OTTO VON GUERICKE
UNIVERSITÄT
MAGDEBURG

VST
FAKULTÄT FÜR VERFAHRENS-
UND SYSTEMTECHNIK

Module catalogue

Master course

Chemical and Energy Engineering

1st October 2019

Table of contents

1 Concept of our process engineering study program 3
1.1 Process technology as engineering discipline 3
1.2 The study concept 3
2 Description of the prime objectives of the master course Chemical and Energy Engineering 4
2.1 Goals of the study program 4
2.2 Goals of the Master course Chemical and Energy Engineering 4
3 Master course Chemical and Energy Engineering, compulsory modules 5
3.1 Chemistry 5
3.2 Advanced Fluid Dynamics 7
3.3 Advanced Heat and Mass Transfer 9
3.4 Mechanical Process Engineering 10
3.5 Chemical Reaction Engineering 12
3.6 Thermal Process Engineering 14
3.7 Process Systems Engineering 16
3.8 Combustion Engineering 17
3.9 Plant Design 19
3.10 Laboratory Work 21
3.11 Master thesis 23
4 Master course Chemical and Energy Engineering, Selective modules 24
4.1 Advanced Process System Engineering 24
4.2 Analysis and Design of Experiments 26
4.3 Computational Fluid Dynamics 27
4.4 Consequences of accidents in industry 29
4.5 Control of Toxic Trace Elements 31
4.6 Dispersed Phase Systems in Chemical Engineering 32
4.7 Dispersion of Hazardous Materials 34
4.8 Drying Technology 35
4.9 Environmental Biotechnology 36
4.10 Fuel Cells 37
4.11 Internship 38
4.12 Micro Process Engineering 39
4.13 Modern organic synthesis 40
4.14 Molecular Modelling/Computational Biology and Chemistry 41
4.15 Multiphase Flow Fundamentals 43
4.16 Nanoparticle technology 44
4.17 Numerical simulation in explosion protection 46
4.18 Plant and apparatus engineering in solid-state process engineering: design, implementation and problem-solving 47
4.19 Process Control 48
4.20 Process Engineering of Metals and Ceramics 49
4.21 Product quality in the chemical industry 50
4.22 Renewable Energies: Materials, Components, Function 51
4.23. Simulation of Mechanical Processes 52
4.24. Sustainability Assessment (LCA) for Biofuels 54
4.25. Thermal Power Plants 56
4.26. Transport phenomena in granular, particulate and porous media 57
4.27. Waste Water and Sludge Treatment 59

1 Concept of our process engineering study program

1.1. Process technology as engineering discipline

Process technology investigates, develops and achieves

- energetically efficient,
- ecological compatible and
- economical successful

industrial material conversion processes, which creates products out of raw materials by physical, biological or chemical effects.

The economical usage of energy resources and the protection of the environment are getting more important in the chemical industry.

The basic knowledge of the processes and technologies of the following subjects are assumed.

- Nanoparticle technology
- Molecular Modeling
- Transport and storage
- Modeling and analyzing of energetic processes
- Fuel cells
- Environmental analysis
- Recycling
- Safety technology

1.2. The study concept

The Master course Chemical and Energy Engineering is a study course in English language. Applicants should have a 3,5 year Bachelor certificate in:

- Chemical engineering
- Process engineering
- Energy engineering
- Or similar courses.

English language skills:

- TOEFL-test
  550 (525*) points paper based
  213 (197*) points computer based
  80 (70*) points internet based
- IELTS-test overall band score 6.0.

2. Description of the prime objectives of the master course Chemical and Energy Engineering

2.1. Goals of the study program

Potential working areas:
Chemical and pharmaceutical industry, animal feed and food industries, materials science, apparatus, machine and plant engineering etc.

Prerequisites for the study:

- Basics: in an engineering study most topics are analyzed theoretically and mathematically.
- For process engineering applications the ability of abstract thinking in combination with sound knowledge is needed.
- Practical skills are transferred in laboratory practicals, projects, excursions and during the preparation of the master thesis.

2.2. Goals of the Master course Chemical and Energy Engineering

Besides the compulsory modules in the topic of process technology, heat- and mass transfer and advanced fluid engineering, the students are required to compose their own study program with the courses from the selective module catalogue.
Furthermore the Master thesis serves to prove that the student is qualified to work independently on academic topics.
After a standard period of study of 4 semesters, the students can acquire 120 Credit points.

The Master course provides students with competences for further research, particularly in areas such as process technology, environmental technology, energy technology and safety technology. The graduates are able to develop products and processes independently, which makes them to national and internationally respected experts in research and industry.

Master (4 semester)	
deepening compulsory modules	
Heat- and mass transfer	
Process technology	
Advanced fluid dynamics	
Fabrikgestaltung	
Deepening internship	
	Master thesis
Selective modules in the area of process technology, environmental technology, energy technology, safety technology	

3. Master course Chemical and Energy Engineering, compulsory modules

3.1. Chemistry

Course:
Compulsory module for the master course Chemical and Energy Engineering

Module:
Chemistry

Objectives:
The participants shall be enabled to understand and work with fundamental terms, important laws and experimental techniques in Chemistry. They obtain the basic knowledge in Inorganic, Industrial and Physical Chemistry. The goal is to assist in the understanding of the fundamentals, and to develop a critical approach to own experiments in the field of Chemistry.

