



OTTO VON GUERICKE  
UNIVERSITÄT  
MAGDEBURG

VST

FAKULTÄT FÜR VERFAHRENS-  
UND SYSTEMTECHNIK

## **Module catalogue**

### **Master course**

### ***Chemical and Energy Engineering***

**1<sup>st</sup> April 2023**



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## 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.

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



### 3. Master course Chemical and Energy Engineering, compulsory modules

#### 3.1. Chemistry

<b>Course:</b> Compulsory module for the master course Chemical and Energy Engineering
<b>Module:</b> Chemistry
<b>Objectives:</b> 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.
<b>Contents:</b> <ul style="list-style-type: none"><li>• Inorganic Chemistry<ul style="list-style-type: none"><li>• 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, <math>\sigma</math>-bonds, <math>\pi</math>-bonds, resonance forms.</li><li>• 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.</li><li>• Solutions, electrolytes, solubility product, acid/base theories, pH value, oxidation numbers, oxidation, reduction, redox processes</li><li>• Chemistry of Main Group Elements</li></ul></li><li>• Industrial Chemistry<ul style="list-style-type: none"><li>• Chemical process technologies: from the raw materials to final products (energy-raw material-product network)</li><li>• Crystallization as an example of industrial inorganic chemistry</li><li>• Industrial organic chemistry</li><li>• fossile resources as raw materials of the chemical industry &amp; energy sources (general aspects, primary oil treatment, oil refinery, chemical (and thermal) treatment of coal)</li><li>• base chemicals and selected intermediates (general aspects, synthesis gas, methanol and intermediates, ethene and intermediates)</li><li>• fine chemicals manufacture (commodities, fine chemicals and specialties: general aspects and examples, characteristic features of fine chemicals manufacture, example of a typical process)</li></ul></li><li>• Physical Chemistry<ul style="list-style-type: none"><li>• Overview: Main parts of Physical Chemistry</li><li>• Thermodynamics (TD): basic terms, techniques</li><li>• System and Surrounding, state functions and variables, perfect gas law, thermal equation of state, real gases, critical point, principle of corresponding states</li><li>• First law of thermodynamics, heat capacities, internal reaction energy and reaction enthalpy, and their dependence on p and T, Hess law</li><li>• Conversion of heat in work: Carnot process, 2<sup>nd</sup> law of TD, entropy, 3<sup>rd</sup> law of TD</li><li>• Gibbs energy, Helmholtz energy, chemical potential</li></ul></li></ul>



- Joule-Thomson effect
- Phase equilibria, Gibbs phase rule, Clapeyron and Clausius-Clapeyron equation
- Mixtures and partial molar quantities, Raoult's 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 co-workers

**Literature:**

Handouts will be given in lecture



### 3.2. Advanced Fluid Dynamics

<b>Modulbezeichnung</b>	<b>Advanced Fluid Dynamics</b>
<i>Englischer Titel</i>	<b>Advanced Fluid Dynamics</b>
<i>Modulniveau nach DQR</i>	Master
<i>Modulnummer</i>	
<i>Untertitel</i>	k.A.
<i>Lehrveranstaltungen</i>	Vorlesung Advanced Fluid Dynamics Übung Advanced Fluid Dynamics
<i>empfohlenes Studiensemester</i>	2. Semester
<i>Häufigkeit des Angebots/ Angebotsturnus</i>	Jedes SoSe
<i>Modulverantwortliche:r</i>	Prof. Dominique Thévenin, FVST-ISUT
<i>Dozent:in</i>	Prof. Dominique Thévenin, FVST-ISUT
<i>Sprache</i>	Englisch
<i>Zuordnung zum Studiengang/ Curriculum / Verwendbarkeit des Moduls</i>	► Pflichtmodul Master Chemical and Energy Engineering (CEE)
<i>Lehrform und SWS</i>	Vorlesung 2 SWS Präsenzzeit Übung 2 SWS Präsenzzeit
<i>Arbeitsaufwand</i>	Präsenzzeit/Selbststudium/Klausur 4 SWS, 56 Std./92 Std./2 Std: insgesamt 150 Std.
<i>Dauer des Moduls</i>	1 Semester
<i>Credit Points (CP)</i>	5
<i>Voraussetzung für die Vergabe von CP</i>	Bestehen der Klausur
<i>Teilnahmevoraussetzungen</i>	Nachweis üblicher Bachelor-Kompetenzen in Mathematik, Physik, Thermodynamik, Strömungsmechanik
<i>Empfehlungen für die Teilnahme</i>	k.A.



<i>Modulziele / angestrebte Lernergebnisse / Learning Outcomes</i>	► During this Module the students will acquire competences concerning all issues related to Fluid Dynamics in the field of Chemical and Energy Engineering. 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 incompressible and compressible flows and to obtain relevant solutions for such flows in an autonomous manner.
<i>Inhalt</i>	<ol style="list-style-type: none"><li>1. Introduction and basic concepts</li><li>2. Important mathematical relations, material derivative</li><li>3. Mass and momentum conservations equations</li><li>4. Hydrostatics and aerostatics</li><li>5. Bernoulli relation for ideal flows</li><li>6. Bernoulli relation for viscous flows involving work exchange</li><li>7. Force and torque induced by a flow</li><li>8. Navier–Stokes equations for viscous flows</li><li>9. Boundary layer</li><li>10. Basics of compressible flows</li><li>11. Shock waves</li><li>12. Similarity theory</li><li>13. Turbulent flows</li></ol>
<i>Studien- / Prüfungsleistungen / Prüfungsformen</i>	Klausur, 120 Minuten
<i>Literatur</i>	Eigenes Skript Fluid Mechanics, Frank M. White, McGraw Hill
<i>Sonstige Informationen</i>	k.A.
<i>Freigabe / Version</i>	





### 3.3. Advanced Heat and Mass Transfer

<b>Course:</b> Compulsory module for the master course Chemical and Energy Engineering
<b>Module:</b> Advanced Heat and Mass Transfer
<b>Objectives:</b> 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.
<b>Contents:</b> <ul style="list-style-type: none"><li>- Fourier differential equations, boundary conditions, analytical solution, numerical methods</li><li>- Semi-infinite bodies, contact heat transfer</li><li>- Heat transfer by radiation, fundamentals, emissivities of solids, liquids and gases, heat exchange between gases and solids, view factors</li><li>- Greenhouse effect, Mechanism of global warming</li><li>- Intensive cooling processes for metals</li><li>- Coupled heat and mass transfer processes for gas-solid reactions.</li></ul>
<b>Teaching:</b> Lectures with tutorials
<b>Prerequisites:</b> Thermodynamics, Fluidmechanics, Mathematics, Basic heat transfer
<b>Work load:</b> 4 SWS Time of attendance: 56 hours, Autonomous work: 94 hours
<b>Examination/Credits:</b> written exam 2 hours / 5 CP
<b>Responsible lecturer:</b> JP A. Dieguez-Alonso, Dr.-Ing. Seidenbecher, FVST
<b>Literature:</b> Heat and Mass Transfer in Thermoprocessing, Vulkan Verlag Essen (2018)



### 3.4. Mechanical Process Engineering

<b>Course:</b> Compulsory module for the master course Chemical and Energy Engineering
<b>Module:</b> Mechanical Process Engineering
<b>Objectives (competences):</b> Students <ul style="list-style-type: none"><li>• Understand the mathematical description of the properties and behavior of a single and of multiple particles.</li><li>• Understand the principal features of dynamic processes of Mechanical Process Engineering and Particle Technology.</li><li>• Understand the principles of storage, transport, mixing, separation and comminution of particle systems.</li><li>• Analyze and optimize the selection, design, and assessment of stochastic and stationary mechanical processes.</li></ul>
<b>Content:</b> <ol style="list-style-type: none"><li>1. Introduction, characterization of <b>disperse material systems</b>, particle characterization, particle size distributions, quantities, statistical moments, distribution characteristics, surface, physical particle test methods, particle shape, packing states.</li><li>2. Behavior of <b>single particles in flows</b>, forces on a particle, particles falling under gravity, and the behavior of non-spherical particles.</li><li>3. Behavior of <b>multiple particles</b>, particles in a suspension, batch and continuous settling.</li><li>4. Behavior of <b>fine particles</b>, Brownian motion, surface forces on particles, sedimentation and rheology, size enlargement of particles.</li><li>5. <b>Storage and flows of powders</b>, flow of solid powders, stress analysis of powders, hopper flows, practical powder handling.</li><li>6. Particle transport, pneumatic transport, vertical and horizontal transport, design of dilute and dense phase transport systems, standpipes.</li><li>7. <b>Particle and fluidized beds</b>. Flow through a particle bed, filtration, fluidization, fluidization regimes.</li><li>8. <b>Particle separation</b>, flow separation, gas cyclones, hydro cyclones, filtration.</li><li>9. <b>Mixing and segregation of particles</b>, analysis of mixing, stochastic homogeneity, mechanisms of mixing, types of mixers.</li><li>10. <b>Comminution of particles</b>, material considerations, energy requirements, mechanisms of comminution, types of comminution equipment.</li></ol>
<b>Teaching:</b> Lectures, tutorials and practical tutorials (4 labs)
<b>Prerequisites:</b> Statistics, Physics, Engineering Mechanics, Fluid Mechanics I
<b>Workload:</b> Lectures and tutorials: 56 h, private studies: 94 h
<b>Examination/Credits:</b> 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
  - 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 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)

