TUHH
Technische Universität Hamburg-Harburg

Module Handbook

Master-Program Chemical and Bioprocess Engineering

Compulsory Modules

1. Semester

Module: Biocatalysis

Course Units:

Title	*Type*	*Duration*
Technical Biocatalysis	Lecture	2
Biocatalysis and Enzyme Technology	Lecture	2

Module Responsible:

Prof. Dr. Andreas Liese

Prerequisites:

None

Recommended Previous Knowledge:

Essentials in Bioprocess Engineering, Chemistry and Biochemistry

Learning Outcomes:

After successful completion of this module, students should be able to

- have an overview of relevant bio-transformations and name the general definitions
- use their gained knowledge about the realisation of processes and transfer this to new tasks
- analyse and discuss special tasks of processes and give solutions
- reflect a broad knowledge about enzymes and their applications in academia and industry
- understand the fundamentals of biocatalysis and enzyme processes and transfer this to new tasks
- know the several enzyme reactors and the important parameters of enzyme processes
- communicate and discuss in English

ECTS Credit Points:

4

Mode of Examination:

Integral Examination

Performance Record:

Written examination

Workload:

Contact Time: 56, Self-study: 64

Course Unit: Biocatalysis and Enzyme Technology

Lecturer:

Prof. Dr. Andreas Liese

Language:

English

Period:

Winter Semester

Contents:

1. Introduction: Impact and potential of enzyme-catalysed processes in biotechnology.
2. History of microbial and enzymatic biotransformations.
3. Chirality - definition & measurement
4. Basic biochemical reactions, structure and function of enzymes.
5. Biocatalytic retrosynthesis of asymmetric molecules
6. Enzyme kinetics: mechanisms, calculations, multisubstrate reactions.
7. Reactors for biotransformations.

Reading Resources:

- 🕮 K. Faber: Biotransformations in Organic Chemistry, Springer, 5th Ed., 2004
- 🕮 Liese, K. Seelbach, C. Wandrey: Industrial Biotransformations, Wiley-VCH, 2006
- 🕮 R. B. Silverman: The Organic Chemistry of Enzyme-Catalysed Reactions, Academic Press, 2000
- 🕮 K. Buchholz, V. Kasche, U. Bornscheuer: Biocatalysts and Enzyme Technology. VCH, 2005.
- 🕮 R. D. Schmidt: Pocket Guide to Biotechnology and Genetic Engineering, Woley-VCH, 2003

Course Unit: Technical Biocatalysis

Lecturer:

Prof. Dr. Andreas Liese

Language:

English

Period:

Winter Semester

Contents:

1. Introduction
2. Production and Down Stream Processing of Biocatalysts
3. Analytics (offline/online)
4. Reaction Engineering & Process Control
   - Definitions
   - Reactors
   - Membrane Processes
   - Immobilization
5. Process Optimization
   - Simplex / DOE / GA
6. Examples of Industrial Processes
   - food / feed
   - fine chemicals
7. Non-Aqueous Solvents as Reaction Media
   - ionic liquids
   - scCO2
   - solvent free

Reading Resources:

- 🕮 Liese, K. Seelbach, C. Wandrey: Industrial Biotransformations, Wiley-VCH, 2006
- 🕮 H. Chmiel: Bioprozeßtechnik, Elsevier, 2005
- 🕮 K. Buchholz, V. Kasche, U. Bornscheuer: Biocatalysts and Enzyme Technology, VCH, 2005
- 🕮 R. D. Schmidt: Pocket Guide to Biotechnology and Genetic Engineering, Woley-VCH, 2003

Module: Applied Microbiology

Course Units:

Title	*Type*	*Duration*
Technical Microbiology	Lecture	2
Advanced Technical Microbiology	Lecture	2

Module Responsible:

Prof. Dr. Garabed Antranikian

Prerequisites:

None

Recommended Previous Knowledge:

Basic knowledge in Microbiology

Learning Outcomes:

Good knowledge of microbiology and deeper understanding of the relevance of microorganisms for biotechnical processes.

The students have the ability to detailed reflection of current questions concerning industrial development of microbiology.

ECTS Credit Points:

4

Mode of Examination:

Integral Examination

Performance Record:

Written examination

Workload:

Contact Time: 56, Self-study: 64

Course Unit: Technical Microbiology

Lecturer:

Prof. Dr. Garabed Antranikian

Language:

English

Period:

Winter Semester

Contents:

- History of microbiology and biotechnology
- Cell morphology and mobility, cell membranes, cell wall, storage compounds, spore formation, transport processes.
- Molecular biology
- Taxonomy of microorganisms including bacteria, archaea and eukarya. Pathogenic and nonpathogenic microorganisms.
- Diversity of viruses, structure and function
- Physiology: cultivation of aerobic and anaerobic microorganisms
- Medium requirements and substrate utilization and transport
- Batch and continuous cultures
- Metabolic pathways in microorganisms: Aerobic and anaerobic pathways
- Phototrophic bacteria, chemolithotrophs and methanogens
- Significance of microorganisms for the industry including food, feed, chemical, pharmaceutical industries and medicine

- Fermentation and the production of solvents, alcohols, acids and gases
- Production of citrate, amino acids and vitamins
- Use of enzymes for various industrial applications. Biocatalysis and formation of high value products
- Biorefinery concept

Reading Resources:

- 🕮 Lengeler, Drews, Schlegel: Biology of the Prokaryotes. Thieme Verlag, Stuttgart, New York, 1999.
- 🕮 Rehm, H. J.: Industrielle Mikrobiologie. Springer Verlag, Berlin, New York u.a. 2. Auflage, 1980.
- 🕮 Brock - Biology of Microorganisms. Prentice-Hall International Editions, 11th Edition, 2006.
- 🕮 Brock - Mikrobiologie. Hrsg. Madigan, Martinko, Pearson Studium, 11. Auflage 2006.
- 🕮 Antranikian - Angewandte Mikrobiologie. Springer-Verlag Berlin Heidelberg New York, 2005.

Course Unit: Advanced Technical Microbiology

Lecturer:

Prof. Garabed Antranikian

Language:

English

Period:

Winter Semester

Contents:

- Industrial relevance of microbial enzymes
- Biotransformation under unconventional conditions
- Modern technologies in genetics
- New methods for molecular cloning
- Genomics of various microorganisms
- Directed evolution for tailor-made enzymes
- Enantioselective biocatalysis
- Compatible solutes and their application
- Synthetic biology
- The future of white (industrial) biotechnology

Reading Resources:

- 🕮 Current publications will be issued in the course of the module

Module: Separation Technologies for Life Sciences

Course Units:

Title	*Type*	*Duration*
Unit Operations for bio-related Systems	Lecture	2
Exercise: Unit Operations for bio-related Systems	Exercise	1
Chromatographic Separation Processes	Lecture	2

Module Responsible:

Prof. Dr. Irina Smirnova

Prerequisites:

None

Recommended Previous Knowledge:

Basic knowledge in unit operations (bachelor level chemical engineering), Fundamentals of Chemistry, Fluid Process Engineering, Thermal Separation Processes, Chemical Engineering, Bioprocess Engineering

Learning Outcomes:

- Basic knowledge of separation processes for biotechnological and pharmaceutical processes
- Identification of specific features and limitations in bio-related systems
- Proof of economical value of the process
- Classify chromatographic separation methods
- Explain separation mechanisms in chromatography
- Describe parameters for evaluation of chromatographic separations
- Differentiate models for chromatography
- Evaluate chromatographic processes regarding productivity, solvent consumption and profitability
- Prepare a special scientific topic and its presentation and discussion

ECTS Credit Points:

5

Mode of Examination:

Integral Examination

Performance Record:

Oral presentation of original scientific article with written summary and written examination

Workload:

Contact Time: 68, Self-study: 82

Course Unit: Chromatographic Separation Processes

Lecturer:

Privatdoz. Dr. Monika Johannsen

Language:

English

Period:

Winter Semester

Contents:

- Introduction: overview, history of chromatography, LC (HPLC), GC, SFC
- Fundamentals of linear (analytical) chromatography, retention time/factor, separation factor, peak resolution, band broadening, Van-Deemter equation
- Fundamentals of nonlinear chromatography, discontinuous and continuous preparative chromatography (annular, true moving bed - TMB, simulated moving bed - SMB)
- Adsorption equilibrium: experimental determination of adsorption isotherms and modeling
- Equipment for chromatography, production and characterization of chromatographic adsorbents

- Method development, scale up methods, process design, modeling of chromatographic processes, economic aspects
- Applications: e.g. normal phase chromatography, reversed phase chromatography, hydrophobic interaction chromatography, chiral chromatography, bioaffinity chromatography, ion exchange chromatography

Reading Resources:

📖 Guiochon, G.; Golshan-Shirazi, S.; Katti, A.M.: Fundamentals of Preparative and Nonlinear Chromatography. Boston, Academic Press (1994).

📖 Guiochon, G.; Lin, B.: Modeling for Preparative Chromatography. Amsterdam, Elsevier (2003).

