TUHH Hamburg University of Technology

Module Manual

Master of Science (M.Sc.)

International Management and Engineering
Dual study program

Cohort: Winter Term 2023

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Program description

Content

It is the major objective of the Masters degree programme „International Management and Engineering“ to offer students the opportunity to acquire the competencies which they will need for their future career, e.g. in a technical or management department of companies in different branches of industry, or for a future career in research (i.e. a PhD) in the area of Management and Engineering. The students’ future sphere of activities hence may include research and development, leadership and management of international projects or tasks in operational or strategic management.

In particular, after having finished their studies, students are supposed to be able to carry out managerial functions in international companies and to act successfully at the interface of management and technology. They can successfully apply methods for solving managerial as well as technical problems, and they are also able to solve new problems in changing and volatile situations. Moreover, they will develop a critical attitude towards these methods and are also able to advance the methods, whenever necessary. Hence, they have a sound foundation for acting responsibly in their jobs and for taking ethical aspects and consequences of their decisions in account.

In addition to the foundational curriculum taught at TUHH, seminars on developing personal skills are integrated into the dual study programme, in the context of transfer between theory and practice. These seminars correspond to the modern professional requirements expected of an engineer, as well as promoting the link between the two places of learning.

The intensive dual courses at TUHH integrating practical experience consist of an academic-oriented and a practice-oriented element, which are completed at two places of learning. The academic-oriented element comprises study at TUHH. The practice-oriented element is coordinated with the study programme in terms of content and time, and consists of practical modules and phases spent in an affiliate company during periods when there are no lectures.

Career prospects

Graduates of the„International Management and Engineering“ programme find many job opportunities in industry, in particular in international companies, in service companies, in particular in consulting, and in research and development. They are particularly qualified for responsible and leading positions at the interface of management and technology.

In addition, students acquire basic professional and personal skills as part of the dual study programme that enable them to enter professional practice at an early stage and to go on to further study. Students also gain practical work experience through the integrated practical modules. Graduates of the dual course have broad foundational knowledge, fundamental skills for academic work and relevant personal competences.

Learning target

The graduates have acquired the basic skills, specialized knowledge and additional competences required for a national and/or international career in the interdisciplinary field of industrial engineering. They have gained scientifically based specialized knowledge of business sciences, as well as an in-depth knowledge of engineering disciplines. Hence, they are qualified for performing interdisciplinary tasks, and they are able to pursue stand-alone tasks at the interface of business management and technology. Moreover, the graduates have the capability to work in strategic and operational management functions in different types of enterprises, including multinationals, or to pursue an academic career, i.e. a PhD.

In particular, the graduates are able to apply the methods and techniques required to solve both business-related and technological tasks, to critically analyze these methods, and to improve their development by applying new insights.

Furthermore, the graduates have acquired competences that enable them:

- To transfer their theoretical knowledge into practice

- To take on complex planning tasks in global value-added networks and successfully apply their theoretical knowledge of the management and engineering sciences in practice.

- To participate, in a leading function, in international technology and management-oriented projects.

- To analyze and critically assess processes, systems, and innovative technologies in different business-related areas.

- To also systematically consider the non-technical consequences of engineering activities and incorporate these responsibly and ethically in a socio-economic context.

- To independently acquire relevant knowledge from the scientific literature, to judge relevant publications critically and to write scientific reports.

- To carry out their own research projects

- To successfully communicate with experts from their field and from other fields in German and English

Moreover, the key qualifications acquired in the Bachelor’s program were extended and enhanced by means of suitable teaching methods within the Master’s degree course. In addition, the students’ intercultural competence was developed and their ability to work in a team was improved.

By continually switching places of learnings throughout the dual study programme, it is possible for theory and practice to be interlinked. Students reflect theoretically on their individual professional practical experience, and apply the results of their reflection to new forms of practice. They also test theoretical elements of the course in a practical setting, and use their findings as a stimulus for theoretical debate.