**Prerequisites:**

**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. Ch. Hamel / Dr.-Ing. Gerlach, FVST

**Literature:**

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



### 3.6. Thermal Process Engineering

<b>Course:</b> Compulsory module for the master course Chemical and Energy Engineering
<b>Module:</b> Thermal Process Engineering
<b>Objectives</b> 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.
<b>Contents</b> Equilibrium separation processes: <ul style="list-style-type: none"><li>• Thermodynamics of vapour-liquid equilibrium</li><li>• Batch and continuous distillation</li><li>• Theory of separation cascades, rectification in tray and packed columns</li><li>• Separation of azeotropic mixtures</li><li>• Practical design and hydraulic dimensioning of tray and packed columns</li><li>• Gas-liquid equilibrium</li><li>• Absorption in tray and packed columns</li><li>• Practical design of absorption apparatuses</li><li>• Thermodynamics of liquid-liquid equilibrium</li><li>• Separation of liquid mixtures by extraction</li><li>• Practical design of extraction equipment</li></ul> Kinetically controlled separation processes: <ul style="list-style-type: none"><li>• Fundamentals of convective drying</li><li>• Adsorption equilibrium and standardized drying curve of the single particle</li><li>• Dimensioning of convective dryers</li><li>• Evaporations of liquid mixtures in inert gas</li><li>• Diffusion distillation and pseudo-azeotropic points</li></ul>
<b>Teaching:</b> Lecture, Tutorial; (winter semester); (1. semester of master studies)
<b>Prerequisites</b> Technical Thermodynamics, Fluid Mechanics I
<b>Workload:</b> 4 hours per week, Lectures and tutorials: 56 hours, Private studies: 94 hours
<b>Examination/Credits:</b> Written / 5 CP
<b>Responsible lecturer:</b> 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

<b>Course:</b> Compulsory module for the master course Chemical and Energy Engineering
<b>Module:</b> Process Systems Engineering
<b>Objectives:</b> 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.
<b>Contents:</b> <ul style="list-style-type: none"><li>• Introduction: Aims, concepts, terms and definitions</li><li>• Balancing of spatially distributed systems, model formulation<ul style="list-style-type: none"><li>- Mass balance</li><li>- Momentum balance</li><li>- Energy balance</li><li>- Constitutive equations (state equations, reaction kinetics, transport kinetics)</li></ul></li><li>• Solution of partial differential equations<ul style="list-style-type: none"><li>- Method of finite volumes</li><li>- Laplace transformation</li><li>- Method of characteristics</li></ul></li><li>• Miscellaneous<ul style="list-style-type: none"><li>- Differential algebraic equation systems</li><li>- Model reduction</li><li>- Stability analysis</li></ul></li></ul>
<b>Teaching:</b> Lecture and Tutorial; (winter semester); (1. semester of master studies)
<b>Prerequisites:</b> Master-level knowledge of mathematics, physics and chemistry
<b>Workload:</b> 3 hours per week, - Lectures and tutorials: 42 h, - Private studies: 108 h
<b>Examination/Credits:</b> Written exam / 5 CP
<b>Responsible lecturer:</b> Prof. K. Sundmacher, FVST
<b>Literature:</b> <ul style="list-style-type: none"><li>- R.B. Bird, W.E. Stewart, E.N. Lightfoot Transport Phenomena, Wiley, Chichester, 1960</li><li>- O. Levenspiel, Chemical Reaction Engineering, Wiley, New York, 1972.</li><li>- D. Kondepudi, I. Prigogine, Modern Thermodynamics, Wiley-VCH, Chichester, 1998</li><li>- S.V. Patankar, Numerical Heat Transfer and Fluid Flow, McGraw-Hill, New York, 1980</li></ul>





### 3.8. Combustion Engineering

<b>Course:</b> Compulsory module for the master course Chemical and Energy Engineering
<b>Module:</b> Combustion Engineering
<b>Objectives and Competence:</b> 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.
<b>Contents:</b> <ul style="list-style-type: none"><li><input type="checkbox"/> Phenomenology and Typology of Combustion</li><li><input type="checkbox"/> Thermodynamics of Combustion</li><li><input type="checkbox"/> Chemical kinetics</li><li><input type="checkbox"/> Ignition</li><li><input type="checkbox"/> Laminar flame theory (premixed and non-premixed flame)</li><li><input type="checkbox"/> Turbulent Combustion</li><li><input type="checkbox"/> Pollutant formations</li><li><input type="checkbox"/> Combustion of Liquids and Solids</li><li><input type="checkbox"/> Combustion diagnostics</li></ul>
<b>Teaching:</b> Lectures with tutorials
<b>Requirement for participation:</b> Thermodynamics, Heat Transfer, Fluid Mechanics, Reaction kinetics
<b>Work load:</b> 3 SWS, Time of attendance: 42 hours, Autonomous work: 78 hours
<b>Examination/Credits:</b> Written exam 120 min / 5 CP
<b>Responsibility:</b> Prof. F. Beyrau



**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

<b>Course:</b> Compulsory module for the master course Chemical and Energy Engineering
<b>Module:</b> Plant Design
<b>Objectives (competences):</b> 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.
<b>Content:</b> 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
<b>Teaching:</b> Lectures 2 SWS, Tutorial 1 SWS in English
<b>Prerequisites:</b> Knowledge of basics in thermo and fluid dynamics, chemical reactions and strength of materials
<b>Workload</b> Class room: 42 hours, Private studies: 108 hours
<b>Type of examination/Credits:</b> Written / 5 CP
<b>Responsible lecturer:</b> Dr.-Ing. D. Gabel, FVST
<b>Literature:</b> <ol style="list-style-type: none"><li>1. Brian D. Ripley: Stochastic Simulation, John Willey &amp; Sons, Inc., 1997</li><li>2. E. Klapp: Apparate- und Anlagentechnik, Springer Verlag, 1980</li><li>3. Winnacker, Küchler: Chemische Technik, Wiley-VCH Verlag GmbH&amp;Co. KGaA, 2003</li><li>4. K. Sattler, W. Kasper: Verfahrenstechnische Anlagen (Band 1 und 2), Wiley-VCH Verlag GmbH &amp; Co., 2000</li><li>5. H.Ullrich: Anlagenbau (Kommunikation- Planung- Management), Georg Thieme Verlag Stuttgart, 1983</li><li>6. G. Bernecker: Planung und Bau Verfahrens-Technischer Anlagen, VDI Verlag, 1984</li><li>7. G.L. Wells, L.M Rose: The art of Chemical Process Design, Elsevier, 1986</li></ol>



### 3.10. Laboratory Work

<b>Course:</b> Compulsory module for the master course Chemical and Energy Engineering
<b>Module:</b> Laboratory work
<b>Objectives:</b> A varied experience in conducting experiments and handling engineering software.
<b>Contents:</b> The laboratory is conducted in groups. Each group consists of 3 to 6 students. There are eight laboratory works to be done: <ul style="list-style-type: none"><li>• Particle size measurement (PSM),</li><li>• Comminution (COM),</li><li>• Time of residence (TRE),</li><li>• Estimation of kinetic rate constants (KRC),</li><li>• Thermography 1 (THG),</li><li>• Safety relevant units (SRU),</li><li>• Laser Doppler velocimetry measurement (LDV),</li><li>• Thermography 2: Measurement of heat transfer coefficients (HTC).</li></ul> <p>Before each laboratory work, an initial test is written to prove that a fundamental understanding of the specific topic is available. The initial test will be marked.</p> <p>Within four weeks after each laboratory work, every group has to submit a report, for which a mark is given as well. The average of the mark of the initial test and the mark of the report will comprise the final grade for each laboratory work. The average of the eight grades from all laboratory works is in the final grade of the laboratory work module.</p> <p>To complete the module, one excursion, organized by the student council, has to be done. The kick-off meeting for the laboratory work will take place in the <b>second week of the first semester</b>. In this meeting, a general health and safety instruction is given. <b>Only those who have participated in this meeting are allowed to participate in the laboratory.</b> The participation must be documented with a signature.</p>
<b>Teaching</b> Conducting experiments and handling software, Tutorial; (winter semester); (1.+2.+3. Semester of master studies).
<b>Prerequisites</b> Study of the instructions for the laboratory works
<b>Workload:</b> 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:**

Dr. W. Hintz, FVST

**Literature:**

Handouts will be provided in lecture



### 3.11. Master thesis

<b>Course:</b> Master Chemical and Energy Engineering
<b>Module:</b> Master thesis
<b>Objectives (competences):</b> 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.
<b>Contents:</b> 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.
<b>Teaching:</b> Independent problem-solving with concluding assignment
<b>Prerequisites</b> 30 CP in Master the Master course Chemical Energy Engineering
<b>Amount of work:</b> 20 weeks
<b>Examination/Credits:</b> Master thesis with colloquium / 30 CP
<b>Responsible lecturer:</b> Chairman of the board of examiners



## 4. Master course Chemical and Energy Engineering, Selective modules

### 4.1. Advanced Process System Engineering

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Advanced Process Systems Engineering
<b>Objectives (competences):</b> 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.
<b>Contents:</b> <ul style="list-style-type: none"><li>• Multilevel modelling concepts</li><li>• Molecular fundamentals of kinetics and thermodynamics</li><li>• Modelling of complex continuum systems</li><li>• Advanced process optimization techniques</li></ul>
<b>Teaching:</b> Lecture and exercises/tutorials; (winter semester)
<b>Prerequisites</b> Bachelor in Process engineering or in a comparable course
<b>Workload:</b> 4 hours per week, Lecture/exercises: 56 hours, Private studies: 94 hours
<b>Examination/Credits:</b> Oral exam / 5 CP
<b>Responsible lecturer:</b> Prof. K. Sundmacher, FVST
<b>Literature:</b> <ul style="list-style-type: none"><li>- R.B. Bird, W.E. Stewart, E.N. Lightfoot Transport Phenomena, Wiley, Chichester, 1960</li><li>- O. Levenspiel, Chemical Reaction Engineering, Wiley, New York, 1972.</li><li>- D. Kondepudi, I. Prigogine, Modern Thermodynamics, Wiley-VCH, Chichester, 1998</li><li>- S.V. Patankar, Numerical Heat Transfer and Fluid Flow, McGraw-Hill, New York, 1980</li></ul>



