonding, electrostatics, van der Waals)
- Protein structures, bioinformatics, protein structural modeling
- Electrostatic interactions and Brownian dynamics
- Molecular dynamics simulations (proteins, conformational changes)
- Quantum chemistry (introduction, examples)
- Additional methods (ab initio molecular dynamics, calculation of experimental observables)

Teaching:
Lecture 2 hours per week, Tutorial 1 hour per week; (winter semester)

Prerequisites:
- Courses in physics, chemistry and biology
- Basic computational knowledge (i.e. Linux)
- Proficiency in English language

Workload:
4 SWS
Lectures and tutorials

Examination/Credits:
Project work and documentation (50%), oral examination (50%) / 5 CP

Responsible lecturer:
HP M. Stein, MPI Magdeburg

5.6 Computational Fluid Dynamics

Elective Course for the **Process Safety and Environmental Engineering** Master Program
Course: Computational Fluid Dynamics
Objectives: Students participating in this course will get both a solid theoretical knowledge of Computational Fluid Dynamics (CFD) as well as a practical experience of problem-solving on the computer. Best-practice guidelines for CFD are discussed extensively. CFD-code properties and structure are described and the students first realize the own, simple CFD-code, before considering different existing industrial codes with advantages and drawbacks. At the end of the module, the students are able to use CFD in an autonomous manner for solving a realistic test-case, including a critical check of the obtained solution
Contents: 1. Introduction and organization. Historical development of CFD. Importance of CFD. Main methods (finite-differences, -volumes, -elements) for discretization. 2. Vector- and parallel computing. Introduction to Linux, main instructions, account structuration, FTP transfer. 3. How to use supercomputers, optimal computing loop, validation procedure, Best Practice Guidelines. Detailed introduction to Matlab, presentation and practical use of all main instructions. 4. Linear systems of equations. Iterative solution methods. Examples and applications. Tridiagonal systems. ADI methods. Realization of a Matlab-Script for the solution of a simple flow in a cavity (Poisson equation), with Dirichlet-Neumann boundary conditions. 5. Practical solution of unsteady problems. Explicit and implicit methods. Stability considerations. CFL and Fourier criteria. Choice of convergence criteria and tests. Grid independency. Impact on the solution. 6. Introduction to finite elements on the basis of Femlab. Introduction to Femlab and practical use based on a simple example. 7. Carrying out CFD: CAD, grid generation and solution. Importance of gridding. Best Practice (ERCOFTAC). Introduction to Gambit, production of CAD-data and grids. Grid quality. Production of simple and complex (3D burner) grids. 8. Physical models available in Fluent. Importance of these models for obtaining a good solution. Introduction to Fluent. Practical solution using Fluent. Influence of grid and convergence criteria. First- and second-order discretization. Grid-dependency. 9. Properties and computation of turbulent flows. Turbulence modeling, k- -Stressmodels. Research methods (LES, DNS). Use of Fluent to compute a turbulent flow behind a backward-facing step, using best practice instructions. Comparison with experiments. Limits of CFD. 10. Non-newtonian flows, importance and computation. Use of Fluent to compute a problem involving a non-newtonian flow (medical application), using best practice guidelines. Analysis of results. Limits of CFD. 11. Multi-phase flows, importance and computation. Lagrangian and Eulerian approaches. Modeling multi-phase flows. Use of Fluent to compute expansion of solid particles in an industrial furnace, using best practice guidelines. Comparison with experiments. Limits of CFD. 12.-14. Summary of the lectures. Short theoretical questionnaire. Dispatching subjects for the final CFD project, begin of work under supervision. Students work on their project during the last weeks,

using also free time. In the second half of the last lecture, oral presentations by the students of the results they have obtained for their project, with intensive questions concerning methods and results.
Forms of Instruction / Course Language: Lecture and hands-on computer lab; (winter semester)
Prerequisites: Fluid Dynamics
Workload: 3 hours per week, Lectures and tutorials: 42 h, Private studies: 78 h
Assessments/Exams/Credits: Written and oral exam / 4 CP
Responsible lecturer: Prof. Dr.-Ing. Gabor Janiga, ISUT/FVST
Text/References: Joel H. Ferziger, Milovan Peric: Computational Methods for Fluid Dynamics

5.7 Control of Toxic Trace Elements

Elective Course for the **Process Safety and Environmental Engineering** Master Program
Course: Control of Toxic Trace Elements
Objectives: The student should be able to ▪ identify the critical toxic trace element emission sources from industrial processes. ▪ understand the principles of the mobility and fate of toxic trace element pollution in the environment ▪ develop solutions to reduce critical toxic trace element emissions from industrial processes
Contents: ▪ introduction and concepts ▪ selenium: mobility in soil, accumulation in plants and animal feeding; volatility in biochemical processes ▪ arsenic: ground water and cleaning of drinking water; inhalation; speciation; phyto-remediation ▪ thallium: accumulation in thermal processes ▪ cadmium: flue dust from thermal processes; mobilisation in soils and accumulation in edible plants ▪ mercury: volatility, aquatic bioaccumulation and immobilisation ▪ chromium: surface treatment and carcinogenic chromium(VI) compounds, control of Cr(VI) in thermal processes ▪ beryllium: controlling inhalation risks from occupational exposure and emission
Forms of Instruction / Course Language: lectures 2h/semester and tutorial 1 h/semester; (summer semester)
Prerequisites: combustion engineering
Workload: lectures and tutorials: 42 h; private studies: 78 h
Assessments/Exams/Credits: Written exam / 4 CP
Responsible lecturer: Prof. Dr.-Ing. Heinz Köser, IAUT/FVST
Text/References: - script - D. Tillman: trace elements in combustion systems, academic press 1994 - E. Merian: Elements and their compounds in the environment, Wiley-VCH 2004; - G Nordberg: Handbook on the toxicology of metals, Elsevier 2008; - A. Wang: heavy metals in the environment, CRC press 2009. - A. Sengupta: environmental separation of heavy metals – engineering processes, Lewis Publ. 2002