📖 Ganetsos, G.; Barker, P.E.: Preparative and Production Scale Chromatography. New York: M. Dekker (1993).

📖 Schmidt-Traub, H.; Preparative Chromatography of Fine Chemicals and Pharmaceutical Agents. Weinheim: Wiley-VCH (2005).

Course Unit: Unit Operations for bio-related Systems

Lecturer:

Prof. Dr. Irina Smirnova

Language:

English

Period:

Winter Semester

Contents:

- Introduction: overview about the separation process in biotechnology and pharmacy
- Handling of multicomponent systems
- Adsorption of biologic molecules
- Crystallization of biologic molecules
- Reactive extraction
- Aqueous two-phase systems
- Micellar systems: micellar extraction and micellar chromatographie
- Electrophoresis
- Membrane technology
- Choice of the separation process for the specific systems

Reading Resources:

📖 „Handbook of Bioseparations“, Ed. S. Ahuja

📖 “Bioseparations Engineering” Ed. M. R. Ladish

Module: Numerical Methods for international Master Programs

Course Units:

Title	*Type*	*Duration*
Numerical Methods for international Master Programs	Lecture	3
Exercise: Numerical Methods for international Master Programs	Exercise	2

Module Responsible:

Prof. Dr. Wolfgang Mackens

Prerequisites:

None

Recommended Previous Knowledge:

Analysis, Linear Algebra, Ordinary Differential Equations

Learning Outcomes:

After successful completion of the course the students will be able to

- name and describe the usual numerical methods to deal with the above cited problem areas and explain the intended effects of their ingredients
- detect the appearance of those problems in simple applications, formulate them in standard mathematical nomenclature, select adequate numerical methods for their solution, and implement them using MATLAB

ECTS Credit Points:

4

Mode of Examination:

Integral Examination

Performance Record:

Written examination

Workload:

Contact Time: 70, Self-study: 50

Course Unit: Numerical Methods for international Master Programs

Lecturer:

Prof. Dr. Wolfgang Mackens

Language:

English

Period:

Winter Semester

Contents:

Basic methods to deal with the numerical treatment of problems from the following mathematical problem areas:

- Error Analysis,
- Interpolation, Quadratur,
- linear systems of equations,
- linear least squares,
- eigenvalue problems,
- systems of nonlinear equations,
- ordinary differential equations (initial- and boundary-value problems)

Reading Resources:

- 🕮 W.Mackens: Basic Numerical Techniques using MATLAB, Script TUHH, November 2009
- 🕮 Cleve Moler, Numerical Computing with MATLAB, SIAM, ISBN: 978-0-898716-60-3, see as well http://www.mathworks.de/moler/chapters.html
- 🕮 K. Sigmon and T. A. Davis : "MATLAB® PRIMER, Sixth Edition", Chapman and Hall/CRC, by, ISBN: 1584882948
- 🕮 Gerald W. Recktenwald : Numerical Methods with Matlab: Implementations and Applications, Prentice-Hall 2000, Upper Saddle River, NJ. ISBN: 0201308606

Module: Applied Thermodynamics

Course Units:

Title	*Type*	*Duration*
Applied Thermodynamics	Lecture	2
Exercise: Applied Thermodynamics	Exercise	1

Module Responsible:

Prof. Dr. Irina Smirnova

Prerequisites:

None

Recommended Previous Knowledge:

Basics in chemical thermodynamics: phase diagrams, modelling of phase equilibria

Learning Outcomes:

Skills: Modern Methods of Thermodynamics modelling of complex multicomponent and biorelated Systems

Methodological Experience: Calculation of phase equilibria and partitioning with equation of states, g^E models and quantum chemistry. Experience in phase equilibria calculations with different thermodynamically based methods (practical exercises)

ECTS Credit Points:

5

Mode of Examination:

Integral Examination

Performance Record:

Written exam

Course Unit: Applied Thermodynamics

Lecturer:

Prof. Dr. Irina Smirnova / Prof. Dr. Frerich Keil

Language:

English

Period:

Winter Semester

Contents:

- Basics of statistical thermodynamics
- Intermolecular forces, interaction Potenitials
- Phase equilibria in multicomponent systems
- Partitioning in biorelevant systems
- Calculation of phase equilibria in colloidal systems: UNIFAC, COSMO-RS (exercises in computer pool)
- Calculation of partitioning coefficients in biological membranes: COSMO-RS (exercises in computer pool)
- Calculation of phase equilibria in multicomponent systems: equation of state, molecular modelling (exercises in computer pool, Prof. Keil)

1. + 2. Semester

Module: Bioreactor and Bioprocess: Theory and Experimental Course

Course Units:

Title	*Type*	*Duration*
Bioreactors	Lecture	2
Experimental Course Bioprocess Engineering	Practical Laboratory	3

Module Responsible:

Prof. Dr. An-Ping Zeng

Prerequisites:

None

Recommended Previous Knowledge:

Bioprocess Engineering- Fundamentals

Learning Outcomes:

After completion of this module participants should be able to:

- Differentiate between different kinds of bioreactors and describe their key features
- Indentify and characterize the peripheral and control systems of bioreactors
- Depict integrated biosystems (bioprocesses including up- and downstream processing)
- Name different sterilization methods and evaluate those in terms of different applications
- Describe different process control strategies for bioreactors and chose them after analysis of characteristics of a given bioprocess
- Plan and construct a bioreactor system including peripherals from lab to pilot plant scale
- Adapt a present bioreactor system to a new process and optimize it
- Develop concepts for integration of bioreactors into bioproduction processes
- Solve a technical problem related to bioreactor and bioprocess in teamwork and present the results in a group

The students have

- acquired capabilities suitable for practical work in biochemical and biotechnological labs,
- extended their know-how of fermentation and enzyme purification techniques and their practical application,
- the ability to estimate process parameters, evaluate simulation methods and their classification in practical applications,
- learned to self-organize complex operation procedures in groups of 4-5 students independently and autonomous.

ECTS Credit Points:

5

Mode of Examination:

Partial Performance Records

Performance Record:

See course unit descriptions for details

Workload:

Contact Time: 70, Self-study: 80

Course Unit: Bioreactors

Lecturer:

Prof. Dr. An-Ping Zeng

Language:

English

Period:

Winter Semester

Contents:

Design of bioreactors and peripheries:

- reactor types and geometry
- materials and surface treatment
- agitation system design
- insertion of stirrer
- sealings
- fittings and valves
- peripherals
- materials
- standardization
- with demonstration in pilot plant.

Sterile operation:

- theory of sterilisation processes
- sterilisation of reactor and probes
- different sterilisation methods
- industrial sterile test, automated sterilisation
- introduction of biological material
- autoclaves
- continuous sterilisation of fluids
- deep bed filters, tangential flow filters
- demonstration and practice in pilot plant

Instrumentation and control:

- temperature control and heat exchange,
- dissolved oxygen control and mass transfer,
- aeration and mixing,
- used gassing units and gassing strategies
- control of agitation and power input,
- pH and reactor volume, foaming, membrane gassing

Bioreactor selection and scale-up:

- selection criteria
- scale-up and scale-down
- reactors for mammalian cell culture

Integrated biosystem:

- interactions and integration of microorganisms,
- bioreactor and downstream processing.

Team work with presentation:

- Operation mode of selected bioprocesses (e.g. fundamentals of batch, fed-batch and continuous cultivation)

Performance Record:

Written examination

Reading Resources:

- 🕮 Storhas, Winfried, Bioreaktoren und periphere Einrichtungen, Braunschweig: Vieweg, 1994
- 🕮 Chmiel, Horst, Bioprozeßtechnik; Bd. 1: Einführung in die Bioprozeßtechnik und Bd. 2: Angewandte Bioverfahrenstechnik, Stuttgart, Fischer, 1991
- 🕮 Krahe, Martin, Biochemical Engineering, Ullmann‘s Encyclopedia of Industrial Chemistry

Course Unit: Experimental Course Bioprocess Engineering

Lecturer:

Prof. Dr. An-Ping Zeng, Prof. Dr. Andreas Liese

Language:

English

Period:

Summer Semester

Contents:

This course comprises fermentation and downstream processing technologies which are exemplified by the production of an enzyme with a recombinant organism. Furthermore, kinetic characterization and simulation of the enzyme and its application in an enzyme reactor will be carried out.

Schedule:

- Assembly of bioreactors for the cultivation of microbial organisms
- Characterization and control of the cultivation process based on offline analytics and online measurements
- Cultivation of a recombinant *E. coli* and overexpression of an enzyme
- Analysis of growth kinetics
- Purification of the enzyme
- Kinetic measurements of the enzyme
- Simulation of the enzyme kinetics
- Use of the enzyme in a continuous reactor

Performance Record:

Written protocol

Module: Heterogeneous Catalysis: Theory and Experimental Course

Course Units:

Title	*Type*	*Duration*
Reactors for Heterogeneous Catalysis	Lecture	2
Experimental Course Chemical Engineering (IMP)	Lecture	1
Experimental Course Chemical Engineering (IMP)	Practical Laboratory	3

Module Responsible:

Prof. Dr. Frerich Keil

Prerequisites:

None

Recommended Previous Knowledge:

Bachelor, Fundamentals of Chemical reaction Engineering, knowledge of a computer language is useful (e. g. MATLAB, FORTRAN)

Basic knowledge of chemical reaction engineering

Admission colloquia

Learning Outcomes:

After successful completion of this lecture the students know the models of important heterogeneous catalytic reactors. Furthermore, they know the most important numerical approaches to solve the model equations.