## 4.2. Air Pollution Control

<b>Course:</b> Selective subject for Chemical and Energy Engineering
<b>Module:</b> Air Pollution Control
<b>Objectives (competences):</b> At the end of this course, participants will be able to: <ul style="list-style-type: none"><li>▪ outline the framework of environmental engineering.</li><li>▪ explain and summarize the sources and consequences of air pollution.</li><li>▪ select strategies for the prevention of air pollution through the efficient combination of mechanical, thermal, chemical, and biological processes and justify their solutions in the context of environmental protection and economy.</li><li>▪ design air pollution control processes and equipment using the principles of mechanical, thermal, chemical, and biological processes for the treatment of exhaust gases.</li></ul>
<b>Content:</b> <ul style="list-style-type: none"><li>▪ Sources of air pollution</li><li>▪ Basic meteorological processes</li><li>▪ Health risks of air pollution exposure</li><li>▪ Environmental impact of air pollution</li><li>▪ Gas-phase chemistry and measurements</li><li>▪ Pollution emission controls and regulations</li><li>▪ Technologies for air pollution control</li></ul>
<b>Teaching:</b> Lecture and tutorial / English
<b>Prerequisites:</b>
<b>Workload:</b> 2-1-0, classroom = 42 hours and self-studies = 78 hours (summer semester)
<b>Examination/Credits:</b> K120 / 4 CP
<b>Responsible Lecturer:</b> Prof. U. Krause, FVST
<b>Literature:</b> <ul style="list-style-type: none"><li>- Jacob: Introduction to Atmospheric Chemistry</li><li>- Baumbach: Air Quality Control</li><li>- Tan: Air Pollution and Greenhouse Gases</li><li>- N.F. Gray "Water Technology", Elsevier 2005;</li><li>- Metcalf a. Eddy "Wastewater Engineering" MacGraw Hill 2003,</li><li>- P. A. Vesilind "Wastewater treatment plant design"</li><li>- "Student Workbook" IWA Publishing, 2003</li><li>- Handouts will be given during lecture</li></ul>





#### 4.3. Analysis and Design of Experiments

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Analysis and Design of Experiments
<b>Objectives:</b> 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.
<b>Contents:</b> <ul style="list-style-type: none"><li>• Basic concepts: variables, parameters, models, design of experiments</li><li>• Statistical foundations: probability, probability distributions, population, sample, estimators, confidence intervals</li><li>• Parameter estimation: linear and nonlinear regression, simultaneous multiple regression, Bayesian regression, Maximum-Likelihood method, goodness/lack of fit, individual and joint confidence regions</li><li>• Design of experiments: classical design methods for models of first and second order, factorial and blocked designs, modern methods for use with computational models</li><li>• Interactive use of Matlab for illustrative purposes on important examples</li></ul>
<b>Teaching:</b> 3 SWS, Lectures, tutorials and Matlab tutorials
<b>Prerequisites:</b> Bachelor in chemical engineering or related fields. Basic knowledge of statistics and maths.
<b>Workload:</b> Regular Study: 42 h, Private Study: 78 h
<b>Examination/Credits:</b> Written exam / 90 min / 4 CP
<b>Responsible lecturer:</b> Dr.-Ing. Voigt, FVST Xiang Zhang, MPI



#### 4.4. Bioinorganic Chemistry

<b>Modulbezeichnung</b>	<b>Bioinorganic Chemistry</b>
<i>Englischer Titel</i>	<i>Bioinorganic Chemistry</i>
<i>Modulniveau nach DQR</i>	Niveaustufe 7 (Masterniveau)
<i>Modulnummer</i>	
<i>Untertitel</i>	
<i>Lehrveranstaltungen</i>	► Vorlesung Bioinorganic Chemistry
<i>empfohlenes Studiensemester</i>	1.-2. Semester
<i>Häufigkeit des Angebots/ Angebotsturnus</i>	einmal jährlich
<i>Modulverantwortliche:r</i>	Lehrstuhl für Anorganische Chemie, Prof. Dr. N. Kulak
<i>Dozent:in</i>	Prof. Dr. N. Kulak
<i>Sprache</i>	Englisch
<i>Zuordnung zum Studiengang/ Curriculum / Verwendbarkeit des Moduls</i>	Wahlpflichtmodul Master <ul style="list-style-type: none"><li>- Chemieingenieurwesen: Molekulare und strukturelle Produktgestaltung</li><li>- Umwelt- und Energieprozesstechnik</li><li>- Biosystemtechnik</li><li>- Chemical and Energy Engineering</li><li>- Molekulare Biosysteme (EXPORT nach FNW)</li></ul>
<i>Lehrform und SWS</i>	Vorlesung à 2 SWS
<i>Arbeitsaufwand</i>	Präsenzzeit/Selbststudium 28 Std. / 62 Std.
<i>Dauer des Moduls</i>	1 Semester
<i>Credit Points (CP)</i>	3
<i>Voraussetzung für die Vergabe von CP</i>	Mündliche Prüfung
<i>Teilnahmevoraussetzungen</i>	Teilnahme an Grundvorlesung Anorganische / Allgemeine Chemie
<i>Empfehlungen für die Teilnahme</i>	Es wird empfohlen in der ersten Veranstaltung anwesend zu sein, um die Zugänge zum E-Learning und prüfungsrelevante Informationen zu erhalten.



<i>Modulziele / angestrebte Lernergebnisse / Learning Outcomes</i>	<ul style="list-style-type: none"><li>▶ Acquire principles of Bioinorganic Chemistry</li><li>▶ Knowledge in techniques to investigate structure and activity of metalloproteins</li><li>▶ Knowledge in metal-dependent biological processes (homeostasis, photosynthesis, enzymatic catalysis)</li><li>▶ Apply acquired knowledge on examples of different metalloenzymes</li></ul>
<i>Inhalt</i>	<ul style="list-style-type: none"><li>▶ Role of metals in biology, biomineralization</li><li>▶ Methods to study metals in biological systems (e.g. Mössbauer spectroscopy)</li><li>▶ Transport, storage and homeostasis of metal ions (e.g. Fe homeostasis)</li><li>▶ Biological functions of V, Cr, Mo, W</li><li>▶ Metals in the center of photosynthesis (Mg, Mn)</li><li>▶ Heme proteins (O<sub>2</sub> transport, O<sub>2</sub> activation, electron transport)</li><li>▶ Nonheme Fe proteins (e.g. nitrogenases)</li><li>▶ Cobalamins (e.g. coenzyme B12-dependent enzymes)</li><li>▶ Ni enzymes (e.g. urease)</li><li>▶ Cu proteins (e.g. hemocyanin)</li><li>▶ Zn enzymes (e.g. alcohol dehydrogenase)</li></ul>
<i>Studien- Prüfungsleistungen Prüfungsformen</i>	Mündliche Prüfung
<i>Literatur</i>	W. Kaim, B. Schwederski: Bioanorganische Chemie / Bioinorganic Chemistry (Teubner+Vieweg/Wiley)
<i>Sonstige Informationen</i>	<a href="https://www.bekanntmachungen.ovgu.de/media/Modulhandb%3bccher/Bachelor+_+Studieng%3ca4nge/Chemieingenieurwesen_+Molekulare+und+Strukturelle+Produktgestaltung/Modulhandb%3bccher+ab+Immatrikulation+Wintersemester+2020/Modulhandbuch+vom+01_03_2021_unter+Vorbehalt-p-16528.pdf">https://www.bekanntmachungen.ovgu.de/media/Modulhandb%3bccher/Bachelor+_+Studieng%3ca4nge/Chemieingenieurwesen_+Molekulare+und+Strukturelle+Produktgestaltung/Modulhandb%3bccher+ab+Immatrikulation+Wintersemester+2020/Modulhandbuch+vom+01_03_2021_unter+Vorbehalt-p-16528.pdf</a>
<i>Freigabe / Version</i>	Wahlpflichtmodul „Bioinorganic Chemistry“ Letzte Bearbeitung des Moduls: 29.09.2021



#### 4.5. Computational Biology and Chemistry

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Computational Biology and Chemistry
<b>Objectives:</b> 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.
<b>Contents:</b> <ul style="list-style-type: none"><li>• Introduction, time and size scales of interactions</li><li>• Intermolecular interactions (hydrogen bonding, electrostatics, van der Waals)</li><li>• Protein structures, bioinformatics, protein structural modeling</li><li>• Electrostatic interactions and Brownian dynamics</li><li>• Molecular dynamics simulations (proteins, conformational changes)</li><li>• Quantum chemistry (introduction, examples)</li><li>• Additional methods (ab initio molecular dynamics, calculation of experimental observables)</li></ul>
<b>Teaching:</b> Lecture 2 hours per week, Tutorial 1 hour per week; (winter semester)
<b>Prerequisites:</b> <ul style="list-style-type: none"><li>• Courses in physics, chemistry and biology</li><li>• Basic computational knowledge (i.e. Linux)</li><li>• Proficiency in English language</li></ul>
<b>Workload:</b> 4 SWS Lectures and tutorials
<b>Examination/Credits:</b> Project work and documentation (50%), oral examination (50%) / 5 CP
<b>Responsible lecturer:</b> HP M. Stein, MPI Magdeburg



**Literature:**

- Andrew R. Leach: Molecular Modelling - Principles and Application, Pearson 2001.
- H.D. Höltje, W.Sipl, 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.