5.8 DE project: Visualization of Process engineering Applications

Course of study: Selective module for the master course Process Safety and Environmental Engineering
Module: DE project: Visualization of Process Engineering Applications
Aims and scopes of the module (competences): The aim of the module is the development of Apps, which shall afterwards be used in digital teaching for the visualization of processes in the field of process engineering. This is achieved by the interdisciplinary work of students from FIN and FVST. The students of FIN thereby have a higher workload for the development of the Apps wherefore different gradings are applied. The students from FVST shall apply their knowledge about processes to support the development of the Apps conceptually as well as substantially. The main challenge is to not only employ their theoretical knowledge but also to elaborate technical details which are required for the visualization of the process. For this purpose, the students must provide all the necessary physical, chemical as well as instrumental information and data in a way that the students from FIN (who are not familiar with process engineering) will be able to develop a virtual process. Implementation of the Apps shall be continuously accompanied and supervised by the FVST students. The result of the joint work shall be evaluated and presented at the end of the semester. In addition to that, the continuous documentation of the implementation of the Apps has to be summarized in a report. The specific tasks thus can be summarized as: - Application-oriented work, - Interdisciplinary work, - Organisation of the work in a team, - Targeted, time-optimised work, - Summary of the work in form of a report, - Presentation of the results, - Evaluation of the App. -
Contents: - selection of the process, - written description of the process, including the physical, chemical and technical data of interest, - breakdown of the sub-processes,

- selection of the process parameter, summary of required data, - conception of the App (e.g. simple visualization or implementation of process conditions), - continuous support of the App-implementation, - documentation of the implementation, - presentation of the results (e.g. by Power-Point), - evaluation and functional test of the App.
Forms of teaching: Interdisciplinary work in teams of students from FIN and FVST. Regular meetings every two weeks à la agile software development. Presentation of the subprojects and subtasks (in sprints). Final colloquium with presentation of the Apps and their evaluation. Report. This module is offered in English and German (if necessary bilingual).
Required qualification for participation: Basics of process engineering. The participation is limited to 6 students per semester.
Workload: 3 SWS, Attendance time: 22 hours (also possible by Zoom-Meetings), self-study: 110 hours
Performance record/Exam/Credits: Presentation of the App, report/ - / 4 CP
Responsible persons: Dr.-Ing. Nicole Vorhauer-Huget, FVST Prof. Dr. rer. nat. Gunter Saake, Dr.-Ing. David Broneske, FIN

5.9 Dispersed Phase Systems in Chemical Engineering

Elective Course for the **Process Safety and Environmental Engineering** Master Program
Course: Dispersed Phase Systems in Chemical Engineering
Objectives: The students acquire knowledge on the applications, processes and modelling principles of disperse systems. Various disperse systems are introduced and compared. Basic modelling techniques that are important to all disperse systems are taught, that is, mass and energy balances and the population balance and derived equations thereof (e.g. momentum equations). Three important classes of disperse systems in chemical engineering, i.e. crystallization systems, polymerization systems and emulsions, are discussed consecutively in detail. For all three systems the students learn the basic mechanisms as well as thermodynamic aspects. The students acquire knowledge on the kinetics of the most important mechanisms in crystallization, polymerization and emulsions. An overview of the most important measurement techniques for property distributions is given. In order to employ this knowledge to solve practical problems, industrially relevant example processes are analyzed and modelled. This enables the students to analyze, quantify, model, optimize and design processes and products involving a dispersed phase.
Contents: ▪ Introduction to dispersed phase systems: Fundamentals and characterization ▪ Balance equations: Mass balance, energy balance, population balance ▪ Important dispersed phase systems in chemical engineering: Crystallization systems, polymerization systems, emulsions and dispersions ▪ Mechanisms affecting property distributions ▪ Thermodynamic aspects ▪ Kinetics ▪ Modelling ▪ Process examples ▪ Measurement techniques
Forms of Instruction / Course Language: Full time lecture of 5 days with exercises
Prerequisites: Basic knowledge of chemical engineering, process systems engineering, thermodynamics, reaction engineering, mathematics
Workload: 32 hours of attendance (one-week full-time block seminar), 10 hours outside class presence: 42 hours (3 SWS), self-study time: 78 hours
Assessments/Exams/Credits: Written exam / 4 CP
Responsible lecturer: Dr.-Ing. Christian Borchert (BASF SE), IVT-SVT/FVST
Text/References: - Ramkrishna, Population Balances, Academy Press 2000; L - Lagaly, Dispersionen und Emulsionen Steinkopff Verlag 1997. - Hofmann, Kristallisation in der industriellen Praxis, Wiley-VCH 2004. - Odin, Principles of Polymerization, John Wiley & Sons, 2004. - Mullin, Crystallization, Elsevier, 2000. Takeo, Disperse Systems, Wiley-VCH, 2001.

5.10 Drying Technology

Elective Course for the **Process Safety and Environmental Engineering** Master Program

Course: Drying Technology

Objectives:

The students gain fundamental and exemplary deepened knowledge about the state of drying technology. They learn to understand and calculate heat- and matter transport processes proceeding the different drying processes. The most important types of dryers from industrial applications will be explained and calculated exemplary for different drying processes. The aim of the module is, to impart ready to use knowledge to the listeners about calculation of drying processes and especially about their construction.

Contents:

- Introduction to dispersed phase systems: Fundamentals and characterization
- The ways of adhesion of the liquid to a commodity, capillary manner, ideal and real sorption, sorption isotherms
- Characteristics of humid gases and their use for die convective drying
- Theoretical handling of real dryers: single stage, multi stage, circulating air, inert gas cycle, heat pump, exhaust vapor compression
- Kinetics of drying, first and second drying section, diffusion on moist surfaces, Stefan- and Ackermann correction, standardized drying process
- Convective drying at local and temporal changeable air conditions
- Fluid bed drying with gas and overheated solvent vapor
- Fluidized bed granulation drying and various control options of drying plants with and without heat recovery
- Types, constructive design and calculation possibilities of selected types of dryers, such as compartment dryers, fluidized bed dryers, conveying air dryers, drum dryers, spray dryers, conveyor dryers, disk dryers, etc.
- Exemplary calculation and design of selected dryers

Forms of Instruction / Course Language:

lecture (presentation), examples, script, excursion in a drying plant; (winter semester)

Prerequisites:

Basic knowledge of chemical engineering, process systems engineering, thermodynamics, reaction engineering, mathematics

Workload:

3 hours per week, Lectures: 42 hours, Private: 78 hours

Assessments/Exams/Credits:

Oral / 4 CP

Responsible lecturer:

Dr.-Ing. Abdolreza Kharaghani, IVT-TVT/FVST

Text/References:

- Krischer / Kröll/Kast: „Wissenschaftliche Grundlagen der Trocknungstechnik“ (tome 1) „Trockner und Trocknungsverfahren“ (tome 2), „Trocknen und Trockner in der Produktion“ (tome 3), Springer-Verlag 1989
- H. Uhlemann, L. Mörl: „Wirbelschicht-Sprühgranulation“, Springer-Verlag, Berlin-Heidelberg-New-York 2000

5.11 Electrochemical Process Engineering

Elective Course for the **Process Safety and Environmental Engineering** Master Program
Course: Electrochemical Process Engineering
Objectives: The lecture conveys physicochemical and engineering basics of electrochemical process engineering (EPE). In the first part fundamentals of EPE including electrochemical thermodynamics and kinetics, transport phenomena, current distribution and electrochemical reaction engineering will be discussed. In the second part typical applications of electrochemical technologies like electrolysis processes and electrochemical energy sources will be reviewed. Finally, electrochemical fundamentals of corrosion, as well as corrosion prevention and control will be explained. The lectures will be followed by experimental laboratory courses which should contribute to a better understanding of the theory part.
Contents: ▪ Introduction (Fundamental laws, Figures of merit, Cell voltage) ▪ Basics of electrochemistry (Ionic conductivity, Electrochemical thermodynamics, Double layer, Electrochemical kinetics) ▪ Mass transport (Diffusion, Migration, Convection) ▪ Current distribution (Primary, Secondary, Tertiary) ▪ Electrochemical reaction engineering (Electrolyte, Electrodes, Separators, Reactors, Mode of operation) ▪ Electrolysis (Chlor-alkali electrolysis, Organic electrosynthesis, Electroplating) ▪ Electrochemical energy sources (Batteries, Supercapacitors) and Corrosion and its control
Forms of Instruction / Course Language: lectures (2 hours per week), tutorials (1 hours per week); (summer semester)
Prerequisites: Basic knowledge of chemistry and physical chemistry, heat and mass transport, and chemical reaction engineering
Workload: 3 hours per week, lectures and tutorials: 42 hours, private studies: 78 hours
Assessments/Exams/Credits: Oral / 4 CP
Responsible lecturer: Dr.-Ing. Tanja Vidaković-Koch, IVT-SVT/FVST
Text/References: - V. M. Schmidt, Elektrochemische Verfahrenstechnik, Grundlagen, Reaktionstechnik, Prozessoptimierung, Wiley-VCH GmbH & Co. KGaA, 2003, ISBN 3-527-29958-0. - K. Scott, Electrochemical Reaction Engineering, Academic Press Limited, 1991, ISBN 0-12- 633330-0. - D. Pletcher, F. C. Walsh, Industrial Electrochemistry, 2nd Edition, Blackie Academic & Professional, Paperback edition, 1993, ISBN 0-7514-0148-X.

5.12 Fuel Cells

Elective Course for the **Process Safety and Environmental Engineering** Master Program
Course: Fuel Cells
Objectives: The participants understand the principles of electrochemical energy conversion. They are aware of the technical applications and future trends in the area of fuel cells. The participants are able to analyze, design and optimize fuel cell systems and possess basic knowledge in the area of fuel processing.
Contents: ▪ Introduction to fuel cells working principle, types of fuel cells and applications ▪ Steady-state behaviour of fuel cells Potential field, constitutive relations (Nerst equation, electrochemical reaction kinetics, mass transport) Integral balance equations for mass and energy Current-voltage-curve, efficiencies, design ▪ Experimental methods in fuel cell research ▪ Fuels Handling and storage of hydrogen Fuel processing ▪ Fuel cell systems
Forms of Instruction / Course Language: Lecture and Tutorial
Prerequisites: Basic knowledge on thermodynamics, reaction engineering and mass transport
Workload: 32h time of attendance (one-week full-time block seminar), 10h outside classes Presence: 42h (3 SWS), self-study time: 78h (literature survey)
Assessments/Exams/Credits: Oral exam 60 min. / 4 CP
Responsible lecturer: Dr.-Ing. Ivan Ivanov, IVT-SVT/FVST
Text/References: - Lecture notes, available for Download - Vielstich, W. et.al: Handbook of Fuel Cells, Wiley 2003 - Larminie, J. and Dicks, A.: Fuel Cell Systems Explained, Wiley 2003 - Haman, C.H. and Vielstich, W.: Electrochemistry, Wiley 1998 - Bard, A.J. and Faulkner, L.R.: Electrochemical Methods, Wiley 2001 - Wesselingh, J.A. and Krishna, R.: Mass Transfer in Multi-Component Mixtures, Delft Univ. Press 2000

5.13 Fundamentals of Multiphase Flows

Course:
Selective module for the master course Process Safety and Environmental Engineering

Module:
Fundamentals of Multiphase Flows

Objectives:
Students will:

- Understand the mathematical description of the properties and behavior of a single and of multiple particles, bubbles and droplets in a flow.
- Comprehend the phenomenology and the underlying physics of flow problems involving a simultaneous presence of multiple phases in a flow domain.
- Understand the governing equations and underlying assumptions for a wide range of different multiphase flow phenomena studied throughout the course.
- Understand the interaction of turbulence and multiphase phases present in a flow.
- Analyze a number of applications involving multiphase flows.

Contents:
1. Introduction, characterization of multiphase flows, quantities, statistical moments, distribution characteristics, dimensionless parameters and averaging and averages in multiphase flows.
2. Equations of motion governing multiphase flows, averaging techniques on governing equations, kinetic theory of granular flows, and equations for describing dispersed particles, droplets and bubbles.
3. Forces on particles in flows, particle-particle interactions, and granular flows.
4. The governing equations of droplets, bubbles and interfaces in flows, surface tension, wetting, evaporation and mass transfer.
5. Turbulence in multiphase flows, governing equations, effect of turbulence on dispersed particles and effect of dispersed particles on turbulence.
6. Mass and heat transfer in multiphase flows.
7. Applications with multiphase flows.