The students are able to set up reactor models for heterogeneous catalytic reactions and the catalytic reactions. How to solve these model equations numerically on a computer is also known.

After successful completion of the experimental course, students are able to execute experiments in Chemical Reaction Engineering, and to critically evaluate the data.

Soft Skills: team work

ECTS Credit Points:

6

Mode of Examination:

Partial Performance Records

Performance Record:

See course unit descriptions for details

Workload:

Contact Time: 84, Self-study: 66

Course Unit: Reactors for heterogeneous Catalysis

Lecturer:

Prof. Dr. Frerich Keil

Language:

English

Period:

Winter Semester

Contents:

The course stresses the numerical solution of reactor models by computers.

- Material and energy balance of the two-dimensional pseudo-homogeneous model
- Methods for the numerical solution of ordinary differential equations (Euler, Runge-Kutta, stiff solvers, step-size controlled solvers)
- Examples of reactor design (one-dimensional models), ethane cracker and others

- Catalyst deactivation, example: design of a tubular reactor with deactivating catalyst (hydrogenation of benzene, poison: thiophene), regeneration of a catalyst in a moving bed reactor, riser reactor (gas oil cracking), fluidized bed
- Fluidized bed reactors (Davidson-Harrison model)
- Partial Differential Equations, classification, numerical solution (finite difference method, method of lines), examples: isothermal tubular reactor with axial dispersion , dehydrogenation of ethylbenzene to styrene, wrong-way behaviour of reactors
- Boundary value problems, numerical solution (shooting method), examples: composition and temperature profiles inside catalyst pellets
- Multiphase reactors, example: trickle-bed reactor (crude oil desulfurization)

Performance Record:

Written Exam

Reading Resources:

🕮 Script
🕮 S. Fogler: Elements of Chemical Reaction Engineering, Prentice Hall
🕮 G. Froment, K. B. Bischoff: Chemical Reactor Analysis and Design, Wiley

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Course Unit: Experimental Course Chemical Engineering

Lecturer:

Prof. Dr. Frerich Keil and Staff

Language:

English

Period:

Summer Semester

Contents:

Execution and evaluation of several experiments in chemical reaction engineering:

- Calculation of error propagation and error analysis
- Batch reactors – estimation of kinetic parameters for the saponification of ethylacetate
- Continuous stirred tank reactors, residence time distribution, reaction
- Continuous stirred tanks in series, residence time distribution
- Tubular reactor, residence time distribution, reaction
- Steady state Wicke-Kallenbach measurements of diffusivities in a catalyst pellet
- Interaction of reaction and diffusion in a catalyst particle, dissociation of methanol on zinc oxide
- Mass transfer in gas/liquid system
- Stability of a CSTR (hydrolysis of acetic anhydride)
- Computer simulation of various reactor systems

Performance Record:

Written reports on the experiments

2. Semester

Module: Process Systems Engineering

Course Units:

Title	*Type*	*Duration*
Process Systems Engineering	Lecture	2

Module Responsible:

Prof. Dr. Georg Fieg

Prerequisites:

None

Recommended Previous Knowledge:

Separation processes, Chemical reaction engineering, process and plant engineering

Learning Outcomes:

The students have knowledge of both the theory and the practice of process systems engineering with the focus on the understanding of the difficulties on decision-making process. The industrial examples and rules of thumb given in the lectures support the understanding of complex engineering issues.

ECTS Credit Points:

2

Mode of Examination:

Integral Examination

Performance Record:

Written examination

Workload:

Contact Time: 28, Self-study: 32

Course Unit: Process Systems Engineering

Lecturer:

Prof. Dr. Georg Fieg

Language:

English

Period:

Summer Semester

Contents:

Introduction

Process synthesis

- Hierarchical approach
- Economic evaluation
- Process integration

Process control

- System dynamics
- Steady-state design vs. process control
- Process control schemes of typical industrial equipment
- Multivariable systems (control-loop interactions, relative gain concept)
- Plant startup: an industrial case study

Synthesis of heat recovery systems

- Pinch technology (composite curves, minimum utility requirements, Problem Table Algorithm, heat cascade)
- Design of heat exchanger networks

Exercises:

- Computational exercises
- Software exercises (simulation tool: HX-NET™ / Aspen Tech

Reading Resources:

📖 L. Biegler, I.E. Grossmann, A.W. Westerberg; Systematic methods of Chemical Process Design; Prentice, Hall PTR, 1997

📖 A.C. Dimian; Integrated Design and Simulation of Chemical Processes, Elsevier, 2003

📖 J.M. Douglas; Conceptual Design of Chemical Processes, McGraw-Hill, 1988

Module: Biosystems Analysis and Engineering

Course Units:

Title	*Type*	*Duration*
Biosystems Analysis and Engineering	Lecture	2
Exercise: Biosystems Analysis and Engineering	Exercise	1

Module Responsible:

Prof. Dr. An-Ping Zeng

Prerequisites:

None

Recommended Previous Knowledge:

Advanced knowledge in Bioprocess Engineering

Learning Outcomes:

After passing this course the students have the ability to:

- Recall and define the advanced methods of modern systems-biological approaches
- Assess and apply methods and theories of genomics, transcriptomics, proteomics and metabolomics in order to quantify and optimize biological processes at molecular and process levels.
- Connect the multiple "omics"-methods and evaluate their application for biological questions
- Recall the fundamentals of modelling and simulation of biological networks and biotechnological processes and to discuss their methods
- Combine the different modelling methods into an overall modelling approach, to apply these methods to specific problems and to evaluate the achieved results critically
- Connect all process components of biotechnological processes for a holistic system view.

The students have to debate questions in small teams, thus enhancing their ability to solve problems independently and their capacity for teamwork.

ECTS Credit Points:

4

Mode of Examination:

Integral Examination

Performance Record:

Written examination

Workload:

Contact Time: 42, Self-study: 78

Course Unit: Biosystems Analysis and Engineering

Lecturer:

Prof. Dr. An-Ping Zeng

Language:

English

Period:

Summer Semester

Contents:

Introduction to Systems Biology and Biosystems Engineering

Experimental basis and methods for systems biology

- Introduction to genomics, transcriptomics and proteomics
- More detailed treatment of metabolomics
    - Determination of in-vivo kinetics
    - Techniques for rapid sampling

    - Quenching and extraction
    - Analytical methods for determination of metabolite concentrations

Analysis, modelling and simulation of biological networks

- Metabolic flux analysis
    - Introduction
    - Isotope labelling
    - Elementary flux modes
- Mechanistic and structural network models
- Regulatory networks
- Systems analysis
    - Structural network analysis
    - Linear and non-linear dynamic systems
    - Sensitivity analysis (metabolic control analysis)

Modelling and simulation for bioprocess engineering

- Modelling of bioreactors
- Dynamic behaviour of bioprocesses

Selected projects for biosystems engineering

- Miniaturisation of bioreaction systems
- Miniplant technology for the integration of biosynthesis and downstream processing
- Technical and economic overall assessment of bioproduction processes

Reading Resources:

📖 E. Klipp et al. Systems Biology in Practice, Wiley-VCH, 2006
📖 R. Dohrn: Miniplant-Technik, Wiley-VCH, 2006
📖 G.N. Stephanopoulos et. al.: Metabolic Engineering, Academic Press, 1998
📖 I.J. Dunn et. al.: Biological Reaction Engineering, Wiley-VCH, 2003

Module: Fundamentals of Heat and Mass Transfer

Course Units:

Title	*Type*	*Duration*
Fundamentals of Heat and Mass Transfer	Lecture	2
Exercise: Fundamentals of Heat and Mass Transfer	Exercise	1

Module Responsible:

Prof. Dr. Rudolf Eggers

Prerequisites:

None

Recommended Previous Knowledge:

Basics of Technical Thermodynamics

Learning Outcomes:

After passing this course the students have developed an advanced understanding of heat and mass transfer problems and devices including processes with phase change.