#### 4.6. Computational Fluid Dynamics

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Computational Fluid Dynamics
<b>Objectives</b> 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.
<b>Contents</b> <ol style="list-style-type: none"><li>1. Introduction and organization. Historical development of CFD. Importance of CFD. Main methods (finite-differences, -volumes, -elements) for discretization.</li><li>2. Vector- and parallel computing. Introduction to Linux, main instructions, account structuration, FTP transfer.</li><li>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.</li><li>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.</li><li>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.</li><li>6. Introduction to finite elements on the basis of Femlab. Introduction to Femlab and practical use based on a simple example.</li><li>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.</li><li>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.</li><li>9. Properties and computation of turbulent flows. Turbulence modeling, <math>k-\epsilon</math> 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.</li><li>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.</li><li>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.</li><li>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.</li></ol>
<b>Teaching</b> 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:**

apl. Prof. Dr. G. Janiga, FVST

**Literature:**

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



#### 4.7. Control of Toxic Trace Elements

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Control of Toxic Trace Elements
<b>Objectives (competences):</b> The student should be able to <ul style="list-style-type: none"><li>• identify the critical toxic trace element emission sources from industrial processes.</li><li>• understand the principles of the mobility and fate of toxic trace element pollution in the environment</li><li>• develop solutions to reduce critical toxic trace element emissions from industrial processes</li><li>•</li></ul>
<b>Content:</b> <ul style="list-style-type: none"><li>• introduction and concepts</li><li>• selenium: mobility in soil, accumulation in plants and animal feeding; volatility in biochemical processes</li><li>• arsenic: ground water and cleaning of drinking water; inhalation; speciation; phyto-remediation</li><li>• thallium: accumulation in thermal processes</li><li>• cadmium: flue dust from thermal processes; mobilisation in soils and accumulation in edible plants</li><li>• mercury: volatility, aquatic bioaccumulation and immobilisation</li><li>• chromium: surface treatment and carcinogenic chromium(VI) compounds, control of Cr(VI) in thermal processes</li><li>• beryllium: controlling inhalation risks from occupational exposure and emission</li></ul>
<b>Teaching:</b> lectures 2h/semester and tutorial 1 h/semester; (summer semester)
<b>Prerequisites:</b> combustion engineering
<b>Workload:</b> 3 SWS lectures and tutorials: 42 h; private studies: 78 h
<b>Examination/credits:</b> written exam / 4 CP
<b>Responsible lecturer:</b> Prof. H. Köser, FVST
<b>Literature:</b> 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





#### 4.8. DE project: Visualization of Process Engineering Applications

<b>Course of study:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> DE project: Visualization of Process Engineering Applications
<b>Aims and scopes of the module (competences):</b> 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: <ul style="list-style-type: none"><li>- Application-oriented work,</li><li>- Interdisciplinary work,</li><li>- Organisation of the work in a team,</li><li>- Targeted, time-optimised work,</li><li>- Summary of the work in form of a report,</li><li>- Presentation of the results,</li><li>- Evaluation of the App.</li><li>-</li></ul>
<b>Contents:</b> <ul style="list-style-type: none"><li>- selection of the process,</li><li>- written description of the process, including the physical, chemical and technical data of interest,</li><li>- breakdown of the sub-processes,</li><li>- selection of the process parameter, summary of required data,</li><li>- conception of the App (e.g. simple visualization or implementation of process conditions),</li><li>- continuous support of the App-implementation,</li><li>- documentation of the implementation,</li><li>- presentation of the results (e.g. by Power-Point),</li><li>- evaluation and functional test of the App.</li></ul>
<b>Forms of teaching:</b> 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).
<b>Required qualification for participation:</b> Basics of process engineering. The participation is limited to 6 students per semester.
<b>Workload:</b> 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



#### 4.9. 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 attendance (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. 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.



#### 4.10. Dispersion of Hazardous Materials

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Dispersion of Hazardous Materials
<b>Objectives (competences):</b> 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.
<b>Content</b> <ul style="list-style-type: none"><li>• Emission and passive dispersion of neutral and heavy gases, atmospheric stability conditions,</li><li>• Gaussian distribution based dispersion models,</li><li>• Particle trajectories-based simulation models,</li><li>• Jet dispersion,</li><li>• Partitioning and fate of chemicals in the environment,</li><li>• Toxicity of substances, the Acute Exposure Guideline Level concept,</li><li>• Release of liquids and gases from leakages,</li><li>• Dispersion of radionuclides.</li></ul>
<b>Teaching:</b> Lecture with tutorial/English
<b>Prerequisites:</b> -
<b>Workload:</b> 2-1-0, classroom = 42 hours and self-studies = 78 hours
<b>Examination/Credits:</b> written exam / 4 CP
<b>Responsible Lecturer:</b> Dr. R. Zinke, FVST
<b>Literature:</b> <ul style="list-style-type: none"><li>- Steinbach: Safety Assessment for Chemical Processes</li><li>- Steen/Hattwig: Handbook of Explosion protection</li><li>- Eckhoff: Dust explosions in the Process Industries</li><li>- Mannan: Lee's Loss prevention in the Process Industries</li><li>- Stoessel: Thermal Safety of Chemical Processes</li><li>- UN Handbook for Transportation of Dangerous Goods ("Orange Book")</li><li>- TNO Coloured Books Series</li></ul>



#### 4.11. Drying Technology

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Drying Technology
<b>Objectives:</b> 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.
<b>Contents</b> <ol style="list-style-type: none"><li>1. The ways of adhesion of the liquid to a commodity, capillary manner, ideal and real sorption, sorptions isotherms</li><li>2. Characteristics of humid gases and their use for convective drying</li><li>3. Theoretical handling of real dryers: single stage, multi stage, circulating air, inert gas cycle, heat pump, exhaust vapor compression</li><li>4. Kinetics of drying, first and second drying section, diffusion on moist surfaces, Stefan- and Ackermann correction, standardized drying process</li><li>5. Convecting drying at local and temporal changeable air conditions</li><li>6. Fluid bed drying with gas and overheated solvent vapor</li><li>7. Fluidized bed granulation drying and various control options of drying plants with and without heat recovery</li><li>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.</li><li>9. Exemplary calculation and design of selected dryers</li></ol>
<b>Teaching:</b> lecture (presentation), examples, script, excursion in a drying plant; (winter semester)
<b>Prerequisites:</b> Basics of process engineering
<b>Workload:</b> 3 hours per week, Lectures: 42 hours, Private: 78 hours
<b>Examination/Credits:</b> Oral / 4 CP
<b>Responsible lecturers:</b> Dr. A. Kharaghani, FVST
<b>Literature:</b> 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



#### 4.12. Environmental Biotechnology

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Environmental Biotechnology
<b>Objectives:</b> 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.
<b>Contents:</b> <ul style="list-style-type: none"><li>• Biological Fundamentals (structure and function of cells, energy metabolism, turnover/degradation of environmental pollutants)</li><li>• Biological Waste Gas Treatment (Biofilters, Bioscrubbers, Trickle Bed Reactors)</li><li>• Biological Treatment of Wastes (Composting, Anaerobic Digestion)</li><li>• Bioremediation of Soil and Groundwater</li><li>• Prospects of Biotechnological Processes – Benefits for the Environment</li></ul>
<b>Teaching:</b> Lectures/Presentation, script, company visit; (winter semester)
<b>Prerequisites:</b>
<b>Work load:</b> 2 hours per week, Lectures and tutorials: 28 h, Private studies: 62 h
<b>Examinations/Credits:</b> Oral exam / 3 CP
<b>Responsible lecturer:</b> Dr. D. Benndorf, FVST
<b>Literature:</b> <ul style="list-style-type: none"><li>- Michael T. Madigan, John M. Martinko, David Stahl, Jack Parker, Benjamin Cummings: Brock Biology of Microorganisms, 13 edition (December 27, 2010)</li><li>- Jördening, H.-J (ed.): Environmental biotechnology: concepts and applications, Weinheim: Wiley-VCH, 2005</li><li>- Environmental Biotechnology (ed. by Lawrence K. Wang, Volodymyr Ivanov, Joo-Hwa Tay), Springer Science+Business Media, LLC, 2010 (Handbook of Environmental Engineering, 10)</li><li>- Further literature will be given in the lecture</li></ul>



#### 4.13. Electrochemical Process Engineering

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Electrochemical Process Engineering
<b>Objectives:</b> 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.
<b>Contents:</b> <ul style="list-style-type: none"><li>• Introduction (Fundamental laws, Figures of merit, Cell voltage)</li><li>• Basics of electrochemistry (Ionic conductivity, Electrochemical thermodynamics, Double layer, Electrochemical kinetics)</li><li>• Mass transport (Diffusion, Migration, Convection)</li><li>• Current distribution (Primary, Secondary, Tertiary)</li><li>• Electrochemical reaction engineering ( Electrolyte, Electrodes, Separators, Reactors, Mode of operation)</li><li>• Electrolysis (Chlor-alkali electrolysis, Organic electrosynthesis, Electroplating)</li><li>• Electrochemical energy sources (Batteries, Supercapacitors) and Corrosion and its control</li></ul>
<b>Teaching:</b> lectures (2 hours per week), tutorials (1 hours per week); (summer semester)
<b>Prerequisites</b> <ul style="list-style-type: none"><li>• Basic knowledge in chemistry and physical chemistry</li><li>• Mass and heat transport</li><li>• Chemical reaction engineering</li></ul>
<b>Workload:</b> 3 hours per week, lectures and tutorials: 42 hours, private studies: 78 hours
<b>Examinations / Credits:</b> Oral / 4 CP
<b>Responsible lecturer:</b> Dr.-Ing. T. Vidaković-Koch; MPI Magdeburg





**Literature:**

- 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, 2<sup>nd</sup> Edition, Blackie Academic & Professional, Paperback edition, 1993, ISBN 0-7514-0148-X.