Teaching:
Lectures and Tutorials

Prerequisites:
Fluid Mechanics / Strömungsmechanik
Heat and Mass Transfer / Wärme- und Stoffübertragung
Mechanical Process Engineering / Mechanische Verfahrenstechnik

Workload:
Lectures and tutorials: 56 h, private studies: 94 h

Examination/Credits:
Written examination (120 minutes) / proof of achievements / 5 CP

Responsible lecturer:
Prof. Dr. B. van Wachem, Jun.-Prof. Dr. F. Denner, Dr. F. Evrard, Dr. F. Sewerin, FVST

Literature:
Manuscript with text, figures, tutorials and exercises (available from Moodle E-Learning)

5.14 Ignition processes and explosion protected devices

Studiengang: Selective module for the master course Process Safety and Environmental Engineering
Modul: Ignition processes and explosion protected devices
Ziele des Moduls (Kompetenzen): This course provides an overview of the entire life cycle of explosion-protected equipment (Ex equipment). Core issue is to recognize ignition hazards and how to apply measures to prevent the ignition sources becoming effective. Objectives • Know the sources of ignition and their principles of becoming effective • Recognize the frequent ignition hazards of equipment • Describe the basic protection concepts and the types of protection for Ex-equipment and their applications • Know the important aspects of the design, the manufacture and the operation phase of an explosion-protected equipment as well as their typical sources of error • Get an overview of the legal and normative regulations • Specify the stakeholders and their responsibilities
Contents: 1. Basics 2. Ignition sources 3. Protective measures 4. Design and manufacture 5. Conformity assessment and testing
Lehrformen: Vorlesung 2 SWS; max. 40 Teilnehmer

Voraussetzung für die Teilnahme: -
Arbeitsaufwand: 2 SWS Präsenzzeit: 28 Stunden Selbststudium: 56 Stunden
Leistungsnachweise/Prüfung/Credits: Klausur 3 CP
Modulverantwortlicher: Dr. M. Beyer

5.15 Internship

Course: Elective module for the master course Process Safety and Environmental Engineering
Module: Internship
Objectives: Students may decide to conduct a self-organised internship in a company or a research organization outside the education system. Credit points may be awarded for such an internship provided the contents is related to an engineering or research project at master level. In this industrial internship, students have the opportunity to gain experience related to industrial procedures, tools and processes. They will work on a project in an engineering team and learn organizational and social conditions used in practice and will train their social skills. They will also learn to estimate the duration of work processes and experience the complexity of these processes and the role of an engineer in context. The students will contribute to a real-life project and thus apply and extent their knowledge gained in the master course.
Contents: The internship can cover the following fields ➢ Chemical engineering ➢ Power generation ➢ Process engineering ➢ Process safety, fire and explosion protection ➢ Environmental engineering, e.g. air pollution control, waste water treatment ➢ Recycling and waste treatment ➢ Maintenance, service, and repair ➢ Measurement, analysis, testing, and quality control ➢ Development, design, preparation and process analysis ➢ Bioprocess-, pharmaceutical- and environmental engineering. ➢ Production organization A written report written in the style of a master thesis and indicating the work content of the internship and the individual contribution of the student to the project in which he/she was involved must be submitted (maximum 15 pages) to the responsible lecturer.
Teaching: Industrial internship, reporting
Prerequisites

None
Workload: 150 hours (for report writing)
Examination/Credits: Report (maximum 20 pages), Letter of participation with confirmation of host company or institute, Minimum internship time 12 weeks; 5 CP The grade is based on the report. The internship company can propose a numerical grade with respect to the grading system of the University, which can be taken into account.
Responsible lecturer: Prof. U. Krause, PSEE Course Advisor

5.16 Mechanical Process Engineering

Elective Course for the **Process Safety and Environmental Engineering** Master Program
Course: Mechanical Process Engineering
Objectives: Students: ▪ acquire physically basic understanding of essential processes of Mechanical Process Engineering and Particle Technology ▪ can properly handle statistically distributed material properties of disperse particle systems (material analysis), see content 1., to improve product quality (product design) ▪ analyze thoroughly the problems and define the objectives of material conversion processes of disperse material systems (process diagnose) to develop appropriate problem solutions (process design) ▪ are able to develop and consolidate their skills in calculation, design, technological and energetic evaluation of stochastic and stationary processes (process design) ▪ can suitably design mechanical processes and accomplish the basics of functional machine design, see content 2. to 8
Contents: 1. Introduction, characterization of disperse material systems, particle characterization, particle size distributions, quantities, statistical moments, distribution characteristics, surface, physical particle test methods, particle shape, packing states 2.1 Particle processing by comminution, process objectives, solid bindings, material behavior and fracture mechanics, cracking, stressing modes, microprocesses of comminution, 2.2 Evaluation and characteristics of macroscopic process performance, work principles and applications of crushers and mills, machine design 3.1 Separation of particles, mechanical separation processes, evaluation of separation efficiency by separation function, evaluation of separation sharpness 3.2 Sieving (screening), particle dynamics, work principles and applications of screens, machine design 4.1 Flow separation, particle flow in a fluid, fluid and field forces, stationary particle settling velocity, 4.2 Introduction into characterization of turbulent flow, turbulent particle diffusion, turbulent countercurrent and cross-flow classification of particles in water and air, 4.3 Separation models, work principles and applications of turbulent counter-current and cross-flow separators, hydro cyclone design, air separators 5. Combination of comminution and separation processes 6.1 Transport and storage of particle systems, interactions, molecular bindings and micromechanical particle adhesion forces, 6.2 Macroscopic stress states, flow properties, test methods, evaluation of flow behavior of cohesive powders, 6.3 Problems at practical powder handling, problem solutions by appropriate design of mass and funnel flow hoppers 7. Particle formulation by agglomeration, objectives of agglomeration and physical product design, agglomerate strength, work principles and applications of pelletizing, briquetting and tabletting machines, roller press 8. Mixing of particles, stochastic homogeneity, mixing kinetics, work principles and applications of solid mixers, rotating drum mixers and agitators, permeation of fine particle packings and homogenization in a fluidized bed

Forms of Instruction / Course Language: Lectures, tutorials and practical tutorials (particle measurement, comminution, fine classification, powder flow properties); (summer semester);
Prerequisites: Statistics, Physics, Engineering Mechanics, Fluid Mechanics
Workload: 2-2-0, classroom = 56 hours and self-studies = 94 hours
Assessments/Exams/Credits: oral exam / proof of achievements / 5 CP
Responsible lecturer: Prof. v. Wachem/FVST
Text/References: - Manuscript with text, figures, tutorials and lab exercises, see www.mvt.ovgu.de - Rumpf, H., Particle Technology, Chapman & Hall, London, 1991 - Perry, R.H., Green, D.W., Maloney, J.O., Perry's Chemical Engineers' Handbook (CD version)*, McGraw-Hill, New York 1999