Program structure

In this degree programme, students gain broad management competencies, especially for the application in an industrial and international operational area. Students can enhance their knowledge in special fields as, e.g. Supply Chain Management, Technology Management, Human Resource Management, Strategic Management or Marketing, Controlling or Operations Research. They can concentrate on different core areas, namely on

- Marketing and Technology

- Supply Chain Management and Logistics

- Corporate Management

- Entrepreneurship

In addition, students can select an engineering specialization. There are different areas of engineering on offer:

- Civil Engineering

- Electrical Engineering

- Power and Environmental Engineering

- Information Technology

- Logistics

- Aviation Systems

- Mechatronics

- Product Development and Production

- Renewable Energy

- Process Engineering and Biotechnology

As the third semester does not contain any comp1ulsory courses, it is particularly well suited for a stay abroad at one of the many partner universities of TUHH. The TUHH strongly supports students when they are planning such a stay abroad.

The structural model of the dual study programme follows a module-differentiating approach. Given the practice-oriented element, the curriculum of the dual study programme is different compared to a standard Bachelor’s course. Five practical modules are completed at the dual students’ partner company as part of corresponding practical terms during lecture-free periods.

Core Qualification

Module M0560: Institutional Environment of International Management

Courses

Title	Typ	Hrs/wk	CP
Research Methods in International Management (L1911)	Lecture	2	2
Business Environment of Selected Countries (L0159)	Project-/problem-based Learning	4	4

Module Responsible	Prof. Thomas Wrona
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in international and intercultural management, familiarity with the content of the International Management lecture
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Knowledge: Students will be able to • evaluate the importance of the institutional framework for doing business in different countries • outline and critically reflect the economic and legal framework in selected countries • understand historic, demographic and economic indicators in specific economic areas within an international context • understand and apply methods of analysis of the external environment (competitive analysis , industry structure analysis by Porter, PESTEL analysis, Porter's Diamond and Cluster analysis) • explain different objectives of empirical research in general and in international management research in particular • explain and critically reflect on different ways of organizing empirical research • describe and distinguish ideal-typical research designs
Skills	Skills: based on the acquired knowledge, Students will be able to • • recognize and subsequently assess different risks and other influencing factors while conducting an environmental analysis in an international context • identify typical problems within international management to develop solution proposals • analyze, interpret and present external and internal information in different, international economic contexts • to set up a suitable research design based on specific problems within international management • to assess the influence of different research goals on the selected research design • to conceptualize an ideal research process for a simple research problem • to adequately integrate theoretical knowledge in international management into a research design (qual./quan.) • to critically evaluate the quality and meaningfulness (rigor / relevance) of exemplary empirical studies
Personal Competence	
Social Competence	Social competence: After completion of the module Students will be able to • conduct subject-specific and interdisciplinary discussions • present results of their work • respectful work in a team
Autonomy	Self-employment: After completion of the module Students will bee able to • work independently and to transfer the acquired knowledge to new problem areas
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 33 % / Midterm
Examination	Subject theoretical and practical work
Examination duration and scale	approx. 30 pages and presentation
Assignment for the Following Curricula	International Management and Engineering: Core Qualification: Compulsory

Course L1911: Research Methods in International Management	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Thomas Wrona
Language	DE
Cycle	WiSe
Content	• Foundation of empirical research • Types of scientific statements • Objectives of empirical research (designs) • Special research questions of international management research • Content and process of quantitative international management research • Content and process of qualitative international management research • General issues of empirical research (indication of research designs, quality criteria) • Literature reviews as examples of non-empirical research
Literature	• Bortz, J./Döring, N. (2006): Forschungsmethoden und Evaluation für Human- und Sozialwissenschaftler, 4. überarb. Aufl., Nachdruck, Heidelberg 2009. • Brühl, R. (2014): Wie Wissenschaft Wissen schafft - Wissenschaftstheorie für Sozial- und Wirtschaftswissenschaften, Stuttgart 2014 (UTB Taschenbuch) • Bryman, A./Bell, E. (2015). Business research methods. Oxford University Press, USA. • Eisenhardt, K. M./Graebner, M. E. (2007): Theory building from cases: Opportunities and challenges, in: Academy of Management Journal, 50. Jg. 2007, Heft 1, S. 25-32. • Flick, U. (2009). An Introduction to Qualitative Research (4th ed.). Thousand Oaks, CA: Sage Publications. • Kirsch, W./Seidl, D./van Aaken, D. (2007): Betriebswirtschaftliche Forschung. Wissenschaftstheoretische Grundlagen und Anwendungsorientierung, Stuttgart 2007. • Oesterle, Michael-Jörg, and Stefan Schmid. "Internationales Management." Forschung, Lehre, Praxis. Schäffer-Poeschel, Stuttgart (2009). • Töpfer, A. (2009): Erfolgreich forschen, Berlin/Heidelberg 2009. • Wrona, T. (2005): Die Fallstudienanalyse als wissenschaftliche Forschungsmethode, ESCP-EAP Working Paper Nr. 10, Berlin 2005 (wird zum Download zur Verfügung gestellt). • Wrona, T./Bauer, A. (i.V.): Theory-based Qualitative Case Study Research (Lehrbuch in Vorbereitung) Übungstexte, die während der Vorlesung herausgegeben werden.