Contents:

- Inorganic Chemistry
    - Structure of matter, atomic structure, nuclear reactions, radioactivity, Bohr's atomic model, quantum numbers, orbitals (s, p, d), Pauli principle, Hund's rule, structure of the electron shell, multi-electron systems, Periodic Table of the Elements, ionization energy, electron affinity, ionic bonds, covalent bonds, Lewis formulae, octet rule, dative bonds, valence bond (VB) theory, hybridization, σ-bonds, π-bonds, resonance forms.
    - Molecular orbital (MO) theory, dipoles, electronegativity, VSEPR model, van der Waals interactions, ideal gases, thermodynamics of chemical reactions, chemical equilibrium, mass action law, reaction rates, Arrhenius equation, catalysis, ammonia synthesis, synthesis of sulfur trioxide.
    - Solutions, electrolytes, solubility product, acid/base theories, pH value, oxidation numbers, oxidation, reduction, redox processes
    - Chemistry of Main Group Elements

- Industrial Chemistry
    - Chemical process technologies: from the raw materials to final products (energy-raw material-product network)
    - Crystallization as an example of industrial inorganic chemistry
    - Industrial organic chemistry
    - fossile resources as raw materials of the chemical industry & energy sources (general aspects, primary oil treatment, oil refinery, chemical (and thermal) treatment of coal)
    - base chemicals and selected intermediates (general aspects, synthesis gas, methanol and intermediates, ethene and intermediates)
    - fine chemicals manufacture (commodities, fine chemicals and specialties: general aspects and examples, characteristic features of fine chemicals manufacture, example of a typical process)

- Physical Chemistry
    - Overview: Main parts of Physical Chemistry
    - Thermodynamics (TD)*:* basic terms, techniques
    - System and Surrounding, state functions and variables, perfect gas law, thermal equation of state, real gases, critical point, principle of corresponding states
    - First law of thermodynamics, heat capacities, internal reaction energy and reaction enthalpy, and their dependence on p and T, Hess law
    - Conversion of heat in work: Carnot process, 2nd law of TD, entropy, 3rd law of TD
    - Gibbs energy, Helmholtz energy, chemical potential

- Joule-Thomson effect
- Phase equilibria, Gibbs phase rule, Clapeyron and Clausius-Clapeyron equation
- Mixtures and partial molar quantities, Raoults law, vapour pressure and temperature-composition diagrams, azeotropes, liquid-solid phase diagrams in binary systems
- Chemical equilibrium, law of mass action, dependence on pressure and temperature
- Surface tension
- Kinetics of homogeneous and heterogeneous reactions*:* basic terms and general approach
- order and molecularity, elementary reactions
- temperature dependence, Arrhenius approach
- more complex reaction rate laws: consecutive reactions, steady-state approximation, pre-equilibria, explosions
- Catalysis in general, adsorption, heterogeneous catalysis

Teaching:
Lecture (summer semester); (2. semester of master studies)

Prerequisites:
Bachelor Degree in a Chemical or Engineering Course of Studies

Workload:
3 hours per week, Lectures: 42 h, Private studies: 108 h

Examination / Credits:
written exam / 5 CP

Responsible lecturer:
Prof. H. Weiß, FVST, together with Prof. Edelmann and Prof. Schinzer as co-workers

Literature:
Handouts will be given in lecture

3.2. Advanced Fluid Dynamics

Course:
Compulsory module for the master course Chemical and Energy Engineering

Module:
Advanced Fluid Dynamics

Objectives:
During this Module the students will acquire competences concerning all basic issues related to Fluid Dynamics. In particular, they will learn when and how to use different forms of the Bernoulli equation to solve realistic flows, possibly involving losses and energy exchange. They will furthermore be able to distinguish between simple and semi-complex incompressible and compressible flows and to obtain solutions for such flows in an autonomous manner.

Contents:
1. Introduction and basic concepts
2. Important mathematical relations, material derivative
3. Control volumes, transport theorem, Reynolds theorem
4. Euler equations for ideal fluid
5. Hydrostatics and Aerostatics
6. Bernoulli relation for ideal flows
7. Bernoulli relation for viscous flows involving work exchange
8. Force and torque induced by a flow
9. Kinematics, tensors, Navier-Stokes equations for viscous flows
10. Similarity theory
11. Introduction to compressible flows, Laval nozzle
12. Introduction to turbulent flows
13. Introduction to Computational Fluid Dynamics

Teaching:
Lecture with Exercises (summer semester); (2. semester of master studies)

Prerequisites:
Mathematics, Thermodynamics

Workload:
4 hours per week, Lectures and exercises: 56 h, Private studies: 94 h

Examination/Credits:
written exam / 5 CP

Responsible lecturer:
M. Eng. O. Cleynen, FVST

Literature:

[1] Fundamentals of Fluid Mechanics, Munson B.R., Okiishi T.H.
[2] Introduction to Fluid Mechanics, Fay J.A.
[3] Fluid Flow for Chemical Engineers, Holland F.A., Bragg R.
[4] Mechanics of Fluids, Massey B S., Van Nostrand Reinhold.
[5] Fluid Mechanics, Douglas J F, Gasiorek J M, and Swaffield J A, Longman.
[6] Theoretical and Computational Fluid Dynamics, Pozrikidis, C.,Oxford Univ. Press.
[7] Handbook of Chemistry and Physics, 69 th Ed., CRC Press, 1988
[8] http://mathworld.wolfram.com

A script of the lecture can be downloaded from the website: http://www.uni-magdeburg.de/isut/master/afd.html

3.3. Advanced Heat and Mass Transfer

Course:
Compulsory module for the master course Chemical and Energy Engineering

Module:
Advanced Heat and Mass Transfer

Objectives:
The students can calculate the heating and cooling of solid materials. They can apply the equations for convective and radiative heat transfer. They can simulate the radiative heat exchange between walls, solids and gases of different temperatures. They know how the heat transfer can be influenced by umbrellas and secondary radiation. They can determine the radiation from flames. They can explain the greenhouse effect, the earth climate and the global warming.

Contents:

- Fourier differential equations, boundary conditions, analytical solution, numerical methods
- Semi-infinite bodies, contact heat transfer
- Heat transfer by radiation, fundamentals, emissivities of solids, liquids and gases, heat exchange between gases and solids, view factors
- Greenhouse effect, Mechanism of global warming
- Intensive cooling processes for metals
- Coupled heat and mass transfer processes for gas-solid reactions.