5.7 Nanoparticle Technology

Elective Course for the **Process Safety and Environmental Engineering** Master Program
Course: Nanoparticle Technology
Objectives: Students get to know main physical and chemical theories on nanoparticle formation and particle formation processes including important technical products. The lecture includes modern physical characterization methods for nanoparticles as well as application examples for nanoparticles
Contents: ▪ Introduction into nanotechnology, definition of the term nanotechnology and nanoparticle, nanoparticles as a disperse system, properties, applications ▪ Thermodynamics of disperse systems, nucleation theory and particle growth, homogeneous and heterogeneous nucleation, nucleation rates, model of LaMer and Dinegar, Ostwald ripening, agglomeration ▪ Electrochemical properties of nanoparticle, surface structures, electrochemical double layer, models (Helmholtz, Gouy-Chapman, Stern), electrochemical potential, Zeta potential ▪ Stabilisation of disperse systems, sterical and electrostatic stabilisation, DLVO theory, van-derWaals attraction, electrostatic repulsion, critical coagulation concentration, Schulze-Hardy rule, pH and electrolyte concentration ▪ Coagulation processes, coagulation kinetics, fast and slow coagulation, transport models, Smoluchowski theory, interaction potential, stability factor, structures ▪ Precipitation process, basics, precipitation in homogeneous phase, nucleation, particle growth, reaction processes, particle formation models, apparatuses (CDJP, T mixer), hydro thermal processes ▪ Precipitation in nano-compartments, principles, nano compartments, surfactant-water systems, structures, emulsions (micro, mini and macro), phase behaviour, particle formation, kinetic models ▪ Sol-Gel process, Stöber process, titania, reactions, stabilisation, morphology, pH, electrolyte, RLCA, RLMC, drying, gelation, aging, coating, thin films, ceramics ▪ Aerosol process, particle formation, gas-particle and particle-particle conversion, flame hydrolysis, Degussa and chlorine process, soot, spray pyrolysis ▪ Formation of polymer particles (latex particles), emulsion polymerisation, theory of Fikentscher and Harkins, perl polymerisation, latex particles ▪ Nanoparticles und and their application, technical products, silica, titania, soot, Stöber particles, nanoparticles in medicine and pharmaceutics, functionalised nanoparticles, diagnostics, carrier systems, magnetic nanoparticles and liquids, ▪ Characterisation of nanoparticles - particle sizing, TEM, SEM, light scattering, laser diffraction, theory (Rayleigh, Fraunhofer, Mie), ultra sonic and ESA technique, Instruments ▪ Characterisation of nanoparticles - Zeta potential determination, electrokinetic phenomena, electrophoresis, electro osmosis, streaming and sedimentation potential, electrophoretical mobility, Zeta potential, theories according to Smoluchowski, Hückel, Henry, electrophoretical mobility, instruments, PALS techniques
Forms of Instruction / Course Language: lecture, tutorials, laboratory work (nanoparticle synthesis); (winter semester)
Prerequisites:

Workload: 3 hours per week, Lectures: 42 hours, Private studies: 78 hours
Assessments/Exams/Credits: Oral / 4 CP
Responsible lecturer: Dr. rer. nat. Werner Hintz, IVT-MVT/FVST
Text/References: - Tadao, Sugimoto: Monodispersed Particles, Elsevier, ISBN 978-0-444-546456 - Masuo Hosokawa: Nanoparticle Technology Handbook, Elsevier, ISBN 978-0-444-563361

5.17 Numerical simulation in explosion protection

Course: Selective module for the master course Process Safety and Environmental Engineering
Module: Numerical simulation in explosion protection
Objectives: The students understand the theoretical foundations of the methodology of numerical simulations in the frame of flows of relevance to explosion protection in process industries. In particular, the students are able to use the terminology in computational fluid dynamics, choose independently a suitable numerical approaches for specific flow situations, and interpret and discuss the results. Besides fundamental aspects, insight will be given in current research topics such as modeling of sprays, electrification of particulate flows or flame propagation in pipe systems. Further, the participants of the course will learn the basics of the application of an existing computer tool, namely OpenFOAM. This tool will be used to treat simple flow situations as well as complex real-scale systems. Finally, the students will understand the necessity of experimental measurements to support mathematical modeling and to validate simulations.
Contents: • Fundamentals of computational fluid dynamics • Concepts of multiphase flow modeling • Liquid jets, sprays, spray drying • Triboelectric charging of particles • Expansion of explosion flames • Computer exercises in OpenFOAM • Laboratory exercise at Physikalisch-Technische Bundesanstalt
Teaching: Lectures, computer and laboratory exercises / English
Prerequisites: Mathematics, Thermodynamics, Fluid Dynamics, basic knowledge of a programing language
Workload: 2 SWS, lectures and computer exercises = 28 hours, private studies = 42 hours
Examinations/Credits: Project report and presentation/ 3 CP
Responsible lecturer: Dr. H. Grosshans / PTB Braunschweig
Literature: - Ferziger & Peric: Computational Methods for Fluid Dynamics

- Crowe, Schwarzkopf, Sommerfeld & Tsuji: Multiphase Flows with Droplets and Particles

5.13 Plant and apparatus engineering in solid-state process engineering: design, implementation and problem-solving

Modulbezeichnung	***Anlagen- und Apparatebau in der Feststoff-Verfahrenstechnik: Auslegung, Umsetzung und Problemlösung***
Englischer Titel	Plant and apparatus engineering in solid-state process engineering: design, implementation and problem-solving
Modulniveau nach DQR	Masterniveau
Modulnummer	
Untertitel	
Lehrveranstaltungen	Vorlesung
empfohlenes Studiensemester	1. Semester
Häufigkeit des Angebots/ Angebotsturnus	min. einmal jährlich
Modulverantwortliche:r	Hon.-Prof. Dr.-Ing. Mirko Peglow
Dozent:in	Hon.-Prof. Dr.-Ing. Mirko Peglow
Sprache	Deutsch
Zuordnung zum Studiengang/ Curriculum / Verwendbarkeit des Moduls	▸ MA Verfahrenstechnik ▸ MA Chemical and Energy Engineering
Lehrform und SWS	Vorlesung 2 SWS Präsenzzeit
Arbeitsaufwand	Präsenzzeit / Selbststudium / Prüfung 2 SWS, 28 Std. / 80 Std. / 1 Std.
Dauer des Moduls	1 Semester
Credit Points (CP)	4
Voraussetzung für die Vergabe von CP	Bestehen der Prüfung mit Note
Teilnahmevoraussetzungen	keine
Empfehlungen für die Teilnahme	Regelmäßige und aktive Teilnahme an den Vorlesungen