#### 4.14. Fuel Cells

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Fuel Cells
<b>Objectives:</b> 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.
<b>Contents:</b> <ul style="list-style-type: none"><li>• Introduction to fuel cells working principle, types of fuel cells and applications</li><li>• Steady-state behaviour of fuel cells Potential field, constitutive relations (Nernst equation, electrochemical reaction kinetics, mass transport) Integral balance equations for mass and energy Current-voltage-curve, efficiencies, design</li><li>• Experimental methods in fuel cell research</li><li>• Fuels Handling and storage of hydrogen Fuel processing</li><li>• Fuel cell systems</li></ul>
<b>Teaching:</b> Lecture and Tutorial
<b>Prerequisites:</b> Basic knowledge on thermodynamics, reaction engineering and mass transport is advantageous.
<b>Workload:</b> 32h time of attendance (one-week full-time block seminar), 10h outside classes Presence: 42h (3 SWS), self study time: 78h (literature survey)
<b>Examination/Credits:</b> Oral exam 60 min. / 5 CP
<b>Responsible lecturer:</b> Dr. T. Vidakovic-Koch, MPI Magdeburg
<b>Literature:</b> <ul style="list-style-type: none"><li>- Lecture notes, available for Download</li><li>- Vielstich, W. et.al: Handbook of Fuel Cells, Wiley 2003</li><li>- Larminie, J. and Dicks, A.: Fuel Cell Systems Explained, Wiley 2003</li><li>- Haman, C.H. and Vielstich, W.: Electrochemistry, Wiley 1998</li><li>- Bard, A.J. and Faulkner, L.R.: Electrochemical Methods, Wiley 2001</li><li>- Wesselingh, J.A. and Krishna, R.: Mass Transfer in Multi-Component Mixtures, Delft Univ. Press 2000</li></ul>



#### 4.15. Fundamentals of Multiphase Flows

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Fundamentals of Multiphase Flows
<b>Objectives:</b> Students will: <ul style="list-style-type: none"><li>• Understand the mathematical description of the properties and behavior of a single and of multiple particles, bubbles and droplets in a flow.</li><li>• Comprehend the phenomenology and the underlying physics of flow problems involving a simultaneous presence of multiple phases in a flow domain.</li><li>• Understand the governing equations and underlying assumptions for a wide range of different multiphase flow phenomena studied throughout the course.</li><li>• Understand the interaction of turbulence and multiphase phases present in a flow.</li><li>• Analyze a number of applications involving multiphase flows.</li></ul>
<b>Contents:</b> <ol style="list-style-type: none"><li>1. Introduction, characterization of multiphase flows, quantities, statistical moments, distribution characteristics, dimensionless parameters and averaging and averages in multiphase flows.</li><li>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.</li><li>3. Forces on particles in flows, particle-particle interactions, and granular flows.</li><li>4. The governing equations of droplets, bubbles and interfaces in flows, surface tension, wetting, evaporation and mass transfer.</li><li>5. Turbulence in multiphase flows, governing equations, effect of turbulence on dispersed particles and effect of dispersed particles on turbulence.</li><li>6. Mass and heat transfer in multiphase flows.</li><li>7. Applications with multiphase flows.</li></ol>
<b>Teaching:</b> Lectures and Tutorials
<b>Prerequisites:</b> Fluid Mechanics / Strömungsmechanik Heat and Mass Transfer / Wärme- und Stoffübertragung Mechanical Process Engineering / Mechanische Verfahrenstechnik
<b>Workload:</b> Lectures and tutorials: 56 h, private studies: 94 h
<b>Examination/Credits:</b> Written examination (120 minutes) / proof of achievements / 5 CP
<b>Responsible lecturer:</b> Prof. Dr. B. van Wachem, Dr. F. Evrard, Dr. F. Sewerin, FVST
<b>Literature:</b> Manuscript with text, figures, tutorials and exercises (available from Moodle E-Learning)



#### 4.16. Hazardous Materials and Safety Characteristics

<b>Course:</b> Selective subject for Chemical and Energy Engineering
<b>Module:</b> Hazardous Materials and Safety Characteristics
<b>Objectives (competences):</b> At the end of this course, students will be able to: <ul style="list-style-type: none"><li>▪ identify important properties of chemicals and recall the analytical methods to determine these properties.</li><li>▪ explain reaction behavior in terms of the molecular structure and thermodynamic process conditions.</li><li>▪ calculate safety indicators from thermo-chemical properties and categorize the substances according to a reactivity assessment.</li><li>▪ assess the hazard potential of materials.</li><li>▪ judge industrial scenarios according to their hazards and develop safety concepts.</li></ul>
<b>Content:</b> <ul style="list-style-type: none"><li>▪ Overview of groups of hazardous materials (toxicity, ignition sensitivity, fire and explosion hazards)</li><li>▪ safety indicators of hazardous materials</li><li>▪ experimental testing procedures for safety data</li><li>▪ computational methods for safety data</li><li>▪ application of safety indicators in protective measures</li></ul>
<b>Teaching:</b> Lecture with tutorial / English
<b>Prerequisites:</b>
<b>Workload:</b> 2-0-0, classroom = 28 hours and self-studies = 62 hours (winter semester)
<b>Examination/Credits:</b> K90 / 3 CP
<b>Responsible Lecturer:</b> Prof. U. Krause, FVST
<b>Literature:</b> <ul style="list-style-type: none"><li>- Steinbach: Safety Assessment for Chemical Processes</li><li>- Steen/Hattwig: Handbook of Explosion protection</li><li>- Eckhoff: Dust explosions in the process industries</li><li>- Mannan: Lee's Loss prevention in the Process Industries</li><li>- Stoessel: Thermal Safety of Chemical Processes</li><li>- UN Handbook for Transportation of Dangerous Goods ("Orange Book")</li><li>- Visscher: Air Dispersion Modeling: Foundations and Applications</li><li>- TNO Coloured Books Series</li></ul>



#### 4.17. Introduction to the approval process of medical devices

<b>Course:</b> Selective subject for Chemical and Energy Engineering
<b>Module:</b> Introduction to the approval process of medical devices
<b>Objectives (competences):</b> In contrast to pharmaceuticals, no worldwide uniform legally requirements are available for the approval and CE certification of medical devices. Every manufacturer is responsible to set up the process and documentation of his medical devices to get it approved according to defines OECD Guidelines and ISO norms. The regulatory affair offers an unexpectedly exciting and diverse range of tasks for all students, especially in small and medium-sized companies. As part of the elective module, we want to arouse students' interest in these regulatory affairs topics in the modules including active participation of representatives of the medical device industry. We want to teach the essential basics for an activity in the regulatory environment. In the first semester, we will address the process as whole as well as regulatory and structural requirements.
<b>Content:</b> The content is based on the specifications for the European CE approval and relevant DIN ISO specification. It includes the following topics: <ul style="list-style-type: none"><li>▪ Introduction to the process of market approval</li><li>▪ GxPractice and alternative</li></ul> We will build groups of two students to perform a Term work. Content of work are selected examples to illuminate the approval procedures for different medical device classes and to address particular regulatory issues. These Term work are presented and discussed in a short lecture to all students. The homework is 50% of the examination performance. In addition, an exam is written at the end of the course, which also accounts for 50% of the total grade.
<b>Teaching:</b> Lecture, Seminar
<b>Prerequisites:</b> None (recommended prerequisites: attending the module Basics for Medical Device Approval of MT Bachelor is an advantage)
<b>Workload:</b> Time of attendance: 2 SWS Lecture, 1 SWS Seminar Autonomous work: follow-up lecture and exercises - elaboration of term paper Every winter semester
<b>Examination/Credits:</b> Written examination 90 min (Term paper and exam each 50% of the final grade) Term paper and its presentation 5 CP = 150 h (45 h time of attendance + 105 h autonomous work)
<b>Responsible Lecturer:</b> Prof. Dr. rer. biol. hum. Heike Walles, FVST



**Literature:**

Will be made available digitally at the beginning of the course



#### 4.18. Introduction to the pre-market phase in the approval process of medical devices

<b>Course:</b> Selective subject for Chemical and Energy Engineering
<b>Module:</b> Introduction to the pre-market phase in the approval process of medical devices
<b>Objectives (competences):</b> In contrast to pharmaceuticals, no worldwide uniform legally requirements are available for the approval and CE certification of medical devices. Every manufacturer is responsible to set up the process and documentation of his medical devices to get it approved according to defines OECD Guidelines and ISO norms. The regulatory affair offers an unexpectedly exciting and diverse range of tasks for all students, especially in small and medium-sized companies. As part of the compulsory elective module, we want to deepen the differences between international admission procedures in this module.
<b>Contents:</b> The content is based on the specifications for the European CE approval and relevant DIN ISO specification. It includes following basics of the pre-market phase: Risk management and assessment, risk-benefit analysis, regulatory affairs manager, technical documentation, quality management, PDCA cycle, patient safety vs. Customer satisfaction, clinical evaluation and proof of effectiveness. After the lectures, different international admission procedures in the USA, Russia, Brazil, Japan, ASEAN, Canada, China, India, Saudi Arabia and Mexico will be examined. Therefore we will build groups of two students to perform a Term work. Content of work are selected examples to illuminate the approval procedures for different medical device classes and to address particular regulatory issues. These Term work are presented and discussed in a short lecture to all students. The homework is 50% of the examination performance. In addition, an exam is written at the end of the course, which also accounts for 50% of the total grade.
<b>Teaching:</b> Lecture, Seminar
<b>Prerequisites:</b> Attending the module Introduction to the approval process of medical devices
<b>Workload:</b> Time of attendance: 2 SWS Lecture, 1 SWS Seminar Autonomous work: follow-up lecture and exercises - elaboration of term paper Every summer semester
<b>Examination/Credits:</b> Written examination 90 min (Term paper and exam each 50% of the final grade) Term paper and its presentation 5 CP = 150 h (45 h time of attendance + 105 h autonomous work)
<b>Responsible Lecturer</b> Dr. Karim Djamshidi (Executive Director Global Regulatory Affairs – KARL STORZ SE and Co. KG), Prof. Dr. rer. biol. Heike Walles, FVST
<b>Literature:</b>



#### 4.19. Internship

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Internship
<b>Objectives:</b> 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 subsequently present the results and insights in a seminar presentation and answer the audience's questions. They will receive feedback based on the quality and delivery of the presentation and how understandable it was. Internships in research institutes (e.g. Fraunhofer, IFAK) require prior written approval from the CEE course advisor (Jun.-Prof. Dr. F. Denner) or the chairwoman of the FVST examination committee (Prof. Dr. F. Scheffler), and are only admissible if the tasks conducted during the internship are in an industrial context.
<b>Contents:</b> The internship can cover the following fields <ul style="list-style-type: none"><li>➤ Power generation</li><li>➤ Treatment of solids</li><li>➤ Treatment of fluids</li><li>➤ Maintenance, service, and repair</li><li>➤ Measurement, analysis, testing, and quality control</li><li>➤ Development, design, preparation and process analysis</li><li>➤ Assembly and initial operations</li><li>➤ Bioprocess-, pharmaceutical- and environmental engineering.</li><li>➤ Production organization</li><li>➤ Manufacturing planning, preparation and order processing</li><li>➤ Practical position related to the field that is accepted by the Praktikantenamt</li></ul> A written report with the general structure of a master thesis must be submitted (maximum 15 pages). The work and results are to be presented in an oral presentation (maximum 15 min) with a discussion after the presentation.
<b>Teaching:</b> Industrial internship, seminar presentation
<b>Prerequisites</b> None
<b>Workload:</b> 300 hours (2 months)
<b>Examination/Credits:</b> Report (maximum 15 pages), Letter of participation, Seminar presentation (maximum 15 minutes) / 10 CP The grade is the mean value of report and presentation. The internship company can propose a numerical grade with respect to the grading system of the University, which can be taken into account.