Teaching:
Lectures with tutorials

Prerequisites:
Thermodynamics, Fluidmechanics, Mathematics, Basic heat transfer

Work load:
4 SWS
Time of attendance: 56 hours, Autonomous work: 94 hours

Examination/Credits:
written exam 2 hours / 5 CP

Responsible lecturer:
Prof. E. Specht, FVST

Literature:
E. Specht: Heat and Mass Transfer in Thermoprocessing, Vulkan Verlag Essen (2018)

3.4. Mechanical Process Engineering

Course:
Compulsory module for the master course Chemical and Energy Engineering

Module:
Mechanical Process Engineering

Objectives (competences):
Students

- Understand the mathematical description of the properties and behavior of a single and of multiple particles.
- Understand the principal features of dynamic processes of Mechanical Process Engineering and Particle Technology.
- Understand the principles of storage, transport, mixing, separation and comminution of particle systems.
- Analyze and optimize the selection, design, and assessment of stochastic and stationary mechanical processes.

Content:

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. Behavior of **single particles in flows**, forces on a particle, particles falling under gravity, and the behavior of non-spherical particles.
3. Behavior of **multiple particles**, particles in a suspension, batch and continuous settling.
4. Behavior of **fine particles**, Brownian motion, surface forces on particles, sedimentation and rheology, size enlargement of particles.
5. **Storage and flows of powders**, flow of solid powders, stress analysis of powders, hopper flows, practical powder handling.
6. Particle transport, pneumatic transport, vertical and horizontal transport, design of dilute and dense phase transport systems, standpipes.
7. **Particle and fluidized beds.** Flow through a particle bed, filtration, fluidization, fluidization regimes.
8. **Particle separation**, flow separation, gas cyclones, hydro cyclones, filtration.
9. **Mixing and segregation of particles**, analysis of mixing, stochastic homogeneity, mechanisms of mixing, types of mixers.
10. **Comminution of particles**, material considerations, energy requirements, mechanisms of comminution, types of comminution equipment.

Teaching:
Lectures, tutorials and practical tutorials (4 labs)

Prerequisites:
Statistics, Physics, Engineering Mechanics, Fluid Mechanics I

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

Examination/Credits:
written exam (120 min.) / proof of achievements / 5 CP

Responsible lecturer: Prof. B. van Wachem, FVST
Script/Literature: [1] Manuscript with text, figures, tutorials and lab exercises, available from Moodle E-Learning. [2] M. Rhodes, Introduction to Particle Technology, John Wiley & Sons Ltd. 2008

3.5. Chemical Reaction Engineering

Course:
Compulsory module for the master course Chemical and Energy Engineering

Module:
Chemical Reaction Engineering

Objectives:
Topic of the lecture Chemical Reaction Engineering is the quantitative assessment of chemical reactions, the selection of suitable reactor types and their design.

Contents:

1. Stoichiometry of chemical reactions
   - Key components and key reactions
   - Extend of reaction, conversion, selectivity and yield
2. Chemical thermodynamics
   - Reaction enthalpy
   - Temperature and pressure dependency
   - Chemical equilibrium
   - Free Gibbs enthalpy
   - Equilibrium constant Kp 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 Chemisorptions
   - 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 tube reactor (PFTR)
   - 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

Teaching:
Lecture, Tutorial; (summer semester); (2. semester of master studies)

Prerequirements:

Workload:
2 hours per week Lecture, 2 hours per week Tutorial, Lectures and tutorials: 56 hours, Private studies: 94 hours

Examination/ Credits:
written examination, 120 min, 5 CP

Responsible lecturer:
Prof. Dr.-Ing. A. Seidel-Morgenstern, FVST, with Prof. Ch. Hamel as co-worker

Literature:
O. Levenspiel, Chemical Reaction Engineering, John Wiley & Sons, 1972

3.6. Thermal Process Engineering

Course:
Compulsory module for the master course Chemical and Energy Engineering

Module:
Thermal Process Engineering

Objectives
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 vapour-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

Teaching:
Lecture, Tutorial; (winter semester); (1. semester of master studies)

Prerequisites
Technical Thermoydynamics, Fluid Mechanics I

Workload:
4 hours per week, Lectures and tutorials: 56 hours, Private studies: 94 hours

Examination/Credits:
Written / 5 CP

Responsible lecturer:
Prof. E. Tsotsas, FVST

Literature:

- 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

3.7. Process Systems Engineering

Course:
Compulsory module for the master course Chemical and Energy Engineering

Module:
Process Systems Engineering

Objectives:
The students have learned the fundamentals of systematic modeling, simulation and analysis of process systems. Essential methods for the formulation and solution of spatially distributed balance equations will be provided. The relevant concepts and methods for the analysis of the steady-state and the dynamical process behavior are additionally covered by this course.

Contents:

- Introduction: Aims, concepts, terms and definitions
- Balancing of spatially distributed systems, model formulation
    - Mass balance
    - Momentum balance
    - Energy balance
    - Constitutive equations (state equations, reaction kinetics, transport kinetics)
- Solution of partial differential equations
    - Method of finite volumes
    - Laplace transformation
    - Method of characteristics
- Miscellaneous
    - Differential algebraic equation systems
    - Model reduction
    - Stability analysis

Teaching:
Lecture and Tutorial; (winter semester); (1. semester of master studies)

Prerequisites:
Master-level knowledge of mathematics, physics and chemistry

Workload:
3 hours per week, - Lectures and tutorials: 42 h, - Private studies: 108 h

Examination/Credits:
Written exam / 5 CP

Responsible lecturer:
Prof. K. Sundmacher, FVST, with Dr.-Ing. Teng Zhou as co-worker

Literature:

- 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

3.8. Combustion Engineering

Course:
Compulsory module for the master course Chemical and Energy Engineering

Module:
Combustion Engineering

Objectives and Competence:
The students can conduct energy and mass balances in order to calculate product composition, flame temperature of burners or firing efficiency for heating devices. The student can formulate reaction rates for elementary reactions and identify elementary reactions from global mechanism. They are aware of the techniques to simplify detailed mechanism for specific situations (e.g. lean or rich combustion). The students understand the concept of explosion and flammability, and are able to assess risk related to combustion. They understand the concept of laminar flame propagation that gradients sustained by the chemical reactions permit the necessary heat and mass transport for flame propagation. They can draw qualitatively for a premixed flame, where the flame front is, and the profiles of various quantities (temperature, density, velocity, mass fractions of reactant, intermediate and products). They can estimate the flame height, and they can evaluate the effect of various parameters (pressure, fuel, reactant temperature) on the laminar flame speed. For laminar non-premixed flame, they can draw qualitatively mass fraction and temperature contours, and estimate the length of flame. They grasp the concept of turbulence, and understand the effect of turbulence on the length of turbulent flames whether premixed or non-premixed. They have a basic understanding of the main mechanism involved in the combustion of liquid and solid and fuels. They know the main routes for pollutant formations and available reductive measures. They understand the functioning principles and limitations of the measurement techniques for temperature, velocity, or species concentration for combustion research.