Modulziele / angestrebte Lernergebnisse / Learning Outcomes	The students understand the basic procedure for the design, implementation and problem solving of equipment and plant engineering concepts in solids process engineering. On the basis of various application examples from industrial practice, the students will be taught the ability to abstract the process to such an extent that an estimation of the plant size, the achievable throughputs and the necessary energy input is possible with simple means. It will be shown how these simple estimates can initially be used as a basis for a plant design and later be supported by more complex models. The application examples used in the lecture are mainly drying and granulation processes in which solids are treated by means of convection and contact dryers.
Inhalt	Content: • Basics of apparatus and plant engineering • Basics of plant design • – Drying and granulation processes in solids process engineering • Design of convection dryers (mass and energy balances) • Design of contact dryers (mass and energy balances) • Heat and mass transfer in convection and contact dryers • Application examples and case studies from industrial practice
Studien- / Prüfungsleistungen / Prüfungsformen	Mündliche Prüfung ca. 60 min.
Literatur	Vorlesungsskript Ausgewählte wissenschaftliche Publikationen aus dem Fachgebiet
Sonstige Informationen	Keine
Freigabe / Version	Letzte Überarbeitung des Moduls, 20.09.21

5.13 Plan Design

Course: Selective module for the master course Process Safety and Environmental Engineering
Module: Plant Design
Objectives (competences): The participants shall acquire the ability to deal with basic questions of plant design such as the elaboration of flow sheets and P&Is, cost, material and energy balances, erection, organization, safety and environmental as well as legal aspects. They are enabled to coarsely calculate the equipment required for a plant.
Content: Feasibility study, Project organization and documentation, types of contracts and liability Basic engineering Detail engineering P&I diagram, material and energy flow charts Material and heat balances Equipment Pipework and valves Assembly Commissioning Time schedules (including critical path method) Aspects of safety and licensing
Teaching: Lectures 2 SWS,Tutorial 1 SWS in English

Prerequisites:

Knowledge of basics in thermo and fluid dynamics, chemical reactions and strength of materials

Workload

Class room: 42 hours, Private studies: 108 hours

Type of examination/Credits:

Written / 5 CP

Responsible lecturer:

Dr.-Ing. D. Gabel, FVST

Literature:

1. Brian D. Ripley: Stochastic Simulation, John Willey & Sons, Inc., 1997
2. E. Klapp: Apparate- und Anlagentechnik, Springer Verlag, 1980
3. Winnacker, Küchler: Chemische Technik, Wiley-VCH Verlag GmbH&Co. KGaA, 2003
4. K. Sattler, W. Kasper: Verfahrenstechnische Anlagen (Band 1 und 2), Wiley-VCH Verlag GmbH & Co., 2000
5. H.Ullrich: Anlagenbau (Kommunikation- Planung- Management), Georg Thieme Verlag Stuttgart, 1983
6. G. Bernecker: Planung und Bau Verfahrens-Technischer Anlagen, VDI Verlag, 1984
7. G.L. Wells, L.M Rose: The art of Chemical Process Design, Elsevier, 1986

5.13 Process Control

Elective Course for the **Process Safety and Environmental Engineering** Master Program	
Course:	Process Control

Objectives:

Students should

- learn fundamentals of multivariable process control with special emphasis on decentralized control
- gain the ability to apply the above mentioned methods for the control of single and multi unit processes
- gain the ability to apply advanced software (MATLAB) for computer aided control system design

Contents:

1. Introduction
2. Process control fundamentals
   - Mathematical models of processes
   - Control structures
   - Decentralized control and Relative gain analysis
   - Tuning of decentralized controllers
   - Control implementation issues
3. Case studies
4. Plantwide control

Forms of Instruction / Course Language:

Lecture and exercises/tutorials; (summer semester)

Prerequisites:

Basic knowledge in control theory

Workload:

2-1-0, classroom = 42 hours and self-studies = 78 hours

Assessments/Exams/Credits:

oral / 4 CP and project report

Responsible lecturer:

Prof. Dr.-Ing. Achim Kienle and Dr. Ilknur Disli-Kienle, IFAT/FEIT

Text/References:

- B. Wayne Bequette: "Process Control: Modeling, Design and Simulation", Prentice Hall, 2002.
- Seborg, Edgar, Mellichamp, Doyle: "Process Dynamics and Control", Wiley, 3 edition, 2010.
- Thomas E. Marlin: "Process Control: Designing Processes and Control Systems for Dynamic Performance", McGraw-Hill, 2 edition, 2000.
- George Stephanopoulos: "Chemical Process Control: An introduction to Theory and Practice", Prentice Hall, 1984.

5.14 Product Quality in the Chemical Industry

Elective Course for the **Process Safety and Environmental Engineering** Master Program
Course: Product Quality in the Chemical Industry
Objectives: Understanding the ▪ Requirement profiles for products of the chemical and process industry ▪ Relationship between structure and functionality of complex products ▪ Opportunities and methods for product design
Contents: ▪ Fundamentals of product design and product quality in the chemical industry (differences to mechanical branches of industry, customer orientation, multi-dimensionality and complexity as opportunities for product design) ▪ Formulation and properties of granular materials (dustiness, fluidizability, storage, color and taste, pourability, adhesion and cohesion, bulk density, redispersibility, instantization etc.) ▪ Detergents (design by composition and structure, molecular fundamentals and forces, tensides and their properties, competitive aspects of quality, alternative design possibilities, production procedures) ▪ Solid catalysts (quality of active centres, function and design of catalyst carriers, catalyst efficiency, formulation, competitive aspects and solutions in the design of reactors, esp. of fixed bed reactors, remarks on adsorption processes) ▪ Drugs (quality of active substances and formulations, release kinetics and retard characteristics, coatings, microencapsulation, implants, further possibilities of formulation) ▪ Clean surfaces (the "Lotus Effect", its molecular background and its use, different ways of technical innovation) ▪ Short introduction to quality management after ISO in the chemical industry (block lecture and workshop by Mrs. Dr. Fruehauf, Dow Deutschland GmbH)
Forms of Instruction / Course Language: Lectures / Exercises / Lab exercises / Workshop; (summer semester)
Prerequisites:
Workload: 3 hours per week, Lectures and tutorials: 42 h, Private studies: 78 h
Assessments/Exams/Credits: Oral exam / 4 CP
Responsible lecturer: Prof. Dr.-Ing. Evangelos Tsotsas /Dr.-Ing. Abdolreza Kharaghani, IVT-TVT/FVST
Text/References: Handouts will be given in lecture