ECTS Credit Points:

4

Mode of Examination:

Integral Examination

Performance Record:

Written examination

Workload:

Contact Time: 42, Self-study: 78

Course Unit: Fundamentals of Heat and Mass Transfer

Lecturer:

Prof. Dr. Rudolf Eggers

Language:

English

Period:

Summer Semester

Contents:

- Introduction, Equipment
- Transport Laws and Mass Balances
- Steady State Processes
- Multilayer Problems
- Diffusion of Steam in Solid Walls
- Heat Flow Through fins
- Unsteady State Processes
- Solution Methods
- Diffusion in Porous Solids
- Experimental and Theoretical Determination of Transport Coefficients
- Convection
- Forced Convection
- Processes with Phase Changes
- Vaporization and Condensation
- Melting and Solidification
- Heat Radiation

Reading Resources:

- 🕮 Baehr/Stephan: Heat and Mass Transfer, Edition Springer, 2000
- 🕮 Bird/Stewart/Lightfood: Transport Phenomena, Wiley, 2002
- 🕮 Beek/Muttzall: Transport Phenomena, Wiley, 1983

Module: Particle Technology for International Master Programs

Course Units:

Title	*Type*	*Duration*
Particle Technology for International Master Programs	Lecture	2
Exercise: Particle Technology for International Master Programs	Exercise	1
Experimental Course Particle Technology for Int. Master Programs	Practical Laboratory	3

Module Responsible:

Prof. Dr. Stefan Heinrich

Prerequisites:

None

Recommended Previous Knowledge:

None

Learning Outcomes:

Expertise in Solids Process Engineering and Apparatuses of Particle Technology

ECTS Credit Points:

7

Mode of Examination:

Partial Performance Records

Performance Record:

See course unit descriptions for details

Workload in hours:

Contact Time: 84, Self-study: 126

Course Unit: Particle Technology for International Master Programs

Lecturer:

Prof. Dr. Stefan Heinrich

Language:

English

Period:

Summer Semester

Contents:

- Introduction
- Characterization of particles and bulk solid materials
- Classification
- Mixing
- Comminution
- Agglomeration and particle growth
- Basics of fluid-solid flows
- Classification methods for bulk solid materials
- Solids separation
- Fluid dynamic characteristics of fluidized beds
- Hydraulic and pneumatic solids transport

Performance Record:

Written Exam

Reading Resources:

- 🕮 M. Rhodes: Introduction to Particle Technology - Second Edition, John Wiley & Sons, 2008

- 🕮 M.E. Fayed & L. Otten: Handbook of Powder Science & Technology, 2nd Ed., Chapman & Hall, 1997
- 🕮 M. Stieß: Mechanische Verfahrenstechnik Band 1 + 2, Springer-Verlag; Heidelberg, Berlin, New York, 2. Auflage 1995 + 2001
- 🕮 Heinrich Schubert: Mechanische Verfahrenstechnik, Deutscher Verlag für Grundstoffindustrie, Leipzig, 1990
- 🕮 M. Zogg: Einführung in die Mechanische Verfahrenstechnik, Teubner Verlag, Stuttgart, 1987
- 🕮 Heinrich Schubert (ed.): Handbuch der Mechanischen Verfahrenstechnik Band 1 + 2, Wiley-VCH, Weinheim, 2002
- 🕮 M. Bohnet (ed.): Mechanische Verfahrenstechnik, Wiley-VCH, Weinheim, 2004
- 🕮 Löffler, Raasch: Grundlagen der Mechanischen Verfahrenstechnik, Vieweg Verlag
- 🕮 Dialer, Onken, Leschonski: Grundzüge der Verfahrenstechnik und Reaktionstechnik, Hanser Verlag
- 🕮 Ullmann's Encyclopedia of Industrial Chemistry, VCH Verlagsgesellschaft

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Course Unit: Experimental Course Particle Technology for Int. Master Programs

Lecturer:

Prof. Dr. Stefan Heinrich and Staff

Language:

English

Period:

Summer Semester

Contents:

Experiments on

- Sieving
- Bulk properties
- Size reduction
- Mixing
- Gas cyclone
- Blaine-test, filtration
- Fluidization
- Agglomeration
- Hydrocyclone
- Sedimentation

Performance Record:

Written reports on the experiments

Reading Resources:

- 🕮 M. Rhodes: Introduction to Particle Technology - Second Edition, John Wiley & Sons, 2008
- 🕮 M.E. Fayed & L. Otten: Handbook of Powder Science & Technology, 2nd Ed., Chapman & Hall, 1997
- 🕮 Schubert, H.; Heidenreich, E.; Liepe, F.; Neeße, T.: Mechanische Verfahrenstechnik. Deutscher Verlag für die Grundstoffindustrie, Leipzig, 1990.
- 🕮 Stieß, M.: Mechanische Verfahrenstechnik I und II. Springer Verlag, Berlin, 1992.

3. Semester

Module: Process Design Course

Module Responsible:

Rotating between heads of institutes

Prerequisites:

None

Recommended Previous Knowledge:

All knowledge, skills and competencies that are taught and developed in the first year.

Learning Outcomes:

The students are able to finish one of several sub-projects in the design of a whole chemical or biochemical production plant within a given time frame in self organized small teams. They have the ability to coordinate their sub-project with the other groups to result in a complete, working plant concept. They can write down a correct project report and present the results.

ECTS Credit Points:

4

Mode of Examination:

Proficiency Examination

Performance Record:

Project report and final presentation

Workload:

Self-study: 120

Module: Project Work

Module Responsible:

A professor of the TUHH

Prerequisites:

None

Recommended Previous Knowledge:

All knowledge, skills and competencies that are taught and developed in the first year.

Learning Outcomes:

The students are able to work scientifically correct. They have the ability to complete and document research on a subject matter assignment with scientific methods independently and within a given timeframe. The students are able to develop solutions for technical problems on the basis of pure science with regards to safety, environmental, ethical and economic aspects.

ECTS Credit Points:

10

Mode of Examination:

Integral Examination

Performance Record:

Project work and oral exam

Workload:

Self-study: 450

4. Semester

Module: Master Thesis

Module Responsible:

A professor of the TUHH

Prerequisites:

Achievements of at least 80 ECTS from the curriculum

Recommended Previous Knowledge:

All knowledge, skills and competencies that are taught and developed in semesters 1-3.

Learning Outcomes:

The graduates have the necessary competencies for correct scientific work and are able to write profound research papers. They have the ability to complete research on a pure science subject matter with sophisticated scientific methods independently and within a given timeframe. The students are able to analyze and evaluate possible solutions for the given problem and can put their work into the context of current research.

ECTS Credit Points:

30

Mode of Examination:

Integral Examination

Performance Record:

Thesis and Presentation

Workload:

Self-study: 900

Technical Elective Modules

Summer Semester

Module: Cell and Tissue Engineering

Course Units:

Title	*Type*	*Duration*
Fundamentals of Cell and Tissue Engineering	Lecture	2
Bioprocess Engineering for Medical Application	Lecture	2

Module Responsible:

Prof. Dr. Ralf Pörtner

Prerequisites:

None

Recommended Previous Knowledge:

Process or bioprocess engineering knowledge on bachelor level

Learning Outcomes:

After successful completion of this module the students are able to

- explain and describe basic principles of cell and tissue engineering,
- explain main metabolic and physiological properties of mammalian cells,
- explain and describe basic principles of reactor systems for cell and tissue engineering different to microbial fermentation ,
- understand, analyze and perform mathematical modeling of cellular actions on an advanced level.
- explain, analyze and calculate main process strategies and suitable applications,
- explain main steps (unit operations) required for downstream.

ECTS Credit Points:

4

Mode of Examination:

Integral Examination

Performance Record:

Written examination

Workload:

Contact Time: 56, Self-study: 64

Course Unit: Fundamentals of Cell and Tissue Engineering

Lecturer:

Prof. Dr. Ralf Pörtner, Prof. Dr. An-Ping Zeng

Language:

English

Period:

Summer Semester

Contents:

- Overview of cell culture technology and tissue engineering (cell culture product manufacturing, complexity of protein therapeutics, examples of tissue engineering)

- Fundamentals of cell biology for process engineering (cells: source, composition and structure. interactions with environment, growth and death – cell cycle, protein glycolysation)
- Cell physiology for process engineering (Overview of central metabolism, genomics etc.)
- Medium design (impact of media on the overall cell culture process, basic components of culture medium, serum and protein-free media)
- Stochiometry and kinetics of cell growth and product formation (growth of mammalian cells, quantitative description of cell growth & product formation, kinetics of growth)

Reading Resources:

🕮 Butler, M (2004) Animal Cell Culture Technology – The basics, 2nd ed. Oxford University Press
🕮 Ozturk SS, Hu WS (eds) (2006) Cell Culture Technology For Pharmaceutical and Cell-Based Therapies. Taylor & Francis Group, New York
🕮 Eibl, R.; D. Eibl; R. Pörtner; G. Catapano and P. Czermak: Cell and Tissue Reaction Engineering, Springer (2008). ISBN 978-3-540-68175-5
🕮 Pörtner R (ed) (2007) Animal Cell Biotechnology – Methods and Protocols. Humana Press

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Course Unit: Bioprocess Engineering for Medical Application

Lecturer:

Prof. Dr. Ralf Pörtner

Language:

English

Period:

Summer Semester

Contents:

- Requirements for cell culture processess, shear effects, microcarrier technology
- Reactor systems for mammalian cell culture (production systems) (design, layout, scale-up: suspension reactors (stirrer, aeration, cell retention), fixed bed, fluidized bed (carrier), hollow fiber reactors (membranes), dialysis reactors
- Reactor systems for Tissue Engineering
- Prozess strategies (batch, fed-batch, continuous, perfusion, mathematical modelling), control (oxygen, substrate etc.)
- Downstream