Contents:
- Phenomenology and Typology of Combustion
- Thermodynamics of Combustion
- Chemical kinetics
- Ignition
- Laminar flame theory (premixed and non-premixed flame)
- Turbulent Combustion
- Pollutant formations
- Combustion of Liquids and Solids
- Combustion diagnostics

Teaching:
Lectures with tutorials

Requirement for participation:
Thermodynamics, Heat Transfer, Fluid Mechanics, Reaction kinetics

Work load:
3 SWS, Time of attendance: 42 hours, Autonomous work: 78 hours

Examination/Credits:
Written exam 120 min / 5 CP

Responsibility:
Jun.-Prof. B. Fond, FVST

Literature:

- Documents to be downloaded on e-learning platform
- S. Turns, *“An introduction to Combustion: Concepts and Applications”* McGraw-Hills, 2011
- J. Warnatz, U. Mass and R.W. Dibble, *“Combustion”* Springer, 2006

3.9. Plant Design

Course:
Compulsory module for the master course Chemical and Energy 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

3.10. Laboratory Work

Course:
Compulsory module for the master course Chemical and Energy Engineering

Module:
Laboratory work

Objectives:
A varied experience in execution of experiments and handling of engineering software

Contents:
The kick of meeting for the laboratory work will take place in the second week of the first semester. In this meeting, a general health and safety instruction is given.
Only those who have participated in this meeting are allowed to participate in the laboratory. The participation must be documented with a signature.
The laboratory is conducted in groups. Each group consists of 3 to 6 students. There are eight laboratory works to be done:

- Fine particle separation
- Particle size measurement
- Comminution
- Modeling of the time of residence
- Estimation of kinetic rate constants
- Thermography and measurement of heat transfer coefficients
- Safety relevant units
- Laser Doppler velocimetry measurement

Before each laboratory work, an initial test is written to prove that a fundamental understanding of the specific topic is available. The initial test is being marked.

Within four weeks after each laboratory work, every group has to submit a report, which is marked as well. The average of both marks give a final grade for each laboratory work. The average grade of the eight grades from all laboratory works is in the final grade of the laboratory work module.

To complete the module, one excursion, organized by the student council, has to be done.

Teaching
Execution experiment and handling software, Tutorial; (winter semester); (1.+2.+3. semester of master studies)

Prerequisites
Study of the instructions for laboratory work

Workload:
Lectures and tutorials: 50 hours, Private studies: 100 hours

Examination/Credits: Written and oral / 4 CP + 1 CP for one excursion (organized by the student council or by yourself)
Responsible lecturer: M. Sc. Jakob Seidenbecher, FVST
Literature: Handouts will be given in lecture

3.11. Master thesis

Course: Master Chemical and Energy Engineering
Module: Master thesis
Objectives (competences): 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 to current research projects are published by the professors of the faculty. The students can chose a subject of their tendency. 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.
Teaching: Independent problem-solving with concluding assignment
Prerequisites 30 CP in Master the Master course Chemical Energy Engineering
Amount of work: 20 weeks
Examination/Credits: Master thesis with colloquium / 30 CP
Responsible lecturer: Chairman of the board of examiners

4. Master course Chemical and Energy Engineering, Selective modules

4.1. Advanced Process System Engineering

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Advanced Process Systems Engineering

Objectives (competences):

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

Teaching:
Lecture and exercises/tutorials; (winter semester)

Prerequisites
Bachelor in Process engineering or in a comparable course

Workload:
4 hours per week, Lecture/exercises: 56 hours, Private studies: 94 hours

Examination/Credits:
Oral exam / 5 CP

Responsible lecturer:
Prof. K. Sundmacher, FVST

Literature:

- 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

4.2. Analysis and Design of Experiments

Course:
Selective module for the master course Chemical and Energy 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. M. Wenzel, MPI Magdeburg

4.3. Computational Fluid Dynamics

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
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-ε models, Reynolds-Stress-models. 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.

Teaching

Lecture and hands-on on the computer; (winter semester)

Prerequisites:

Fluid Dynamics

Workload:

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

Examination/Credits:

Written and oral exam / 4 CP

Responsible lecturer:

PD Dr. G. Janiga, FVST

Literature:

Joel H. Ferziger, Milovan Peric: Computational Methods for Fluid Dynamics

4.4. Consequences of accidents in industry

Course:
Selective subject for Chemical and Energy Engineering

Module:
Consequences of accidents in industry

Objectives (competences):
The students are capable to identify, assess and evaluate the major safety hazards in the process industries, namely hazardous release of substances, fires, explosions and runaway reactions.
Course participants are capable to apply mathematical tools to calculate concentration profiles for emission of toxic or otherwise harmful substances, fire effects like flame radius and height, radiative heat and explosion effects like overpressures in process equipment.
Students learn about safe operation of chemical reactors and calculation of safety parameters like adiabatic temperature rise and time to maximum rate. The relevant analytical methods for thermal stability of substances (differential scanning calorimetry, thermogravimetric analysis, Dewar test, hot storage test) are also presented.
Participants design event trees and fault trees for identification of plant damage states and the probable chain of undesired events.
Assessment of individual and group risk from industrial accidents using probit functions and dose calculations is also included.