5.23 Renewable Energies: Materials, Components, Function

Modulbezeichnung	*Renewable Energies: Materials, Components, Function*
Englischer Titel	Renewable Energies: Materials, Components, Function
Modulniveau nach DQR	7
Modulnummer	
Untertitel	
Lehrveranstaltungen	lectures and seminars
empfohlenes Studiensemester	Master 1-3
Häufigkeit des Angebots/ Angebotsturnus	summer term
Modulverantwortliche:r	Prof. Michael Scheffler, FMB-IWF
Dozent:in	Prof. Michael Scheffler, FMB-IWF Dr. Ulf Betke, FMB-IWF
Sprache	English
Zuordnung zum Studiengang/ Curriculum / Verwendbarkeit des Moduls	► Chemical and Energy Engineering (CEE) ► Process Safety and Environmental Engineering (PSEE) ► free movers
Lehrform und SWS	Lecture, 2 hours per week á 14 weeks, physical presence Seminar, 1 hour per week á 14 weeks, physical presence
Arbeitsaufwand	42 hours lecture and seminar; 72 hours of private studies
Dauer des Moduls	1 semester
Credit Points (CP)	5
Voraussetzung für die Vergabe von CP	passed exam; participation after homework/assignment paper was evaluated with > 50 %
Teilnahmevoraussetzungen	basics in chemistry and/or physics
Empfehlungen für die Teilnahme	

Modulziele / angestrebte Lernergebnisse / Learning Outcomes	► basic knowledge of renewable energy conversion components/statistics, fundamentals and definitions; chemical and physical knowledge of the working principles; technical limits and economic importance of several systems ► attendees are able to describe the above processes, to select converters for specific applications, to estimate/calculate specific size and design for specific purposes;
Inhalt	► content: statistics in energy consumption; types of energy resources; terms and definitions; conversion devices and materials thereof: photovoltaics; solar thermal; wind, water and planetary energy; fuel cells; geothermal; biomass, solar chemistry; dimensioning examples
Studien- / Prüfungsleistungen / Prüfungsformen	submitted homework or assignment paper as prerequisite for exam attendance (passed when > 50 %); electronic exam with random distribution of tasks (moodle, unsupervised, 45 minutes),
Literatur	-handouts will be given in lecture -Regenerative Energiesysteme: Technologie - Berechnung - Simulation, Volker Quaschning, Hanser-Verlag, 7. Auflage 2011 -Energy Science: Principles, technologies and impacts, Jelley Andrews, Oxford Univ. Press. -Renewable Energy and Climate Change, Volker Quaschning, Jon Wiley & Sons, 2010 -Survey of Energy Ressources; Verlag: Elsevier Science Publishing Company; Auflage: 20th Bk&CD
Sonstige Informationen	--
Freigabe / Version	

5.16 Risk-based Effect Analysis

Studiengang: Master Process Safety and Environmental Engineering, Master Sicherheit und Gefahrenabwehr
Module: Elective courses/Risk-based Effect Analysis
Module Objectives: (Competences): By attending the lecture, the students will be able to apply the methodological basics of risk engineering and translate them into practical applications. The focus is on conveying an understanding of the need to consider and carry out risk-based effect analysis when dealing with hazards/risks. The students develop an understanding of situation-adapted risk management and are enabled to analyse complex systems in a targeted manner and to evaluate them methodically.
Contents The control of risks has a high priority in industry, in the private environment and in society – depending on temporal, regional and civilizational developments. Protective measures exist with a whole range of effects ranging from highly effective to counterproductive. Ideally, the protective measures taken solve safety/security problems. In the worst case, they increase the risk situation. The actual performance of an initiated measure can be determined methodically and systematically using risk-based effect analysis. This step is methodologically decisive in the specific situation and in risk prevention. As part of the lecture, the concept of risk-based effect analysis will be presented and the approach explained using practical examples on the basis of studies. In addition to specific case analyses, lines of further development for risk-based effect analysis are outlined, also based on specific studies, and possible new approaches are explained. - Introduction to the lecture - Current risk situation and the approach of system theory - Disciplinary, terminological and methodological classification of risk-based effect analysis - Risks and protective measures in the industrial, private and social environment - Risk-based effect analysis (theory and methods) - Case studies (occupational health and safety, fire protection, process safety and security) - Lines of further development of risk-based effect analysis - Effect analyses in other disciplines and applications - New approaches
Forms of Instruction: Lecture
Prerequisites: no
Workload: 1 SWS Attendance time: 15 hours Self-study 35 hours

Assessments/Exams/Credits: written exam, 2 CP
Responsible: Dr.-Ing. S. Festag
References:

5.16 Seminar Mechanical Process Engineering

Modulbezeichnung	
Englischer Titel	**Seminar Mechanical Process Engineering**
Modulniveau nach DQR	MSc level
Modulnummer	
Untertitel	
Lehrveranstaltungen	Mechanische Verfahrenstechnik or Mechanical Process Engineering Fluid Mechanics
empfohlenes Studiensemester	
Häufigkeit des Angebots/ Angebotsturnus	2x per year: Summer and winter semesters
Modulverantwortliche:r	Prof. Berend van Wachem
Dozent:in	Prof. Berend van Wachem
Sprache	English
Zuordnung zum Studiengang/ Curriculum / Verwendbarkeit des Moduls	► Master CEE ► Master Verfahrenstechnik ► Master Process Safety and Environmental Engineering ► Master Chemieingenieurwesen
Lehrform und SWS	Lectures 1hr, group work 2 hrs, and tutorials 1hr
Arbeitsaufwand	Lectures, group-work, presentation and tutorials: 56 h, self-study: 94 h 4 SWS
Dauer des Moduls	1 Semester
Credit Points (CP)	5 CP
Voraussetzung für die Vergabe von CP	Pass grade for individual hand-in and presentation combined.
Teilnahmevoraussetzungen	-
Empfehlungen für die Teilnahme	Basic knowledge of Mechanical Process Engineering and Fluid Mechanics.