Reading Resources:

🕮 Butler, M (2004) Animal Cell Culture Technology – The basics, 2nd ed. Oxford University Press
🕮 Ozturk SS, Hu WS (eds) (2006) Cell Culture Technology For Pharmaceutical and Cell-Based Therapies. Taylor & Francis Group, New York
🕮 Eibl, R.; D. Eibl; R. Pörtner; G. Catapano and P. Czermak (2008): Cell and Tissue Reaction Engineering. Springer. ISBN 978-3-540-68175-5
🕮 Pörtner R (ed) (2007) Animal Cell Biotechnology – Methods and Protocols. Humana Press

Module: High Pressure Chemical Engineering

Course Units:

Title	*Type*	*Duration*
Production Processes under High Pressures	Lecture	2
Advanced Separation Processes	Lecture	2

Module Responsible:

Privatdoz. Dr. Monika Johannsen

Prerequisites:

None

Recommended Previous Knowledge:

Fundamentals of Chemistry, Thermodynamics, Chemical Engineering, Fluid Process Engineering, Thermal Separation Processes

Learning Outcomes:

After a successful completion of this module, the students are able to

- understand the influence of pressure on properties of compounds, phase equilibria, and production processes
- apply high pressure approaches in the complex process design task
- estimate Efficiency of high pressure alternatives with respect to investment and operational costs
- explain thermodynamic fundamentals of separation processes with supercritical fluids
- define parameter for optimisation of processes with supercritical fluids
- describe solid extraction and countercurrent extraction with models
- identify the application potential of separation processes with supercritical fluids
- compare and evaluate separation processes with supercritical fluids and with conventional solvents
- prepare a special scientific topic and its presentation and discussion

ECTS Credit Points:

4

Mode of Examination:

Integral Examination

Performance Record:

Oral presentation of original scientific article with written summary

Written examination and case study

Workload:

Contact Time: 56, Self-study: 64

Course Unit: Production Processes under High Pressure

Lecturer:

Dr. Carsten Zetzl

Language:

English

Period:

Summer Semester

Contents:

Part I: Physical Chemistry and Thermodynamics

1. Introduction: Overview, achieving high pressure, range of parameters.

2. Influence of pressure on properties of fluids: P,v,T-behaviour, enthalpy, internal energy, entropy, heat capacity, viscosity, thermal conductivity, diffusion coefficients, interfacial tension.
3. Influence of pressure on heterogeneous equilibria: Phenomenology of phase equilibria
4. Overview on calculation methods for (high pressure) phase equilibria).
   Influence of pressure on transport processes, heat and mass transfer.

Part II: High Pressure Processes

5. Separation processes at elevated pressures: Absorption, adsorption (pressure swing adsorption), distillation (distillation of air), condensation (liquefaction of gases)
6. Supercritical fluids as solvents: Gas extraction, cleaning, solvents in reacting systems, dyeing, impregnation, particle formation (formulation)
7. Reactions at elevated pressures. Influence of elevated pressure on biochemical systems: Resistance against pressure

Part III: Industrial production

8. Reaction : Haber-Bosch-process, methanol-synthesis, polymerizations; Hydrations, pyrolysis, hydrocracking; Wet air oxidation, supercritical water oxidation (SCWO)
9. Separation : Linde Process, De-Caffeination, Petrol and Bio-Refinery
10. Industrial High Pressure Applications in Biofuel and Biodiesel Production
11. Sterilization and Enzyme Catalysis
12. Solids handling in high pressure processes, feeding and removal of solids, transport within the reactor.
13. Supercritical fluids for materials processing.
14. Cost Engineering

Reading Resources:

- 🕮 Script: High Pressure Chemical Engineering.
- 🕮 G. Brunner: Gas Extraction. An Introduction to Fundamentals of Supercritical Fluids and the Application to Separation Processes. Steinkopff, Darmstadt, Springer, New York, 1994.

Course Unit: Advanced Separation Processes

Lecturer:

Privatdoz. Dr. Monika Johannsen

Language:

English

Period:

Summer Semester

Contents:

- Introduction/Overview on Properties of Supercritical Fluids (SCF)and their Application in Gas Extraction Processes
- Solubility of Compounds in Supercritical Fluids and Phase Equilibrium with SCF
- Extraction from Solid Substrates: Fundamentals, Hydrodynamics and Mass Transfer
- Extraction from Solid Substrates: Applications and Processes (including Supercritical Water)
- Countercurrent Multistage Extraction: Fundamentals and Methods, Hydrodynamics and Mass Transfer
- Countercurrent Multistage Extraction: Applications and Processes
- Solvent Cycle, Methods for Precipitation
- Supercritical Fluid Chromatography (SFC): Fundamentals and Application
- Simulated Moving Bed Chromatography (SMB)
- Membrane Separation of Gases at High Pressures
- Separation by Reactions in Supercritical Fluids (Enzymes)

Reading Resources:

- 🕮 G. Brunner: Gas Extraction. An Introduction to Fundamentals of Supercritical Fluids and the Application to Separation Processes. Steinkopff, Darmstadt, Springer, New York, 1994.

Winter Semester

Module: Implants and Regenerative Medicine

Course Units:

Title	*Type*	*Duration*
Regenerative Medicine	Lecture	2
Biomaterials	Lecture	2

Module Responsible:

Prof. Dr. Michael Morlock

Prerequisites:

None

Recommended Previous Knowledge:

None

Learning Outcomes:

The students have an overview of problems and current approaches in the field of regenerative medicine. They have good knowledge of composition, structure, properties, function and changes/adaptations of biological and technical materials (which are used for replacements in-vivo).

They have acquired the essential knowledge and skills to work in the area of biomechanics.

ECTS Credit Points:

5

Mode of Examination:

Partial Performance Records

Performance Record:

See course unit descriptions for details

Workload:

Contact Time: 56, Self-study: 94

Course Unit: Regenerative Medicine

Lecturer:

Prof. Dr. Ralf Pörtner, Frank Feyerabend

Language:

English/German (as required by students)

Period:

Winter Semester

Contents:

The course deals with the application of biotechnological engineering principles for re-generation of human tissues. The main topics are stem cells, "tissue engineering", the generation of "artificial organs" such as cartilage, liver, blood vessel etc., and their applications:

- Introduction (historical development, examples for medical and technical applications, commercial aspects)
- Cell specific fundamentals (cell physiology, biochemistry, metabolism, special requirements for cell cultivation "in vitro")
- Process specific fundamentals (requirements for culture systems, examples for reactor design, mathematical modelling, process and control strategies)
- Examples for applications (gene therapy, tissue engineering)

The fundamentals will be presented by the lecturers.

The "state of the art" of specific applications will be explored by the students based on selected papers and presented during the course.

Performance Record:

Written or oral examination

Reading Resources:

- 🕮 Regenerative Biology and Medicine (Taschenbuch) von David L. Stocum; Academic Pr Inc; ISBN-10: 0123693713, ISBN-13: 978-0123693716
- 🕮 Fundamentals of Tissue Engineering and Regenerative Medicine von Ulrich Meyer (Herausgeber), Thomas Meyer (Herausgeber), Jörg Handschel (Herausgeber), Hans Peter Wiesmann (Herausgeber): Springer, Berlin; ISBN-10: 3540777547; ISBN-13: 978-3540777540

Course Unit: Biomaterials

Lecturer:

Prof. Dr. Michael Morlock

Language:

English/German (as required by students)

Period:

Winter Semester

Contents:

1. Introduction (Importance, nomenclature, relations)
2. Biological Materials
    a. Basics (components, testing methods)
    b. Bone (composition, development, properties, influencing factors)
    c. Cartilage (composition, development, structure, properties, influencing factors)
    d. Fluids (blood, synovial fluid)
3. Biological Structures
    a. Menisci of the knee joint
    b. Intervertebral discs
    c. Teeth
    d. Ligaments
    e. Tendons
    f. Skin
    g. Nervs
    h. Muscles
4. Replacement Materials
    a. Basics (history, requirements, norms)
    b. Steel (alloys, properties, reaction of the body)
    c. Titan (alloys, properties, reaction of the body)
    d. Ceramics and glas (properties, reaction of the body)
    e. Plastics (properties of PMMA, HDPE, PET, reaction of the body)
    f. Natural replacement materials
    g. Fibrin glue

Performance Record:

Written or oral examination

Reading Resources:

- 🕮 Black, J.: Orthopedic Biomaterials in Research and Practice, Churchill Livingstone, 1988 (TUB 2711/60).
- 🕮 Recum, A. F.: Handbook of Biomaterials Evaluation, Macmillan Publishing, 1986 (TUB 2733/320).
- 🕮 Wintermantel, E. und Ha, S.-W.: Biokompatible Werkstoffe und Bauweisen. Berlin: Springer, 1996.