Content
- Introduction to industrial hazards, case studies, basics of risk assessment
- Emission and dispersion of neutral and heavy gases
- Toxicity of substances, the AEGL concept
- Release of liquids and gases from leakages
- Room fires, pool fires, heat radiation
- Hazardous exothermic reactions, thermal runaway
- Explosion hazards, explosion characteristic data
- Explosion protection
- Hazards from radioactivity
- Risk calculation, probit functions, probit distribution

Teaching:
Lecture and tutorials

Prerequisites:
Mathematics, Chemistry, Thermodynamics, Fluid Dynamics

Workload:
3 hours per week, Tutorials: 42 hours, Private Studies: 78 hours

Examination/Credits:
K 120 / 4 CP

Responsible Lecture:
Dr.-Ing. K. Hecht, FVST

Literature:

[1] Mannan: Lee’s Loss Prevention in the Process Industries (2003)
[2] Hattwig, M; Steen, H., Handbook of Explosion Protection, Wiley-VCH, Weinheim 2004
[3] Bussenius, S: Wissenschaftliche Grundlagen des Brand- und Explosionsschutzes, Kohlhammer, 1995
[4] Schultz, Heinrich: Grundzüge der Schadstoffausbreitung in der Atmosphäre, Köln: Verlag TÜV Rheinland GmbH (1986)
[5] Zenger, A.: Atmosphärische Ausbreitungsmodellierung - Grundlagen und Praxis, Berlin, Heidelberg: Springer Verlag (1988)
[6] Stoessel, F; Thermal Safety of Chemical Processes, Wiley-VCH-Verlag, Weinheim, 2008

4.5. Control of Toxic Trace Elements

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Control of Toxic Trace Elements

Objectives (competences):
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
-

Content:

- 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

Teaching:
lectures 2h/semester and tutorial 1 h/semester; (summer semester)

Prerequisites:
combustion engineering

Workload:
3 SWS
lectures and tutorials: 42 h; private studies: 78 h

Examination/credits:
written exam / 4 CP

Responsible lecturer:
Prof. H. Köser, FVST

Literature:
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

4.6. Dispersed Phase Systems in Chemical Engineering

Course:
Selective module for the Master course Chemical and Energy Engineering

Module:
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 analysed and modelled. This enables the students to analyse, quantify, model, optimize and design processes and products involving a dispersed phase.

Contents:
- Introduction to dispersed phase systems: Fundamentals and characterisation
- 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

Teaching:
Full time lecture of 5 days with exercises

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

Workload:
18 hours of attendence (one-week full-time block seminar), 10 hours outside class
presence: 28 hours (2 SWS), self study time: 78 hours

Examination/Credits:
Written exam / 3 CP

Responsible lecturer:
Dr.-Ing. C. Borchert (BASF SE)

Literature:

- Ramkrishna, Population Balances, Academy Press 2000;
- 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.

4.7. Dispersion of Hazardous Materials

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Dispersion of Hazardous Materials

Objectives (competences):
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 organism present in the radius of action of the release by comparing the calculated concentrations with relevant hazard threshold values.

Content
- 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.

Teaching:
Lecture with tutorial/English

Prerequisites:
-

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

Examination/Credits:
written exam / 4 CP

Responsible Lecturer:
Dr. R. Zinke, FVST

Literature:
- 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 Transportation of Dangerous Goods (“Orange Book”)
- TNO Coloured Books Series

4.8. Drying Technology

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
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

1. The ways of adhesion of the liquid to a commodity, capillary manner, ideal and real sorption, sorptions isotherms
2. Characteristics of humid gases and their use for Nutzung für die convective drying
3. Theoretical handling of real dryers: single stage, multi stage, circulating air, inert gas cycle, heat pump, exhaust vapor compression
4. Kinetics of drying, first and second drying section, diffusion on moist surfaces, Stefan- and Ackermann correction, standardized drying process
5. Convecting drying at local and temporal changeable air conditions
6. Fluid bed drying with gas and overheated solvent vapor
7. Fluidized bed granulation drying and various control options of drying plants with and without heat recovery
8. 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 et al.
9. Exemplary calculation and design of selected dryers

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

Prerequisites:
Basics of process engineering

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

Examination/Credits:
Oral / 4 CP

Responsible lecturers:
Dr. A. Kharaghani, FVST

Literature:
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

4.9. Environmental Biotechnology

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Environmental Biotechnology

Objectives:
The students achieve a deeper understanding in microbiological fundamentals. They are able to characterize the industrial processes of the biological waste gas and biogenic waste treatment and the corresponding reactors and plants. They know the fundamentals of the reactor and plant design. They realise the potential of biotechnological processes for more sustainable industrial processes.

Contents:
- Biological Fundamentals (structure and function of cells, energy metabolism, turnover/degradation of environmental pollutants)
- Biological Waste Gas Treatment (Biofilters, Bioscrubbers, Trickle Bed Reactors)
- Biological Treatment of Wastes (Composting, Anaerobic Digestion)
- Bioremediation of Soil and Groundwater
- Prospects of Biotechnological Processes – Benefits for the Environment

Teaching:
Lectures/Presentation, script, company visit; (winter semester)

Prerequisites:

Work load:
2 hours per week, Lectures and tutorials: 28 h, Private studies: 62 h

Examinations/Credits:
Oral exam / 3 CP

Responsible lecturer:
Dr. D. Benndorf, FVST

Literature:
- Michael T. Madigan, John M. Martinko, David Stahl, Jack Parker, Benjamin Cummings: Brock Biology of Microorganisms, 13 edition (December 27, 2010)
- Jördening, H.-J (ed.): Environmental biotechnology: concepts and applications, Weinheim: Wiley-VCH, 2005
- Environmental Biotechnology (ed. by Lawrence K. Wang, Volodymyr Ivanov, Joo-Hwa Tay), Springer Science+Business Media, LLC, 2010 (Handbook of Environmental Engineering, 10)
- Further literature will be given in the lecture

4.10. Fuel Cells

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
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 posses 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

Teaching:
Lecture and Tutorial

Prerequisites:
Basic knowledge on thermodynamics, reaction engineering and mass transport is advantageous.