OTTO VON GUERICKE  
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FAKULTÄT FÜR VERFAHRENS-  
UND SYSTEMTECHNIK

**Responsible lecturer:**

Dr. Hintz, FVST, CEE Course Advisor



#### 4.20. Machine Learning in Chemical Engineering

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Machine Learning in Chemical Engineering
<b>Objectives:</b> Key ability is to familiarize students with the emerging topic of machine learning in chemical engineering. Students are encouraged to use Python and Jupyter Notebooks as a self-study tool. The students are enabled to analyze data sets with respect to missing values, duplicates or outliers and edit them accordingly in preparation for applying suitable machine learning algorithms. Consecutively, the students are familiarized with typical problem types such as regression, classification and clustering of data and are enabled to apply different models/estimators such as regression, partial least squares, artificial neural networks, ... With these methods in mind, different examples from chemical engineering are used as an illustration of the methods such as fault detection, process optimization and hybrid modeling where a combination of mechanistic and data driven models are used. In summary, the students are enabled to assess the use of either a mechanistic or data driven model or a combination of both.
<b>Contents:</b> <ul style="list-style-type: none"><li>• Analyze and edit data sets relevant in chemical engineering</li><li>• Typical problem types: regression, classification and clustering</li><li>• Different machine learning estimators/models such as regression, partial least squares, artificial neural networks, ...</li><li>• Application to typical examples from chemical engineering such as fault detection, process optimization and hybrid modeling</li><li>• Interactive use of Python for both illustrative purposes and self-learning</li></ul>
<b>Teaching:</b> 3 SWS, Lectures, tutorials and Python tutorials
<b>Prerequisites:</b> Bachelor in chemical engineering or related fields. Recommended are the following modules: Simulationstechnik, Prozessdynamik I, Analysis and Design of Experiments
<b>Workload:</b> Präsenzzeit: 42 Stunden, Selbststudium: 108 Stunden
<b>Examinations / Credits:</b> Written exam / 90 min / 4 CP
<b>Responsible Lecturer:</b> N.N.
<b>Literature:</b>



#### 4.21. Methods of Risk Analysis

<b>Course:</b> Selective subject for Chemical and Energy Engineering
<b>Module:</b> Methods of Risk Analysis
<b>Objectives (competences):</b> At the end of this course, students will be able to: <ul style="list-style-type: none"><li>▪ summarize knowledge in the field of probabilistic safety analysis and quantitative risk assessment for technical systems and processes.</li><li>▪ discuss 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.</li><li>▪ perform a risk analysis and calculate the reliability of technical systems.</li><li>▪ analyze the outcome of different methods of risk analysis and judge these methods.</li><li>▪ evaluate an example scenario by a complete quantitative risk assessment including event tree and fault tree analysis, consequence assessment and risk integration techniques and create safety concepts to minimize the risk from industrial situations.</li></ul>
<b>Contents:</b> <ul style="list-style-type: none"><li>▪ Probability distributions and functions (Kolmogorov Axioms), conditional probability, Bayes theorem, maximum likelihood function.</li><li>▪ Risk analysis terminology.</li><li>▪ In detail HAZOP study (content, structure and implementation).</li><li>▪ Quantitative Risk Analysis consisting of Master Logic Diagram preparation, selection of the analysis area, development of Event Trees for technical incidents and Fault Trees for failure of safety barriers.</li><li>▪ Methods to determine the magnitude of damage for industrial accidents, damage effects on individuals, and Probit function distributions.</li><li>▪ Calculation methods for individual and group risk and development of risk graph.</li><li>▪ Reliability models, failure rates, availability of technical systems.</li><li>▪ Safety Integrity levels (SIL).</li></ul>
<b>Teaching:</b> Lecture, tutorial, and lab / English
<b>Prerequisites:</b>
<b>Workload:</b> 2-1-0, classroom = 42 hours and self-studies = 78 hours (summer semester)
<b>Examination/Credits:</b> K120 / 4 CP
<b>Responsible Lecturer:</b> Prof. U. Krause, FVST
<b>Literature:</b> <ul style="list-style-type: none"><li>- Steinbach: Safety Assessment for Chemical Processes</li><li>- Bedford/Cooke: Probabilistic Risk Analysis - Foundations and Methods</li><li>- Mannan: Lee's Loss prevention in the Process Industries</li><li>- SFPE Handbook Fire protection Engineering</li><li>- Drysdale: An introduction to fire dynamics</li></ul>



#### 4.22. Modern organic synthesis

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Modern organic synthesis
<b>Objectives:</b> 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.
<b>Contents:</b> <ul style="list-style-type: none"><li>• Short overview reactivity, carbon hybrids, organic chemical basic reactions</li><li>• Concept of the acyclic stereoselection on the example of Aldol reactions</li><li>• Demonstration of the concept on the example of miscellaneous total synthesis of natural products</li><li>• Basics of metal organic chemistry</li><li>• Vinyl silanes</li><li>• Allyl silanes</li></ul>
<b>Teaching:</b> Lecture; (winter semester)
<b>Prerequisites:</b> Module Chemistry
<b>Work load:</b> 2 hours per week, lectures: 28 hours, private studies: 62 hours
<b>Examinations/Credits:</b> Oral / 3 CP
<b>Responsible lecturer:</b> Prof. D. Schinzer, FVST
<b>Literature:</b> Handouts will be given in lecture



#### 4.23. Nanoparticle technology

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Nanoparticle technology
<b>Objectives:</b> 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
<b>Contents:</b> <ul style="list-style-type: none"><li>• <b>Introduction into nanotechnology</b>, definition of the term nanotechnology and nanoparticle, nanoparticles as a disperse system, properties, applications</li><li>• <b>Thermodynamics of disperse systems</b>, nucleation theory and particle growth, homogeneous and heterogeneous nucleation, nucleation rates, model of LaMer and Dinegar, Ostwald ripening, agglomeration</li><li>• <b>Electrochemical properties of nanoparticle</b>, surface structures, electrochemical double layer, models (Helmholtz, Gouy-Chapman, Stern), electrochemical potential, Zeta potential</li><li>• <b>Stabilisation of disperse systems</b>, sterical and electrostatic stabilisation, DLVO theory, van-der-Waals attraction, electrostatic repulsion, critical coagulation concentration, Schulze-Hardy rule, pH and electrolyte concentration</li><li>• <b>Coagulation processes</b>, coagulation kinetics, fast and slow coagulation, transport models, Smoluchowski theory, interaction potential, stability factor, structures</li><li>• <b>Precipitation process</b>, basics, precipitation in homogeneous phase, nucleation, particle growth, reaction processes, particle formation models, apparatuses (CDJP, T mixer), hydro thermal processes</li><li>• <b>Precipitation in nano-compartments</b>, principles, nano compartments, surfactant-water systems, structures, emulsions (micro, mini and macro), phase behaviour, particle formation, kinetic models</li><li>• <b>Sol-Gel process</b>, Stöber process, titania, reactions, stabilisation, morphology, pH, electrolyte, RLCA, RLMC, drying, gelation, aging, coating, thin films, ceramics</li><li>• <b>Aerosol process</b>, particle formation, gas-particle and particle-particle conversion, flame hydrolysis, Degussa and chlorine process, soot, spray pyrolysis</li><li>• <b>Formation of polymer particles (latex particles)</b>, emulsion polymerisation, theory of Fikentscher and Harkins, pearl polymerisation, latex particles</li><li>• <b>Nanoparticles and their application</b>, technical products, silica, titania, soot, Stöber particles, nanoparticles in medicine and pharmaceuticals, functionalised nanoparticles, diagnostics, carrier systems, magnetic nanoparticles and liquids,</li><li>• <b>Characterisation of nanoparticles - particle sizing</b>, TEM, SEM, light scattering, laser diffraction, theory (Rayleigh, Fraunhofer, Mie), ultra sonic and ESA technique, Instruments</li><li>• <b>Characterisation of nanoparticles - Zeta potential determination</b>, electrokinetic phenomena, electrophoresis, electro osmosis, streaming and sedimentation potential, electrophoretical mobility, Zeta potential, theories according to Smoluchowski, Hückel, Henry, electrophoretical mobility, instruments, PALS techniques</li></ul>
<b>Teaching:</b> 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