Module: Computational Fluid Dynamics and Multi Phase Flows

Course Units:

Title	*Type*	*Duration*
Computational Fluid Dynamics in Process Engineering	Lecture	2
Multi Phase Flows	Lecture	1
Problem based learning: Multi Phase Flows	PBL	1

Module Responsible:

Prof. Dr. Michael Schlüter

Prerequisites:

None

Recommended Previous Knowledge:

Basic knowledge and skills in Fluid Dynamics

Learning Outcomes:

After successful completion of the module the students are able to:

- deduce and interpret the fundamental equations in special cases from fluid dynamics and in some selected examples,
- understand methods of discretization as well as their characteristics,
- assess the reliability of numerical simulations and
- use data from experimental results to validate the numerical simulation.

They have thorough understanding of phenomena associated with the flow of gas/vapour-liquid mixtures

ECTS Credit Points:

4

Mode of Examination:

Integral Examination

Performance Record:

Oral or written examination

Workload:

Contact Time: 56, Self-study: 64

Course Unit: Multi Phase Flows

Lecturer:

Prof. Dr. Michael Schlüter

Language:

German

Period:

Winter Semester

Contents:

1. Classification of multiphase flows
2. Basic definitions and properties of two-phase gas/liquid flows
3. Approaches and models
4. Conservation equations of mass, momentum and energy
5. Constitutive relations resp. design parameters
    a. Pressure drop
    b. Gas/vapour content (void fraction)
    c. Slip
    d. Entrainment
    e. Critical mass flow rate

6. Heat transfer
    a. Binary mixtures
    b. Evaporation/condensation
    c. Subcooled boiling
    d. Burnout
    e. Flow instabilities
7. Mass transfer
8. Experimental techniques
9. Similarity analysis and scaling rules

Reading Resources:

- 🕮 Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971.
- 🕮 Clift, R.; Grace, J.R.; Weber, M.E.: Bubbles, Drops and Particles, Academic Press, New York, 1978.
- 🕮 Fan, L.-S.; Tsuchiya, K.: Bubble Wake Dynamics in Liquids and Liquid-Solid Suspensions, Butterworth-Heinemann Series in Chemical Engineering, Boston, USA, 1990.
- 🕮 Hewitt, G.F.; Delhaye, J.M.; Zuber, N. (Ed.): Multiphase Science and Technology. Hemisphere Publishing Corp, Vol. 1/1982 bis Vol. 6/1992.
- 🕮 Kolev, N.I.: Multiphase flow dynamics. Springer, Vol. 1 and 2, 2002.
- 🕮 Levy, S.: Two-Phase Flow in Complex Systems. Verlag John Wiley & Sons, Inc, 1999.
- 🕮 Crowe, C.T.: Multiphase Flows with Droplets and Particles. CRC Press, Boca Raton, Fla, 1998.

Course Unit: Computational Fluid Dynamics in Process Engineering

Lecturer:

Prof. Dr. Michael Schlüter

Language:

German

Period:

Winter Semester

Contents:

- Introduction to the Computational Fluid Dynamics (CFD) and their problems
- Fundamental equations (a selection of fundamental equations and turbulence modelling)
- Geometry and mesh generation (definition of geometry, mesh generation, local refined meshes (refinement strategy for local meshes), moving meshes)
- Discretization (in space and time, errors, convergence, consistence, stability and finite volume methods)
- Reynolds equation and Reynolds-stress
- Turbulent flows (transition, stability of laminar flows)
- Turbulence modelling (direct numerical simulation (DNS), large-eddy simulation (LES), statistical turbulence modelling (RANS), models consisting of one or more equations)
- CFD-programs (verification and validation, practical examples)
- Numerical methods for multiphase systems (Volume of Fluid (VOF), front tracking, Piecewise Linear Interface Calculation (PLIC))

Reading Resources:

- 🕮 Ferziger, J.H.: Computational methods for fluid dynamics. Springer-Verlag Berlin, 2002.
- 🕮 Fletcher, C. A. J.: Computational Techniques for Fluid Dynamics. I: Fundamental and General Techniques. Springer-Verlag, Berlin, 1991.
- 🕮 Laurien, E.: Numerische Strömungsmechanik, Vieweg+ Teubner / GWV Fachverlage GmbH, Wiesbaden, 2009.
- 🕮 Prosperetti, A.: Computational methods for multiphase flow. Cambridge, Cambridge Univ. Press, 2007.
- 🕮 Wilcox, D.C.: Turbulence modeling for CFD, DCW Industries, La Canada, California, 2004.

Module: Selected Applications of Solids Process Engineering

Course Units:

Title	*Type*	*Duration*
Fluidization Technology	Lecture	2
Product Design for Fine Chemical, Pharmaceutical and Food products	Lecture	2

Module Responsible:

Prof. Dr. Stefan Heinrich

Prerequisites:

None

Recommended Previous Knowledge:

Basic knowledge of particle technology

Learning Outcomes:

The students achieve deepened understanding of the gas/solids-fluidization technology, which allows them to choose proper fluidization methods and to design fluidized beds for given technical processes.

The students gain insight into the procedures for developing new processes in practice (particularly in comparison group companies / medium-sized companies) and can name and explain given examples.

ECTS Credit Points:

4

Mode of Examination:

Partial Performance Records

Performance Record:

See course unit descriptions for details

Workload:

Contact Time: 56, Self-study: 60

Course Unit: Fluidization Technology

Lecturer:

Prof. Dr. Stefan Heinrich

Language:

English

Period:

Winter Semester

Contents:

- Introduction: definition, fluidization regimes, comparison with other types of gas/solids reactors
- Typical fluidized bed applications
- Fluidmechanical principle
- Local fluid mechanics of gas/solid fluidization
- Fast fluidization (circulating fluidized bed)
- Entrainment
- Solids mixing in fluidized beds

Performance Record:

Written exam

Reading Resources:

📖 Kunii, D.; Levenspiel, O.: Fluidization Engineering. Butterworth Heinemann, Boston, 1991.

Course Unit: Product Design for Fine Chemical, Pharmaceutical and Food Products

Lecturer:

Prof. Dr. Stefan Palzer

Language:

English

Period:

Winter Semester

Contents:

This lecture focuses on the specific aspects to be considered in developing food products, functional food and neutraceuticals. During the lecture food products will also be compared with fine chemicals and pharmaceutical products and their similarities and differences will be elaborated.

In order to understand the specificity of food products, the consumer landscape and special requirements in food products will be explained. The main aim of the lecture is to explain how to apply the most important principles of process engineering to food matrices, pharmaceutical products and fine chemicals whilst leveraging existing lectures.

The relevance of these basic principles will be demonstrated using various concrete examples from the global food, pharma and chemical industries. In this sense this lecture is complementary to existing lectures and very practically oriented.

Specific solutions for selected consumer needs will be tackled. We will discuss functional food, encapsulation technologies as well as particular solutions for under- and over nutrition.

Last but not least a major objective of the lecture series is to create passion and excitement for food processing and the food industry.

Performance Record:

Written exam

Reading Resources:

- 🕮 Fayed, M.E. Handbook of Powder Science & Technology. 2nd Ed. New York: Chapman & Hall, 1997
- 🕮 Hounslow, M & Salman, A. Handbook on Granulation. Elsevier, 2006.
- 🕮 Onwulata, C. Encapsulated and Powdered Foods. CRC Press, 2005
- 🕮 Rhodes, M. Introduction to Particle Technology. 2nd Ed. Chichester:John Wiley & Sons, 2008
- 🕮 Salman, A.D., Hounslow, M.J. & Seville, J.P.K. Handbook of Powder Technology. Elsevier, 2007.
- 🕮 Seville, J.P., Tüzun, U. & Clift, R. Processing of Particulate Solids. Netherlands: Springer, 1997.
- 🕮 Ziegler, E. & Ziegler, H. Flavourings. 2nd Ed. Wiley-VCH, 2006.
- 🕮 Ullmann's Encyclopedia of Industrial Chemistry, VCH Verlagsgesellschaft

Module: Applied Statistics for Engineers

Course Units:

Title	*Type*	*Duration*
Applied Statistics for Engineers	Lecture	2
Exercise: Applied Statistics for Engineers	Exercise	1

Module Responsible:

Prof. Dr. Michael Morlock

Prerequisites:

None

Recommended Previous Knowledge:

Fundamentals in mathematics (stochastics)

Fundamentals in using PC's

Learning Outcomes:

The students are familiar with basic statistical methods and can apply them to simple problems using established software (SPSS).