Workload:
32h time of attendance (one-week full-time block seminar), 10h outside classes
Presence: 42h (3 SWS), self study time: 78h (literature survey)

Examination/Credits:
Oral exam 60 min. / 5 CP

Responsible lecturer:
Dr. T. Vidakovic-Koch, MPI Magdeburg

Literature:

- 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

4.11. Internship

Course: Selective module for the master course Chemical and Energy Engineering
Module: Internship
Objectives: In this industrial internship, students have the opportunity to gain experience related to industrial procedures, tools and processes. They will 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 then present the results and insights in a seminar presentation and answer the audience's questions. They will the receive feedback based on the quality and delivery of the presentation and how understandable it was.
Contents The internship can cover the following fields ➢ Power generation ➢ Treatment of solids ➢ Treatment of fluids ➢ Maintenance, service, and repair ➢ Measurement, analysis, testing, and quality control ➢ Development, design, preparation and process analysis ➢ Assembly and initial operations ➢ Bioprocess-, pharmaceutical- and environmental engineering. ➢ Production organization ➢ Manufacturing planning, preparation and order processing ➢ Practical position related to the field that is accepted by the Praktikantenamt The work and results are to be presented in an oral presentation (maximum 15 min) with a discussion after the presentation. A written report must also be turned in (8-16 pages).
Teaching Industrial internship, seminar presentation
Prerequisites None
Workload: 300 hours (2 months)
Examination/Credits: Report (8-16 pages), Letter of participation, Seminar participation (15 minutes) / 10 CP The grade is the mean of value of report and presentation.
Responsible lecturer: B. Gopalkrishna, FVST

4.12. Micro Process Engineering

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Micro Process Engineering (Aussetzung bis auf Weiteres)

Objectives:

- Basic understanding of all important physical and chemical phenomena relevant in microstructures
- Real-life know-how and relevant methods for choice, evaluation and designing of microstructured process equipment
- Adequate model representations for realistic and convenient design and simulation of microstructured process equipment

Contents:

- Heat and mass transfer in microstructures
- Safety and economic aspects of microstructured process equipment
- Designing of micro heat exchangers, mixers and reactors
- Role of surface/interfacial forces: Capillary effects and wetting
- Design concepts of microstructured equipment, commercial realisations and suppliers
- Process design and scale-up of microstructured process equipment
- Real life experience: Design rules, Dos & Don'ts
- Limitations of microstructured process equipment

Teaching:
Seminar-style lecture with group work (calculation examples etc.); (winter semester)

Prerequisites
Heat Transfer, Fluid Mechanics, Chemical Reaction Eng.
Also helpful: Process Systems Engineering, Process Dynamics.

Workload:
2 hours per week lecture incl. group work, 28h lectures and tutorials, 78h private studies

Examinations / Credits
Written (90 min.); If less than 20 participants: Oral examinations (30 min.) / 3 CP

Responsible lecturer:
N.N.

Literature:

- W. Ehrfeld, V. Hessel, H. Löwe: Microreactors, Wiley-VCH, Weinheim, 2000
- V. Hessel, S. Hardt, H. Löwe: Chemical Micro Process Engineering: Fundamentals, Modeling and Reactions, Wiley-VCH, Weinheim, 2004
- V. Hessel, S. Hardt, H. Löwe: Chemical Micro Process Engineering: Processing, Applications and Plants, Wiley-VCH, Weinheim, 2004
- W. Menz, J. Mohr, O. Paul: Microsystem Technology, Wiley-VCH, Weinheim, 2001

4.13. Modern organic synthesis

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Modern organic synthesis

Objectives:
Constitutive to the basic knowledge of the „Chemistry“ module in this module the expertise for development of strategy for complex synthesis will be procured. On example of chosen synthesis the principles of total synthesis will be trained.

Contents:

- Short overview reactivity, carbon hybrids, organic chemical basic reactions
- Concept of the acyclic stereoselection on the example of Aldol reactions
- Demonstration of the concept on the example of miscellaneous total synthesis of natural products
- Basics of metal organic chemistry
- Vinyl silanes
- Allyl silanes

Teaching:
Lecture; (winter semester)

Prerequisites:
Module Chemistry

Work load:
2 hours per week, lectures: 28 hours, private studies: 62 hours

Examinations/Credits:
Oral / 3 CP

Responsible lecturer:
Prof. D. Schinzer, FVST

Literature:
Handouts will be given in lecture

4.14. Molecular Modelling/Computational Biology and Chemistry

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Molecular Modelling/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:
3 SWS
Lectures and tutorials: 42 hrs (28/14)
Private studies: 78 hrs

Examination/Credits:
Project work and documentation (50%), oral examination (50%) / 4 CP

Responsible lecturer:
Dr. M. Stein, MPI Magdeburg

Literature:

- Andrew R. Leach: Molecular Modelling - Principles and Application, Pearson 2001.
- H.D. Höltje, W.Sippl, D. Rognan, G. Folkers: Molecular Modeling, Wiley-VCH 1996.
- D. Frenkel, B. Smit: Understanding molecular simulation: from algorithms to applications, Acad. Press, 2007.
- D. Higgin, W. Taylor: Bioinformatics: sequence, structure, and databanks; a practical approach, Oxford University Press, 2000.
- Wolfram Koch; Max C. Holthausen: A chemist's guide to density functional theory, Wiley-VCH, 2008.

4.15. Multiphase Flow Fundamentals

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Multiphase Flow Fundamentals

Objectives:
The lecture aims at giving an introduction to multiphase flows frequently found in industry, environment and daily life. The main focus will be related to dispersed multiphase flows where particles are distributed in a flow system. Here the main relevant transport mechanisms occurring on the scale of the particles will be introduced. Hence the students will learn about the complexity of multiphase flows and obtain some guidelines about process lay-out.

Contents:
The lecture begins with an introduction of the features of multiphase flows and their characterization. Then the main focus will be related to dispersed multiphase flows where the dispersed phase consists of solid particles, droplets or bubbles which are distributed in the carrier phase (i.e. gas or liquid). For each of these types of dispersed multiphase flows, such as gas-particles systems, sprays and bubbly flows, the relevant transport processes will be introduced, such as for example:

- Fluid forces on particles
- Turbulent transport of particles
- Inter-particle collisions and their outcomes, such as bouncing and coalescence
- Agglomeration of particles
- Wall interaction of particles and possible deposition
- Atomization of liquids
- Droplet heat and mass transfer

Following that some typical processes with dispersed multiphase flows will be introduced, reviewing the main design criteria. Finally also the numerical methods for calculating dispersed multiphase flows will be summarized.