#### 4.24. Numerical simulation in explosion protection

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Numerical simulation in explosion protection
<b>Objectives:</b> 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.
<b>Contents:</b> <ul style="list-style-type: none"><li>• Fundamentals of computational fluid dynamics</li><li>• Concepts of multiphase flow modeling</li><li>• Liquid jets, sprays, spray drying</li><li>• Triboelectric charging of particles</li><li>• Expansion of explosion flames</li><li>• Computer exercises in OpenFOAM</li><li>• Laboratory exercise at Physikalisch-Technische Bundesanstalt</li></ul>
<b>Teaching:</b> Lectures, computer and laboratory exercises / English
<b>Prerequisites:</b> Mathematics, Thermodynamics, Fluid Dynamics, basic knowledge of a programming language
<b>Workload:</b> 2 SWS, lectures and computer exercises = 28 hours, private studies = 42 hours
<b>Examinations/Credits:</b> Project report and presentation/ 3 CP
<b>Responsible lecturer:</b> Dr. H. Grosshans / PTB Braunschweig
<b>Literature:</b> <ul style="list-style-type: none"><li>- Ferziger &amp; Peric: Computational Methods for Fluid Dynamics</li><li>- Crowe, Schwarzkopf, Sommerfeld &amp; Tsuji: Multiphase Flows with Droplets and Particles</li></ul>



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

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





<i>Modulziele / angestrebte Lernergebnisse / Learning Outcomes</i>	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.
<i>Inhalt</i>	Content: <ul style="list-style-type: none"><li>• Basics of apparatus and plant engineering</li><li>• Basics of plant design</li><li>• – Drying and granulation processes in solids process engineering</li><li>• Design of convection dryers (mass and energy balances)</li><li>• Design of contact dryers (mass and energy balances)</li><li>• Heat and mass transfer in convection and contact dryers</li><li>• Application examples and case studies from industrial practice</li></ul>
<i>Studien- / Prüfungsleistungen / Prüfungsformen</i>	Mündliche Prüfung ca. 60 min.
<i>Literatur</i>	Vorlesungsskript Ausgewählte wissenschaftliche Publikationen aus dem Fachgebiet
<i>Sonstige Informationen</i>	Keine
<i>Freigabe / Version</i>	Letzte Überarbeitung des Moduls, 20.09.21



#### 4.26. Process Control

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Process Control
<b>Objectives</b> Students should <ul style="list-style-type: none"><li>• learn fundamentals of multivariable process control with special emphasis on decentralized control</li><li>• gain the ability to apply the above mentioned methods for the control of single and multi unit processes</li><li>• gain the ability to apply advanced software (MATLAB) for computer aided control system design</li></ul>
<b>Contents</b> 1. Introduction 2. Process control fundamentals <ul style="list-style-type: none"><li>• Mathematical models of processes</li><li>• Control structures</li><li>• Decentralized control and Relative gain analysis</li><li>• Tuning of decentralized controllers</li><li>• Control implementation issues</li></ul> 3. Case studies 4. Plantwide control
<b>Teaching</b> Lecture and exercises/tutorials; (summer semester)
<b>Prerequisites</b> Basic knowledge in control theory
<b>Workload:</b> Lectures and tutorials: <ul style="list-style-type: none"><li>• 2 hours/week – lecture</li><li>• 1 hour/week – exercise/tutorial</li></ul> Private studies <ul style="list-style-type: none"><li>• Post-processing of lectures, preparation of project work/report and exam (78 hours)</li></ul>
<b>Examination/Credits:</b> oral / 4 CP and project report
<b>Responsible lecturer:</b> Prof. A. Kienle, FEIT, with Dr. A. Disli-Kienle as co-worker
<b>Literature:</b> [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.



#### 4.27. Product quality in the chemical industry

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Product quality in the chemical industry
<b>Objectives:</b> Understanding the <ul style="list-style-type: none"><li>• Requirement profiles for products of the chemical and process industry</li><li>• Relation between structure and functionality of complex products</li><li>• Opportunities and methods for product design</li></ul>
<b>Contents:</b> <ul style="list-style-type: none"><li>• 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)</li><li>• Formulation and properties of granular materials (dustiness, fluidizability, storage, color and taste, pourability, adhesion and cohesion, bulk density, redispersibility, instantization etc.)</li><li>• Detergents (design by composition and structure, molecular fundamentals and forces, tensides and their properties, competitive aspects of quality, alternative design possibilities, production procedures)</li><li>• 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)</li><li>• Drugs (quality of active substances and formulations, release kinetics and retard characteristics, coatings, microencapsulation, implants, further possibilities of formulation)</li><li>• Clean surfaces (the "Lotus Effect", its molecular background and its use, different ways of technical innovation)</li><li>• Short introduction to quality management after ISO in the chemical industry (block lecture and workshop by Mrs. Dr. Fruehauf, Dow Deutschland GmbH)</li></ul>
<b>Teaching:</b> Lectures / Exercises / Lab exercises / Workshop; (summer semester)
<b>Prerequisites:</b>
<b>Work load:</b> 3 hours per week, Lectures and tutorials: 42 h, Private studies: 78 h
<b>Examinations /Credits:</b> Oral exam / 4 CP
<b>Responsible lecturer:</b> Prof. E. Tsotsas / Dr. A. Kharaghani, FVST
<b>Literature:</b> Handouts will be given in lecture



4.28.

***Seminar Mechanical Process Engineering***

**Modulbezeichnung**

<i>Englischer Titel</i>	<b>Seminar Mechanical Process Engineering</b>
<i>Modulniveau nach DQR</i>	MSc level
<i>Modulnummer</i>	
<i>Untertitel</i>	
<i>Lehrveranstaltungen</i>	Mechanische Verfahrenstechnik or Mechanical Process Engineering Fluid Mechanics
<i>empfohlenes Studiensemester</i>	
<i>Häufigkeit des Angebots/ Angebotsturnus</i>	2x per year: Summer and winter semesters
<i>Modulverantwortliche:r</i>	Prof. Berend van Wachem
<i>Dozent:in</i>	Prof. Berend van Wachem
<i>Sprache</i>	English
<i>Zuordnung zum Studiengang/ Curriculum / Verwendbarkeit des Moduls</i>	<ul style="list-style-type: none"><li>▶ Master CEE</li><li>▶ Master Verfahrenstechnik</li><li>▶ Master Process Safety and Environmental Engineering</li><li>▶ Master Chemieingenieurwesen</li></ul>
<i>Lehrform und SWS</i>	Lectures 1hr, group work 2 hrs, and tutorials 1hr
<i>Arbeitsaufwand</i>	Lectures, group-work, presentation and tutorials: 56 h, self-study: 94 h 4 SWS
<i>Dauer des Moduls</i>	1 Semester
<i>Credit Points (CP)</i>	5 CP
<i>Voraussetzung für die Vergabe von CP</i>	Pass grade for individual hand-in and presentation combined.
<i>Teilnahmevoraussetzungen</i>	-
<i>Empfehlungen für die Teilnahme</i>	Basic knowledge of Mechanical Process Engineering and Fluid Mechanics.



<i>Modulziele / angestrebte Lernergebnisse / Learning Outcomes</i>	<p>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.</p> <p>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.</p>
<i>Inhalt</i>	<p>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:</p> <ul style="list-style-type: none"><li>- Fluid drag on ellipsoidal particles</li><li>- Flow around a spherical particle</li><li>- Navier-Stokes equations</li><li>- Discrete Element Modelling (DEM)</li><li>- Elastic, visco-elastic and plastic particle interactions</li><li>- Stokes flow and its solutions</li><li>- Modelling of fluidized beds</li><li>- Flows through fixed beds</li><li>- Modelling of pyrolysis</li><li>- Mass transfer modelling at gas-liquid interfaces</li><li>- Particle-turbulence interactions</li></ul>
<i>Studien- / Prüfungsleistungen / Prüfungsformen</i>	Hand-in (project work), 80% and Presentation, 20%
<i>Literatur</i>	
<i>Sonstige Informationen</i>	
<i>Freigabe / Version</i>	01.01.2023



#### 4.29. Renewable Energies: Materials, Components, Function

<b>Modulbezeichnung</b>	<i>Renewable Energies: Materials, Components, Function</i>
<i>Englischer Titel</i>	Renewable Energies: Materials, Components, Function
<i>Modulniveau nach DQR</i>	7
<i>Modulnummer</i>	
<i>Untertitel</i>	
<i>Lehrveranstaltungen</i>	lectures and seminars
<i>empfohlenes Studiensemester</i>	Master 1–3
<i>Häufigkeit des Angebots/ Angebotsturnus</i>	summer term
<i>Modulverantwortliche:r</i>	Prof. Michael Scheffler, FMB-IWF
<i>Dozent:in</i>	Prof. Michael Scheffler, FMB-IWF Dr. Ulf Betke, FMB-IWF
<i>Sprache</i>	English
<i>Zuordnung zum Studiengang/ Curriculum / Verwendbarkeit des Moduls</i>	<ul style="list-style-type: none"><li>▶ Chemical and Energy Engineering (CEE)</li><li>▶ Process Safety and Environmental Engineering (PSEE)</li><li>▶ free movers</li></ul>
<i>Lehrform und SWS</i>	Lecture, 2 hours per week á 14 weeks, physical presence Seminar, 1 hour per week á 14 weeks, physical presence
<i>Arbeitsaufwand</i>	42 hours lecture and seminar; 72 hours of private studies
<i>Dauer des Moduls</i>	1 semester
<i>Credit Points (CP)</i>	5
<i>Voraussetzung für die Vergabe von CP</i>	passed exam; participation after homework/assignment paper was evaluated with > 50 %
<i>Teilnahmevoraussetzungen</i>	basics in chemistry and/or physics
<i>Empfehlungen für die Teilnahme</i>	



<p><i>Modulziele / angestrebte Lernergebnisse / Learning Outcomes</i></p>	<ul style="list-style-type: none"><li>▶ 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</li><li>▶ attendees are able to describe the above processes, to select converters for specific applications, to estimate/calculate specific size and design for specific purposes;</li></ul>
<p><i>Inhalt</i></p>	<ul style="list-style-type: none"><li>▶ 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</li></ul>
<p><i>Studien- / Prüfungsleistungen / Prüfungsformen</i></p>	<p>submitted homework or assignment paper as prerequisite for exam attendance (passed when &gt; 50 %); electronic exam with random distribution of tasks (moodle, unsupervised, 45 minutes),</p>
<p><i>Literatur</i></p>	<p>-handouts will be given in lecture</p> <ul style="list-style-type: none"><li>-Regenerative Energiesysteme: Technologie – Berechnung – Simulation, Volker Quaschnig, Hanser-Verlag, 7. Auflage 2011</li><li>-Energy Science: Principles, technologies and impacts, Jelley Andrews, Oxford Univ. Press.</li><li>-Renewable Energy and Climate Change, Volker Quaschnig, Jon Wiley &amp; Sons, 2010</li><li>-Survey of Energy Ressources; Verlag: Elsevier Science Publishing Company; Auflage: 20th Bk&amp;CD</li></ul>
<p><i>Sonstige Informationen</i></p>	<p>--</p>
<p><i>Freigabe / Version</i></p>	