ECTS Credit Points:

4

Mode of Examination:

Integral Examination

Performance Record:

written or oral examination

Workload:

Contact Time: 40, Self-study: 80

Course Unit: Applied Statistics for Engineers

Lecturer:

Prof. Dr. Michael Morlock

Language:

English

Period:

Winter Semester

Contents:

- Chi square test
- Simple regression and correlation
- Multiple regression and correlation
- One way analysis of Variance
- Two way analysis of variance
- Discriminant analysis
- Analysis of categorial data
- Choosing the appropriate statistical method
- Determining critical Sample sizes

Reading Resources:

📖 Applied Regression Analysis and Multivariable Methods, 3rd Edition, David G. Kleinbaum Emory University, Lawrence L. Kupper University of North Carolina at Chapel Hill, Keith E. Muller University of North Carolina at Chapel Hill, Azhar Nizam Emory University, Published by Duxbury Press, CB © 1998, ISBN/ISSN: 0-534-20910-6

Module: Interphases and Food Technology

Course Units:

Title	*Type*	*Duration*
Interphases in Process Technology	Lecture	2
Food Technology	Lecture	2
Experimental Course: Brewing Technology	Laboratory	2

Module Responsible:

Prof. Dr. Rudolf Eggers

Prerequisites:

None

Recommended Previous Knowledge:

Basics in Heat and Mass Transfer and Separation Processes

Learning Outcomes:

The students gain knowledge in

- Thermodynamics of Interfaces
- Experimental Methods
- engineering applications of physical chemistry of fluid interfaces
- material properties for foods
- Basics of production processes in food engineering
- detailed knowledge in selected processes

ECTS Credit Points:

6

Mode of Examination:

Partial Performance Records

Performance Record:

See course unit descriptions for details

Workload:

Contact Time: 60, Self-study: 60

Course Unit: Interphases in Process Technology

Lecturer:

Prof. Dr. Rudolf Eggers, Dr. Philip Jaeger

Language:

English/German (as required by students)

Period:

Winter Semester

Contents:

1. General phenomena, definitions
   1.1. Thermodynamics of interfaces (Gibbs adsorption)
   1.2. Interfacial tension (Principles, Methods, Examples)
   1.3. Wetting, adhesion
   1.4. Breakup and coalescence of droplets
2. Chemistry of surfaces
   2.1. Surfactants, sources, chemical structure, synthesis
   2.2. Principle mechanisms (Adsorption, diffusion)
   2.3. Effect on surface tension
   2.4. HLB, CMC

3. Transport Phenomena
    3.1. Mass transport across phase boundaries
    3.2. Heat transport across phase boundaries
    3.3. Interfacial convection – Marangoni flow
    3.4. Influence of surfactants on interfacial area and transport resistance (bubbles, droplets, falling films)
4. Applications
    4.1. Cleaning
    4.2. Emulsification (Food technology)
    4.3. Crude oil recovery (EOR)
    4.4. Coating
    4.5. Separation technology (Spray towers, packed columns)
    4.6. Nucleation (Polymer foams, evaporation)
    4.7. Recent developments (Surfactant aided extraction)

Performance Record:

Written examination

Reading Resources:

- A.I. Rusanov: Phasengleichgewichte und Grenzflächenerscheinungen, Akademie Verlag, Berlin 1978.
- P. Grassmann: Physikalische Grundlagen der Verfahrenstechnik, Verlag Salle und Sauerländer, 1983.
- M.J. Schwuger: Lehrbuch der Grenzflächenchemie, Thieme Verlag, 1996.
- C. Weser: Die Messung der Grenz- und Oberflächenspannung von Flüssigkeiten - eine Gesamtdarstellung für den Praktiker, GIT Fachzeitschrift f. d. Laboratorium, 24 (1980), 642 - 648 und 734.

Course Unit: Food Technology

Lecturer:

Prof. Dr.Rudolf Eggers

Language:

English/German (as required by students)

Period:

Winter Semester

Contents:

1. Material properties: Rheology, Transport coefficients, Measuring devices, Quality aspects
2. Processes at ambient condition, at elevated temperature and pressure
3. energy analysis
4. Selected processes: Seed oil production; Roasted Coffee

Performance Record:

Written examination

Reading Resources:

- M. Bockisch: Handbuch der Lebensmitteltechnologie , Stuttgart, 1993

Course Unit: Experimental Course: Brewing technology

Lecturer:

Prof. Dr.Rudolf Eggers

Language:

English/German (as required by students)

Period:

Winter Semester

Contents:

- Breeding of yeast from pure culture
- Breeding process of Gyle
- Set up of Gyle with yeast and monitoring of fermentation process

- Quality control and protocol of synthesis

Performance Record:

Written protocol

Reading Resources:

📖 R. Eggers: Script Brewing Technology

Module: Environmental Biotechnology

Course Units:

Title	*Type*	*Duration*
Environmental Microbiology	Lecture	2
Practical Course: Technical and Environmental Microbiology	Laboratory	3

Module Responsible:

Prof. Dr. Rudolf Müller

Prerequisites:

None

Recommended Previous Knowledge:

Fundamentals in microbiology and biochemistry

Learning Outcomes:

The students can explain the importance of microorganisms in the environment and can describe the potential of microorganisms for the degradation of pollutants. They can discuss the consequences for soil remediations, waste water treatment and for political decisions. The students have the ability to analyse and to evaluate environmental problems.

They can apply the theoretical knowledge from the lecture in biological lab work.

ECTS Credit Points:

5

Mode of Examination:

Partial Performance Records

Performance Record:

See course unit descriptions for details

Workload:

Contact Time: 56, Self-study: 82

Course Unit: Environmental Microbiology

Lecturer:

Prof. Dr. Rudolf Müller

Language:

English

Period:

Winter Semester

Contents:

1. Microbial Ecology
2. Detection of microorganisms
3. Disinfection and sterilisation
4. Sources for environmental pollutants
5. Biodegradability tests
6. Toxicity, use and degradation of pollutants:
    - Alkanes, alkenes, alkines
    - Benzene, toluene, xylenes, cresols
    - Polycyclic aromatic compounds
    - Chlorinated aliphatic and aromatic compounds
    - Sulfonated compounds
    - Nitrated compounds, amines, azo-dyes
    - Herbicides, Pharmaceuticals

7. Enzymes involved in the degradation of pollutants
8. Plasmids involved in the degradation of pollutants
9. Construction of novel strains for the degradation of pollutants

Performance Record:

Regular presence and a home work required. Written exam.

Reading Resources:

- 🕮 Allgemeine Mikrobiologie, H.-G. Schlegel, Thieme Verlag Stuttgart ISBN 3-13-444603-0
- 🕮 Praxis der Sterilisation, Desinfektion-Konservierung, K.-H. Wallhäußer (1984), Thieme Verlag ISBN 3-13-416303-9
- 🕮 Umweltchemikalien, R. Koch (1989), VCH-Verlag ISBN 3-527-26902-9

Course Unit: Practical Course: Technical and Environmental Microbiology

Lecturer:

Prof. Dr. Garabed Antranikian, Prof. Dr. Rudolf Müller

Language:

English/German (as required by students)

Period:

Winter Semester

Contents:

- Working with Microorganisms under aerob and anaerob conditions,
- Detection of microorganisms in the ground, water and air
- Cultivation of monocultures
- Growth curves
- Production and detection of enzymes

Performance Record:

Written report

Reading Resources:

- 🕮 Süßmuth, R.; Eberspächer, J.; Haag, R.; Springer, W.: Biochemisch- mikrobiologisches Praktikum. Thieme Verlag, Stuttgart.
- 🕮 Schlegel, H. G.: Allgemeine Mikrobiologie. Georg Thieme Verlag, Stuttgart, New York, 5. Auflage, 1981.
- 🕮 Drews, D.: Mikrobiologisches Praktikum. Springer Verlag, Berlin, Heidelberg, New York, 3. Auflage, 1976.
- 🕮 Gottschalk, G.: Bacterial Metabolism. Springer Verlag, New York, Berlin, Heidelberg, Tokyo, 2nd Edition, 1988.

Module: Cleaning-In-Place-(CIP)

Course Units:

Title	*Type*	*Duration*
Cleaning-In-Place-(CIP)	Lecture	2

Module Responsible:

Prof. Wolfgang Stein

Prerequisites:

None

Recommended Previous Knowledge:

Unit operations, basics in plant engineering

Learning Outcomes:

The students are familiar with the essentials for the design and operation of hygienic plants and can explain the technical requirements.

ECTS Credit Points:

2

Mode of Examination:

Proficiency Examination

Performance Record:

Oral or written examination (subject to number of participants)

Workload:

Contact Time: 28, Self-study: 28

Course Unit: Cleaning-In-Place (CIP)

Lecturer:

Prof. Wolfgang Stein

Language:

English

Period:

Winter Semester

Contents:

Deposits on walls and microbiological growth take place in any pharmaceutical and food plant. For reasons of quality and shelflife such deposits and microorganisms must be regularly removed. In modern plants this has to be done automatically by means of CIP technology. Deposits and microbiological growth can be physically explained. There is, however, also a strong impact of plant design and operation on deposits and growth rates. Consequently, plants must be optimised under cleaning aspects. Also, individual components like vessels, piping, apparatuses and armatures must be cleanable. This requires special design of such components. The wide range of different products requires a wide range of adequate cleaning media, which must be supplied to the production plant from special cleaning plants via cleaning components. Frequency and duration of cleaning cycles can make up for a big share of plant capacity. Consequently, cleanability and cleaning form a major aspect for plant layout, design and operation.