Teaching:
Lecture and Tutorial
The lecture will be offered only in English.

Pre-requisites:
Good knowledge in fluid mechanics and particle technology

Work load:
Lectures and tutorials:
2 hours per week lectures including tutorials
The lectures will be hold in the form of block-seminars every second week (only summer semester).

Examination/Credits:
Written or oral exam / 4 CP

Responsible lecturers:
Prof. M. Sommerfeld, FVST

Literature:
Crowe, C.T., Schwarzkopf, J.D., Sommerfeld, M. and Tsuji, Y.: Multiphase Flows with Droplets and Particles. 2nd Edition, CRC Press, Boca Raton, U.S.A. (2012), ISBN 978-1-4398-4050-4 (507 pages)

4.16. Nanoparticle technology

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
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 characterisation 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-der-Waals 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

Teaching:
lecture, tutorials, laboratory work (nanoparticle synthesis); (winter semester)

Prerequisites:

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

Examinations/Credits:
Oral / 4 CP

Responsible lecturer:
Dr. W. Hintz, FVST

Literature:

- Tadao, Sugimoto: Monodispersed Particles, Elsevier, ISBN 978-0-444-546456 Masuo Hosokawa: Nanoparticle Technology Handbook, Elsevier, ISBN 978-0-444-563361

4.17. Numerical simulation in explosion protection

Course:
Selective module for the master course Chemical and Energy 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

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

Course:
Selective module for the master course Chemical and Energy Engineering

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

Objectives:
The students understand the basic procedure in the design, implementation and problem solving of apparatus and plant engineering concepts in solid-state process engineering. Based on examples from industrial practice, the students should be taught the ability to abstract the process to such an extent that an estimate of the size of the plant, the achievable throughputs and the necessary energy inputs is possible with simple means. It will be shown how these simple estimates can initially be used as the basis for a system design and later be superseded by more complex models. For the more complex process modeling, temporal and spatially distributed models or also population dynamic models are used depending on the complexity of application. The application examples used in the lecture are essentially drying and granulation processes in which solids are treated by means of convection and contact dryers.

Contents:
1. Basics apparatus and plant engineering
2. Basics of process design
3. Drying and granulation processes in solid process technology
4. Design of convection dryers (mass and energy balances)
5. Design of contact dryers (mass and energy balances)
6. Heat and mass transfer in convection and contact dryers
7. Application examples and case studies from industrial practice

Teaching:
lectures and tutorials; (summer semester)

Prerequisites:

Work load:
3 hours per week, lectures and tutorials: 42 h, private studies: 78 h

Examinations/Credits:
Oral / 4 CP

Responsible lecturer:
Hon.-Prof. M. Peglow, FVST

Literature:
lecture notes
Selected scientific publications in the field

4.19. Process Control

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
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

Teaching
Lecture and exercises/tutorials; (summer semester)

Prerequisites
Basic knowledge in control theory

Workload:
Lectures and tutorials:
- 2 hours/week – lecture
- 1 hour/week – exercise/tutorial

Private studies
- Post-processing of lectures, preparation of project work/report and exam (78 hours)

Examination/Credits:
oral / 4 CP and project report

Responsible lecturer:
Prof. A. Kienle, FEIT, with Dr. A. Disli-Kienle as co-worker

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

4.20. Process Engineering of Metals and Ceramics

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Process Engineering of Metals and Ceramics (last lecture in summer 2020)

Objectives:
The students can apply the coupled mechanism of simultaneous heat transfer, mass transfer, solid reactions and reactive flows. They can make energy and mass balances for industrial furnaces. They can design thermal processes in rotary kilns, shaft kilns, tunnel kilns and other kilns for the production of metals and ceramics.
They are able to install quality management systems, make market analysis, consider environmental aspects and assess the cost structure.

Contents:
- Manufacturing process of steel, basic reactions, handling of raw material
- Thermal and chemical treatment of raw materials in shaft kilns and cupola furnaces (reaction kinetics, heat and mass transfer, fluid dynamics)
- Modeling of lime calcination as an example
- Thermal and chemical treatment of materials in rotary kilns
- Manufacturing process of ceramics (shaping, drying, sintering)
- Thermal and chemical treatment of shaped material in tunnel kilns
- Casting and shaping processes of metals (steel, copper, aluminum)
- Thermal treatment of steel (hardening, quenching, carburizing)
- Market analysis, quality management systems, logistics, cost management, ecological aspects, social competence, challenges for innovations (This part is given by Dr. U. Urlau, Director of research and development from Int. Company Schmolz and Bickenbach AG, turnover 3 billion €/a)

Teaching:
Lectures with experiments and excursions

Prerequisites:
Thermodynamics, Heat and Mass Transfer, Combustion Engineering

Work load:
3 SWS, Time of attendance: 42 h, Autonomous work: 78 h

Examination/Credits:
group project (design of a process) or oral exam / 4 CP

Responsible lecturer:
Prof. E. Specht, FVST

Literature:
handouts can be downloaded
R.J.L Guthrie: Engineering in Process Metallurgy, Clarendon Press.
A.F. Mills: Basic Heat and Mass Transfer
S. Turns: An introduction to combustion

4.21. Product quality in the chemical industry

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Product quality in the chemical industry

Objectives:
Understanding the

- Requirement profiles for products of the chemical and process industry
- Relation 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)

Teaching:
Lectures / Exercises / Lab exercises / Workshop; (summer semester)

Prerequisites:

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

Examinations /Credits:
Oral exam / 4 CP

Responsible lecturer:
Prof. E. Tsotsas / Dr. A. Kharaghani, FVST

Literature:
Handouts will be given in lecture

4.22. Renewable Energies: Materials, Components, Function

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Renewable Energies: Materials, Components, Function