#### 4.28. Simulation of Mechanical Processes

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Simulation of Mechanical Processes
<b>Objectives (Skills):</b> The students <ul style="list-style-type: none"><li>➤ Learn the theoretical foundations relevant to the mathematical description and modelling of mechanical processes (statistical analysis, numerical solution of differential equations, stochastic solution methods).</li><li>➤ 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.</li><li>➤ Consolidate their understanding of the physics of the principal dynamic processes in particle technology and mechanical process engineering.</li><li>➤ 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.</li></ul>
<b>Content:</b> <ol style="list-style-type: none"><li>1. Statistical methods for the modelling of mechanical systems<ol style="list-style-type: none"><li>a. Summary and recap of relevant statistical values for the evaluation and design of mechanical processes.</li></ol></li><li>2. Numerical solution of differential equations<ol style="list-style-type: none"><li>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.</li><li>b. Solution of systems of multiple ordinary differential equations.</li><li>c. Evaluating the quality of a numerical solution and the quantifying the associated errors.</li></ol></li><li>3. Stochastic solution methods (Monte-Carlo methods)<ol style="list-style-type: none"><li>a. Single-dimensional and multi-dimensional integration</li><li>b. Sampling and variance reduction</li></ol></li><li>4. Introduction to Discrete Element Methods (DEM) for the simulation of particles<ol style="list-style-type: none"><li>a. Derivation of the equations of motion and conservation laws</li><li>b. Description of the rotation and moment of inertia of spherical and non-spherical particles</li><li>c. Simple models for the simulation of elastic and inelastic particle collisions</li><li>d. Description of elastic deformations</li><li>e. Examples of practical applications.</li></ol></li></ol>
<b>Teaching:</b> Lectures and practical exercises (summer and winter semester)
<b>Prerequisites:</b> Basic knowledge of Matlab, Mechanical Process Engineering
<b>Workload:</b> Attendance time: 42 hours, self-study: 108 hours
<b>Credits:</b> 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)



#### 4.29. Sustainability Assessment (LCA) for Biofuels

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Sustainability Assessment (LCA) for Biofuels
<b>Objectives (Skills):</b> <p>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.</p> <p>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.</p> <p>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.</p>
<b>Content:</b> <ol style="list-style-type: none"><li>1. Sustainability and the principles of sustainable development.</li><li>2. The overview of Life Cycle Assessment (LCA) and the phases</li><li>3. Inventory and energy analysis, system boundaries, cut-off rules, allocation rules for multiproduct systems.</li><li>4. Impact assessment, the input- output related categories,</li><li>5. Reporting, interpretation, evaluation and critical review. Attributional and consequential LCA.</li><li>6. Ethanol production processes (starch and sugar and lignocellulosic based platform)</li><li>7. Thermochemical processes: BTL, biomass gasification, pyrolysis and Fischer-Tropsch</li><li>8. Algae biomass utilization, transesterification of triglycerides, anaerobic digestion</li><li>9. Introduction to exergy analysis</li></ol>
<b>Teaching:</b> Lectures and a guided scientific literature search and a preparation of a literature survey.
<b>Prerequisites:</b> Basic courses of chemistry and chemical engineering (Bachelor level)
<b>Workload:</b> presence: 28 hours (2 SWS), survey: 14 hours (1 SWS)



**Credits:**

written exam / 4 CP

**Responsible lecturer:**

Dr. Techn. L. Rihko-Struckmann, MPI Magdeburg

**Literature:**

lecture notes (free to download)



#### 4.30. Tissue Engineering (I)

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Tissue Engineering (I)
<b>Objectives:</b> After this, a lecture the students will have basic knowledge in cell culture technologies and the principle how to generate human 3D tissue models. An overview of the application of human 3D models in biomedical research will be given.
<b>Contents:</b> In the lecture, we will start with an introduction into: <ul style="list-style-type: none"><li>• Cell culture technology and</li><li>• Principles in tissue engineering.</li></ul> During the course we will focus on: <ul style="list-style-type: none"><li>• The development of (bio)materials as 3D scaffolds</li><li>• The bioreactor technology in Tissue Engineering,</li><li>• Non-invasive detection methods and</li><li>• Modeling cell material interaction for tissue engineering.</li></ul> Finally, we give a brief insight into the application of human 3D tissues.
<b>Teaching:</b> Lecture, Tutorial
<b>Prerequisites:</b> Principles in cell biology and analytical methods to characterize cellular function.
<b>Workload:</b> Time of attendance: 2 SWS Lecture, 2 SWS Tutorial (56 h) Autonomous work: Preparing for tutorials and solving homework assignments (54 h), preparing for exam (20 h), reading additional material (20 h)
<b>Examinations/Credits:</b> Written examination 90 min. / 5 CP
<b>Responsible lecturer:</b> Prof. H. Walles, FVST
<b>Literature</b> <b>Tissue Engineering - From Lab to Clinic</b> - Norbert Pallua, Christoph V. Suschek, Springer Berlin (Verlag), 978-3-642-02823-6 (ISBN)) necessary articles will be provided



#### 4.31. Tissue Engineering Lab

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Tissue Engineering Lab
<b>Objectives:</b> Tissue engineering is an interdisciplinary field that is very application-oriented. In the lecture: Introduction in Tissue Engineering, you have worked out the theoretical basics and heard about numerous, very different fields of application. In this practical course, we want to learn preparing hydrogels and applying tissue models for the risk assessment as well as the necessary molecular evaluation. This course helps you to decide whether tissue engineering is a field for your master's thesis.
<b>Contents:</b> We start with the production and material characterization of hydrogels. Then we will manufacture certified tissue models for testing chemicals. Finally, we carry out a risk assessment on this tissue model. We will evaluate this assessment with molecular methods.
<b>Teaching:</b> Lab Course and Tutorial (Practical course and tutorial in small groups to discuss results and protocol preparation for final protocol of the risk assessment)
<b>Prerequisites:</b> None (recommended prerequisites: attending Introduction in Tissue Engineering)
<b>Workload:</b> Time of attendance: 80 hours of present time in the lab (10 full days), 20 hours exercise for critical review of the experimental data and reports Autonomous work: 50 hours of independent work (follow-up experiments and exercises/discussion of the results - elaboration of final report) 3 SWS - every summer semester
<b>Examinations/Credits:</b> Protocols and final report of the risk assessment 5 CP = 150 h (100 h time of attendance + 50 h autonomous work)
<b>Responsible Lecturer:</b> Prof. Dr. rer. biol. hum. Heike Walles, FVST
<b>Literature:</b>



#### 4.32. Transport phenomena in granular, particulate and porous media

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Transport phenomena in granular, particulate and porous media
<b>Objectives:</b> 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. <ul style="list-style-type: none"><li>• Master transport phenomena in granular, particulate and porous media</li><li>• Learn to design respective processes and products</li><li>• Learn to combine mathematical modelling with lab experiments</li></ul>
<b>Contents:</b> <ul style="list-style-type: none"><li>• Transport phenomena between single particles and a fluid</li><li>• 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</li><li>• Mechanisms of heat transfer through gas-filled gaps</li><li>• Thermal conductivity of fixed beds without flow Axial and lateral heat and mass transfer in fixed beds with fluid flow</li><li>• Heat transfer from heating surfaces to static or agitated bulk materials</li><li>• Contact drying in vacuum and in presence of inert gas</li><li>• Heat transfer between fluidized beds and immersed heating elements</li></ul>
<b>Teaching:</b> Lectures / Exercises; (summer semester)
<b>Prerequisites:</b>
<b>Work load:</b> 3 hours per week, Lectures and tutorials: 42 h, Private studies: 78 h
<b>Examinations/Credits:</b> Oral exam / 5 CP
<b>Responsible lecturer:</b> 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
-



#### 4.33. Waste Water and Sludge Treatment

<b>Course:</b> Selective module for the master course Chemical and Energy Engineering
<b>Module:</b> Wastewater and sludge treatment (WWST)
<b>Objectives (competences):</b> The student should be able to <ul style="list-style-type: none"><li>• identify the relevant physical, chemical and biological properties of a wastewater</li><li>• understand the fundamentals of wastewater treatment technologies</li><li>• identify the relevant physical, chemical and biological properties of biosolids from wastewater treatment</li><li>• develop creative solutions for the treatment of wastewater and the control of emissions to surface water</li></ul>
<b>Content:</b> <ul style="list-style-type: none"><li>• Constituents and analysis of waste water</li><li>• Principles of mechanical treatment processes</li><li>• Principles of biological treatment processes</li><li>• Principles of chemical treatment processes</li><li>• Activated sludge processes</li><li>• Biofilm processes</li><li>• Process selection</li><li>• Wastewater sludge treatment processes</li><li>• Disinfection processes</li><li>• Water reuse</li></ul>
<b>Teaching:</b> lecture (presentation of slides, additional information on blackboard) and tutorial (exercise on board); (winter semester)
<b>Prerequisites:</b> bachelor in chemical or biological engineering or equivalent
<b>Workload:</b> 3 SWS, lectures, tutorials: 42 h; private studies: 78 h
<b>Examination/credits:</b> written exam / 5 CP
<b>Responsible lecturer:</b> Dr.-Ing. D. Müller, FVST
<b>Literature:</b> 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;