- Fouling in hygienic plants
- Removal of deposits (cleaning-in-place)
- Requirements for the design of cleanable plants and components
- Cleaning plants
- Legal rules

Reading Resources:

🕮 Adnan, T. (Ed.): Cleaning-In-Place: Dairy, Food and Beverage Operations. 3rd ed., Blackwell, 2008

Summer + Winter Semester

Module: Renewables

Course Units:

Title	*Type*	*Duration*
Renewable Energy	Lecture	2
Energy from Biomass	Lecture	2

Module Responsible:

Prof. Dr. Martin Kaltschmitt

Prerequisites:

None

Recommended Previous Knowledge:

None

Learning Outcomes:

In-depth knowledge of the interdisciplinary interrelations and the classification of the topic of the lessons within the scientific and social environment

Theory-based use of very demanding methods and processes within the topics of the lessons

Assessment of different approaches for solutions within a multidimensional decision process

ECTS Credit Points:

6

Mode of Examination:

Partial Performance Records

Performance Record:

See course unit descriptions for details

Workload:

Contact Time: 58, Self-study: 122

Course Unit: Renewable Energy

Lecturer:

Prof. Dr.Martin Kaltschmitt

Language:

English

Period:

Summer Semester

Contents:

- Introduction
- Solar energy for heat and electricity production
- Wind energy for electricity production
- Hydropower for electricity production
- Ocean energy for electricity production
- Geothermal energy for heat and electricity production

Performance Record:

Written examination

Reading Resources:

- 🕮 Kaltschmitt, M.; Streicher, W.; Wiese, A. (Hrsg.): Erneuerbare Energien – Systemtechnik, Wirtschaftlichkeit, Umweltaspekte; Springer, Berlin, Heidelberg, 2006, 4. Auflage
- 🕮 Kaltschmitt, M.; Streicher, W.; Wiese, A. (Hrsg.): Renewable Energy – Technology, Economics and Environment; Springer, Berlin, Heidelberg,2007

Course Unit: Energy from Biomass

Lecturer:

Prof.Dr. Martin Kaltschmitt

Language:

English

Period:

Winter Semester

Contents:

- Biomass within the energy system
- Biomass as a source of energy
- Thermo-chemical conversion
- Combustion
- Gasification
- Char coal production
- Physical-chemical conversion
- Bio-chemical conversion
- Biogas
- Bioethanol

Performance Record:

Written examination

Reading Resources:

- 🕮 Kaltschmitt, M.; Hartmann, H. (Hrsg.): Energie aus Biomasse; Springer, Berlin, Heidelberg, 2009, 2. Auflage

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Module: Molecular Modelling and Heterogeneous Equilibria

Course Units:

Title	*Type*	*Duration*
Statistical Thermodynamics and Molecular Modelling	Lecture	2
Heterogeneous Equilibria	Lecture	2

Module Responsible:

Prof. Dr. Frerich Keil

Prerequisites:

None

Recommended Previous Knowledge:

Basic knowledge of chemical thermodynamics Basic theory of thermodynamics

Learning Outcomes:

After successful completion of the module the students have achieved the following qualifications:

Knowledge:

- The basic principles of statistical thermodynamics (ensembles, simple systems)
- The main approaches in classical Molecular Modelling (Monte Carlo, Molecular Dynamics) in various ensembles. Many examples of computer programs will be discussed in detail.

Skills:

- The students are able to set up computer programs for solving simple problems by Monte Carlo or molecular dynamics

Expertise:

- Application of the fundamentals of statistical thermodynamics
- Selection of the proper molecular simulation methods
- System expertise: solving problems by molecular modelling

ECTS Credit Points:

4

Mode of Examination:

Partial Performance Records

Performance Record:

See course unit descriptions for details

Workload:

Contact Time: 56, Self-study: 116

Course Unit: Statistical Thermodynamics and Molecular Modelling

Lecturer:

Prof. Dr. Frerich Keil

Language:

English

Period:

Summer Semester

Contents:

- Introduction to Statistical Mechanics
- Ensembles (canonical, micro canonical, grand canonical)
- The classical limit
- Intermolecular potentials, force fields
- Monte Carlo method, example: Equation of State of the Lennard-Jones fluid
- Molecular Dynamics for atoms, integration of equations of motion, calculating transport properties , example
- Molecular Dynamics for molecules (Shake, Rattle, multiple time steps), example : diffusion coefficients
- Nose-Hoover and Andersen thermostat
- Phase Equilibria
- Gibbs Ensemble, example: Phase equilibrium
- Ising Model

Performance Record:

Written exam

Reading Resources:

- Daan Frenkel, Berend Smit: Understanding Molecular Simulation, Academic Press
- M. P. Allen, D. J. Tildesley: Computer Simulations of Liquids, Oxford Univ. Press
- D. A. McQuarrie: Statistical Mechanics, University Science Books
- T. L. Hill: Statistical Mechanics , Dover Publications

Course Unit: Heterogeneous Equilibria

Lecturer:

Privatdoz. Dr. Ralf Dohrn

Language:

English

Period:

Winter Semester

Contents:

- Importance of fluid properties and phase equilibria in industrial practice,
- Thermodynamic fundamentals
- Equations of state
- Thermodynamic Properties of pure fluids
- Thermodynamic properties of mixtures
- Phase equilibria of mixtures, including examples from industry
- Experimental methods for the measurement of phase Equilibria
- Phase equilibria of polymer systems, industrial examples

Performance Record:

Presentation with group discussion

Reading Resources:

- R. Dohrn, Berechnung von Phasengleichgewichten, Vieweg-Verlag, Wiesbaden, 1994.
- Prausnitz, J.M.; Azevedo, E.G. de; Lichtenthaler, R.: Molecular Thermodynamics of Fluid-Phase Equilibria, Prentice Hall, 2001
- S. I. Sandler, Chemical and Engineering Thermodynamics, 3rd Ed., New York, 1999.

More recent articles are available on the intranet.

Module: Aquatic Chemistry and Environmental Analysis

Course Units:

Title	*Type*	*Duration*
Environmental Aquatic Chemistry and Toxicology	Lecture	2
Environmental Analysis	Lecture	2

Module Responsible:

Prof. Dr. Wolfgang Calmano

Prerequisites:

None

Recommended Previous Knowledge:

Basics in chemistry and physics

Learning Outcomes:

After successful completion of this course, students are able to:

- describe and explain the most important physical-chemical processes which determine the chemical composition of natural aquatic systems
- calculate quantitatively the chemical composition of simple aquatic systems, also for neighbouring disciplines (soil chemistry, water technology, environmental technology)
- select and apply suitable methods to solve water-chemical problems
- name the most relevant analytical methods
- describe and explain fundamental analytical connections
- determine inorganic and organic routine parameters
- explain spectroscopic and chromatographic methods and to assess their applicability for solving analytical problems
- select suitable methods for assessment of environmental pollution and abandoned waste sites
- learn independently and efficiently

ECTS Credit Points:

4

Mode of Examination:

Partial Performance Records

Performance Record:

See course unit descriptions for details

Workload:

Contact Time: 56, Self-study: 64

Course Unit: Environmental Analysis

Lecturer:

Prof. Dr. Wolfgang Calmano, Holger Gulyas, Kim Kleeberg

Language:

English

Period:

Winter Semester

Contents:

- Mathematical and statistical evaluation of analytical methods
- Sampling, sample preparation, error evaluation
- Waste water analysis (inorganic and organic routine parameters)
- Analytical spectroscopy (basics)
- Atomic absorption spectroscopy
- Analytical chromatography (basics)
- Gas chromatography, ion exchange chromatography
- Infrared spectroscopy

Performance Record:

Oral examination

Reading Resources:

- 🕮 Analysis of environmental pollutants : principles and quantitative methods, Poojappan Narayanan. - London : Taylor & Francis, 2003
- 🕮 Introduction to environmental analysis, Roger N. Reeve. - Chichester [u.a.] : Wiley, 2002
- 🕮 Standard Methods for the Examination of Water and Wastewater, 20th Edition, L.S. Clesceri, A.E. Greenberg, A.D. Eaton, eds., published by American Public Health Association, American Water Works Association and Water Environment Federation, 1998

Course Unit: Environmental Aquatic Chemistry and Toxicology

Lecturer:

Prof. Dr. Wolfgang Calmano

Language:

English

Period:

Summer Semester

Contents:

- Chemistry of water treatment
- Solubility of gases in water
- Equilibrium with solid carbonates
- Precipitation and dissolution
- Oxidation and reduction
- Environmental chemistry of water
- Acids and bases
- Sorption and soil chemistry
- Inorganic and organic pollutants
- Basics of biochemistry

- Bioavailability of chemicals
- Effects of pollutants
- Basics of toxicology
- Risk assessment

Performance Record:

Written examination

Reading Resources:

📖 Sigg & Stumm: Aquatische Chemie, vdf, 1989
📖 Stumm & Morgan, Aquatic Chemistry, John Wiley & Sons, 1981