Course L0159: Business Environment of Selected Countries	
Typ	Project-/problem-based Learning
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Prof. Thomas Wrona, Dr. Lydia Schuster
Language	DE
Cycle	WiSe
Content	• Competitiveness of firms/industries/nations/regions • Competition Across Locations & Global Strategy for MNCs • Industry Competition, Strategy and Location • The Diamond Model: developing/developed Economies • Clusters and Cluster Development • Harvard case studies of selected firms/industries/nations/regions • Development and presentation of case studies in groups • Participant-centered learning • Composition of a cluster- and country-related seminar thesis
Literature	• Audretsch, D. and Feldman, M. (1996), “Knowledge spillovers and the geography of innovation and production”, American Economic Review, Vol. 86 No. 3, pp. 630-640. • Bamberger, I. and Wrona, T. (2012), Strategische Unternehmensführung, 2., erweiterte Auflage, München 2012. • Bamberger, I./Wrona, T. (2012): Strategische Unternehmensführung, 2., erweiterte Auflage, München 2012. • Bell, G.G. (2005), “Clusters, networks, and firm innovativeness”, Strategic Management Journal, Vol. 26 No. 3, pp. 287-295. • Krugman, P. (1991), Geography and Trade, MIT Press, Cambridge, MA. • Porter, M.E. (1990), The Competitive Advantage of Nations, Free Press, New York, NY. • Porter, M.E. (1991): Nationale Wettbewerbsvorteile, München 1991 • Porter, M.E. (2008): On Competition, Boston MA 2008 • Tallman, S., Jenkins, M., Henry, N. and Pinch, S. (2004), “Knowledge, clusters and competitive advantage”, Academy of Management Review, Vol. 29 No. 2, pp. 258-271.

Module M0698: Accounting

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Financial Accounting and Finance (L3053)	Lecture	2	3
Management Accounting and Capital Budgeting (L3054)	Lecture	2	3

Module Responsible	Prof. Matthias Meyer
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of accounting and general business administration. The previous knowledge required for successful completion of this module, in particular of bookkeeping, is imparted within the framework of an e-learning programme. Through an online test, the student can earn points which are added to the final examination result of the module. Students receive access and further information to the corresponding online learning module upon enrolment.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know ... • the basic structure of the current cost recording and allocation and can be used in • Different cost classifications (variable/fixed, individual/joint) and can classify them theoretically; • Subdivide into cost element, cost center and cost object accounting • the concept and necessity of cost centers; • Different costing procedures • simulation-based methods for the design of cost accounting systems • Instruments for cost planning and control; • various partial cost accounting systems as an alternative to full cost accounting and can characterize these comprehensively; • modern developments in cost management; • the Accuracy Effort Tradeoff and variance-based criticisms of Activity-Based Costing • the structure of the balance sheet, and they can explain individual balance sheet items with regard to their approach and valuation • the components of the financial statements according to HGB and IFRS and can explain them; • the difference between the total cost method and the cost of sales method; • Function and methodology of the audit; • the procedure of balance sheet analysis and can explain the steps of method selection, data preparation and data evaluation • the most important financial and performance indicators and can derive them • The role of the finance function in internationally operating companies and the interdependencies between investment and financing • the main theories and models in the field of investment and financing; • Methods for evaluating companies and investment decisions; • Approaches to risk assessment in the field of investment and financing and portfolio theory; • alternative financing options and their specific design and valuation; • the contents and methods of short- and long-term financial planning;
Skills	The students are able... • to explain characteristics of the cost and activity accounting and to apply methods from this range to economical problem definitions • to describe the tasks of cost type, cost centre and cost unit accounting as well as to discuss the classification into the basic schema of cost recording and allocation; to differentiate between different possibilities of the case-by-case special allocation of cost center services and to implement them purposefully; to characterize and apply different calculation methods depending on the homogeneity or heterogeneity of the created activity units; to classify and apply marginal cost accounting as well as contribution margins related to bottlenecks as decision-oriented cost accounting systems and to interpret the results of their analyses; to distinguish cost planning from cost management; To apply process cost accounting and target costing and to interpret the results of their analyses; interpret current research results on the design of cost accounting systems to explain the connections between the different parts of the operational accountancy and to differentiate their addressees and arithmetic variables; to explain and interpret the legal provisions of the German Commercial Code on accounting and bookkeeping and to apply them to common facts of business operations; to identify and critically evaluate differences between HGB and IFRS with respect to material balance sheet items; to explain the technique of balance sheet analysis, to apply it to the annual financial statements of various international companies (including IFRS) and to draw conclusions about the prevailing economic conditions there; to explain theories and models for the investment management of international enterprises, to evaluate their application possibilities and to reflect critically on the results; to apply methods of financial mathematics to investment and financing problems and to use suitable software tools for the calculations; to adequately evaluate investment projects of internationally operating companies using suitable business management methods and indicators, to determine the optimal investment portfolio and to decide on it;