Modulziele / angestrebte Lernergebnisse / Learning Outcomes	In this course, you are assigned to write a paper and give a presentation in the area of mechanical process engineering or multiphase flows, based on a selection from 10 pre-defined topics. The paper should be written in LaTeX/Overleaf with a template which will be provided. You must present a critical discussion of the current status of the field, rather than an encyclopedic coverage of existing literature. Your paper should NOT be a literature review. In short, you should provide a compelling and up-to-date presentation that communicates the opportunities, excitement and potential future challenges of the subject. A brief historical account leading up to the state-of-the-art should be included to provide relevance and context. The document should be a minimum of 10 pages and should not exceed 30. After 3 weeks, you should present a "5 minute" presentation on your plans for the paper. Also, during the course, you should present your progress on the topic to your fellow classmates, to receive feedback and input (flipped classroom concept). After handing in your report, you should give a final presentation on your topic.
Inhalt	In this course, you are assigned to write a paper and give a final presentation in the area of mechanical process engineering or multiphase flows, based on a selection from pre-defined topics. The choice of topics include: – Fluid drag on ellipsoidal particles – Flow around a spherical particle – Navier-Stokes equations – Discrete Element Modelling (DEM) – Elastic, visco-elastic and plastic particle interactions – Stokes flow and its solutions – Modelling of fluidized beds – Flows through fixed beds – Modelling of pyrolysis – Mass transfer modelling at gas-liquid interfaces – Particle-turbulence interactions
Studien- / Prüfungsleistungen / Prüfungsformen	Hand-in (project work), 80% and Presentation, 20%
Literatur	
Sonstige Informationen	
Freigabe / Version	01.01.2023

5.16 Simulation of Mechanical Processes

Course: Selective module for the master course Chemical and Energy Engineering
Module: Simulation of Mechanical Processes
Objectives (Skills): The students ➢ Learn the theoretical foundations relevant to the mathematical description and modelling of mechanical processes (statistical analysis, numerical solution of differential equations, stochastic solution methods). ➢ Develop and analyse small computer programs (in Matlab or a programming language of their choice) for the simulation of simple sample problems of mechanical processes. ➢ Consolidate their understanding of the physics of the principal dynamic processes in particle technology and mechanical process engineering. ➢ Develop and consolidate their knowledge and skills with regards to the development and application on numerical methods for the analysis and design of mechanical processes.
Content: 1. Statistical methods for the modelling of mechanical systems a. Summary and recap of relevant statistical values for the evaluation and design of mechanical processes. 2. Numerical solution of differential equations a. Introduction of standard method for the numerical solution of ordinary differential equations (Euler methods, predictor-corrector methods), focusing on methods that are widely used for the simulation of particles. b. Solution of systems of multiple ordinary differential equations. c. Evaluating the quality of a numerical solution and the quantifying the associated errors. 3. Stochastic solution methods (Monte-Carlo methods) a. Single-dimensional and multi-dimensional integration b. Sampling and variance reduction

4. Introduction to Discrete Element Methods (DEM) for the simulation of particles

   a. Derivation of the equations of motion and conservation laws

   b. Description of the rotation and moment of inertia of spherical and non-spherical particles

   c. Simple models for the simulation of elastic and inelastic particle collisions

   d. Description of elastic deformations

   e. Examples of practical applications.

Teaching:

Lectures and practical exercises (summer and winter semester)

Prerequisites:

Basic knowledge of Matlab, Mechanical Process Engineering

Workload:

Attendance time: 42 hours, self-study: 108 hours

Credits:

Written exam (70 %), computer exercises (30 %) / proof of achievements / 5 CP

5.16 Transport Phenomena in Granular, Particulate and Porous media

Elective Course for the **Process Safety and Environmental Engineering** Master Program

Course: Transport Phenomena in Granular, Particulate and Porous media

Objectives:

Dispersed solids find broad industrial application as raw materials (e.g. coal), products (e.g. plastic granulates) or auxiliaries (e.g. catalyst pellets). Solids are in this way involved in numerous important processes, e.g. regenerative heat transfer, adsorption, chromatography, drying, heterogeneous catalysis. To the most frequent forms of the dispersed solids belong fixed, agitated and fluidized beds. In the lecture the transport phenomena, i.e. momentum, heat and mass transfer, in such systems are discussed. It is shown, how physical fundamentals in combination with mathematical models and with intelligent laboratory experiments can be used for the design of processes and products, and for the dimensioning of the appropriate apparatuses.

- Master transport phenomena in granular, particulate and porous media
- Learn to design respective processes and products
- Learn to combine mathematical modelling with lab experiments

Contents:

- Transport phenomena between single particles and a fluid
- Fixed beds: Porosity, distribution of velocity, fluid-solid transport phenomena Influence of flow maldistribution and axial dispersion on heat and mass transfer Fluidized beds: Structure, expansion, fluid-solid transport phenomena
- Mechanisms of heat transfer through gas-filled gaps
- Thermal conductivity of fixed beds without flow Axial and lateral heat and mass transfer in fixed beds with fluid flow
- Heat transfer from heating surfaces to static or agitated bulk materials
- Contact drying in vacuum and in presence of inert gas
- Heat transfer between fluidized beds and immersed heating elements

Forms of Instruction / Course Language:

Lectures / Exercises; (summer semester)

Prerequisites:

Workload:

3 hours per week, Lectures and tutorials: 42 h, Private studies: 78 h

Assessments/Exams/Credits:

oral exam / 4 CP

Responsible lecturer:

Prof. Dr.-Ing. Evangelos Tsotsas, IVT-TVT/FVST

Text/References:

- Own notes for download
- Schlünder, E.-U., Tsotsas, E., Wärmeübertragung in Festbetten, durchmischten Schüttgütern und Wirbelschichten, Thieme, Stuttgart, 1988
- Geankoplis, C.J., Transport processes and separation process principles, Prentice Hall, 2003