Objectives: 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

Contents:

- statistics in energy consumption
- types of energy resources
- terms and definitions
- conversion (devices and materials thereof, processes): photovoltaics; solar thermal; wind, water and planetary energy; fuel cells; geothermal; biomass, solar chemistry
- dimensioning examples

Teaching:
Lectures and Tutorials (summer semester)

Prerequisites:
basics in chemistry and physics

Workload:
3 SWS
Lecture and tutorials: 3 hours per week (2 lecture, 1 tutorial), Regular Study: 42 h, Private Study: 78 h

Examination/Credits:
Written exam (90 minutes) / 5 CP

Responsible lecturer:
Prof. Dr. M. Scheffler, FMB

Literature:

- 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

4.23. 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

Responsible lecturer:
Prof. B. van Wachem, FVST

Literature:
Lecture notes with text, figures and exercises (available on Moodle)

4.24. Sustainability Assessment (LCA) for Biofuels

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Sustainability Assessment (LCA) for Biofuels

Objectives (Skills):
The students will get an overview of the sustainability assessment methodologies. They will learn the theoretical background and the standardized procedures to carry out a life cycle assessment (LCA). The phases (goal and scope, inventory analysis, impact assessment and interpretation and evaluation) in a life cycle assessment (LCA) will be declared in detail. The importance of product system definition and functional unit will be worked out. With the help of examples the students will acquire skills to define the system boundaries, to apply the cut-off rules. Furthermore, the students will learn the principles how to allocate the interventions or expenditures in a case of a multiproduct system and how to use the credit method. The use of flow sheet simulation tools will be taught to quantify the energy and mass flows for chemical production processes. The impact categories will explained and the students will learn to how to select appropriate and relevant impact categories in different types of product systems. The evaluation of the results and the differences between attributional and consequential LCA will be learned.

The thermochemical and biotechnological production processes for renewable fuels and chemicals will be elucidated as case examples for LCA. Beyond the sustainability aspects the students will learn the process limitations and technical challenges for various raw materials (e.g. starch vs. lignocellulosic platforms). Finally the students learn the principles of an exergy analysis.

As another component 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 analyse and critically review the scientific publications, and to report scientific published information appropriately.

Content:
1. Sustainability and the principles of sustainable development.
2. The overview of Life Cycle Assessment (LCA) and the phases
3. Inventory and energy analysis, system boundaries, cut-off rules, allocation rules for multiproduct systems.
4. Impact assessment, the input- output related categories,
5. Reporting, interpretation, evaluation and critical review. Attributional and consequential LCA.
6. Ethanol production processes (starch and sugar and lignocellulosic based platform)
7. Thermochemical processes: BTL, biomass gasification, pyrolysis and Fischer-Tropsch
8. Algae biomass utilization, transesterification of triglycerides, anaerobic digestion
9. Introduction to exergy analysis

Teaching:
Lectures and a guided scientific literature search and a preparation of a literature survey.

Prerequisites:
Basic courses of chemistry and chemical engineering (Bachelor level)

Workload:
presence: 28 hours (2 SWS), survey: 14 hours (1 SWS)

Credits: written exam / 4 CP
Responsible lecturer: Dr. Techn. L. Rihko-Struckmann, MPI Magdeburg, J. Schweizer
Literature: lecture notes (free to download)

4.25. Thermal Power Plants

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Thermal Power Plants

Objectives:
This courses discusses the various devices used to convert various sources of chemical energy, atomic or solar energy into electrical or mechanical power. The course focuses on plant design and control, efficiency and pollutant emission.
This course applies the competence of the students in Thermodynamics, Heat and Mass Transfer, basic Physics and Combustion to the understanding of modern power plants design. The students are able to estimate the power, energy consumption, environmental impacts of various plants and engines and propose efficiency improvements.
Note that this course has a strong overlap with the „Warmekraftanlage“ course taught in German language, and students are not advise to visit both.

Contents:

- Global data of energy consumption
- Overview of power cycles
- The Rankine cycle and its optimization
- Steam generators
- Coal and Biomass Fired power plants
- Solar-thermal power plants
- Nuclear power plants
- Reciprocating Engines
- Gas turbines

Teaching:
Lectures with tutorials

Prerequisites:
Thermodynamics, Heat and Mass Transfer, Combustion Engineering (not mandatory but advised)

Workload:
3 SWS
Time of attendance: 42 h, Autonomous work: 78 h

Examination/Credits:
written exam / 4 CP

Responsible lecturer:
Jun.-Prof. B. Fond, FVST

Literature:

- ➢ Handouts and lectures slides to be downloaded on e-learning platform.
- ➢ Rogers and Mayhews, Engineering Thermodynamics: Work and Heat Transfer (4th Edition

4.26. Transport phenomena in granular, particulate and porous media

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
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

Teaching:
Lectures / Exercises; (summer semester)

Prerequisites:

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

Examinations/Credits:
Oral exam / 5 CP

Responsible lecturer:
Prof. E. Tsotsas, FVST

Literature:

- 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
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4.27. Waste Water and Sludge Treatment

Course:
Selective module for the master course Chemical and Energy Engineering

Module:
Wastewater and sludge treatment (WWST)

Objectives (competences):
The student should be able to

- identify the relevant physical, chemical and biological properties of a wastewater
- understand the fundamentals of wastewater treatment technologies
- identify the relevant physical, chemical and biological properties of biosolids from wastewater treatment
- develop creative solutions for the treatment of wastewater and the control of emissions to surface water

Content:

- 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

Teaching:
lectures, tutorial and essay writing; (winter semester)

Prerequisites:
bachelor in chemical or biological engineering or equivalent

Workload:
3 SWS,
lectures, tutorials: 42 h; private studies: 78 h

Examination/credits:
written exam / 5 CP

Responsible lecturer:
Prof. H. Köser, FVST

Literature:
script; N.F. Gray “Water Technology”, Elsevier 2005; Metcalf a. Eddy “Wastewater Engineering” MacGrawHill 2003, P. A. Vesilind “Wastewater treatment plant design” and “Student Workbook” IWA Publishing, 2003;