	to determine the capital requirements and capital costs of globally operating companies; to evaluate financing alternatives and select them based on the results; to determine, in the context of globalized financial markets, an appropriate level of dividends and the dividend policy of companies, as well as the type, volume, maturity and yield of corporate bonds; to financially assess the attractiveness of acquisitions by international competitors.
Personal Competence	
Social Competence	The students can... • analyse business problems in a team and develop solutions together; present the results of their analyses in an understandable way, also in English; explain the implications of current research results to others and to reflect critically on them togethe • act as a competent contact within the framework of an audit; • determine the ethical dilemmas of investment and financing decisions and to take them into account within the framework of decision analyses; • assume leadership responsibility in questions of investment and financing in the company, but also in teamwork, and to present technically sound proposals for solutions.
Autonomy	The students are able... • to apply the presented methods of cost accounting in order to analyze business problems and to interpret and critically evaluate the results; to critically analyze the capital structure of globally operating companies to transfer the theoretical knowledge about accounting into operational practice; to decide independently which accounting methods can be used for which problems; to acquire knowledge about the subject area independently and to transfer the acquired knowledge to new questions; to use cost accounting systems independently and to design them purposefully; to carry out operational accounting tasks independently, also in internationally active companies; to use methods of the illustration and analysis of the seized business transactions, in order to analyze economical problem definitions and to evaluate the results critically; to interpret and critically evaluate the key figures determined within the framework of a balance sheet analysis; to strategically optimize the capital structure of a company and to use the different forms of corporate financing on the global financial markets in an appropriate manner; to carry out short-term and long-term financial planning; to analyse and optimise the profit and risk position of an internationally operating company; to evaluate companies and make international acquisition decisions.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 33 % / Midterm / Yes / 5 % / Excercises /
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	International Management and Engineering: Core Qualification: Compulsory

Course L3053: Financial Accounting and Finance	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Matthias Meyer
Language	DE
Cycle	WiSe
Content	• Importance of financial accounting and initial overview • Balance sheet and income statement • Total and sales cost format, annex • Accounting principles and regulations: General approach, valuation and disclosure regulations (HGB) • International financial reporting (IFRS, US-GAAP) • Accounting policy • Auditing • Balance sheet analysis: Choice of method(s), data processing, data evaluation • Annual report analysis (financial: investment analysis, financing analysis, liquidity analysis; performance: cost analysis, earnings analysis, profitability analysis) • Risk and return (e.g., measuring risk, risk and diversification, the cost of capital, dividend decisions, valuation principles such as WACC, APV, multiples and real options) • Capital structure (e.g., equity financing and stocks, debt financing and corporate bonds, leasing and off-balance-sheet financing)
Literature	1. Skript und Unterlagen, die zur Vorlesung und Übung herausgegeben werden. 2. Ausgewählte Bücher: • Coenenberg, A./Haller, A./Mattner, G./Schultze, W. (2009): Einführung in das Rechnungswesen, 3. Aufl., Stuttgart. • Döring,U./Buchholz, R. (2009): Buchhaltung und Jahresabschluss, 11. Aufl., Berlin. • Heinhold, M. (2010): Buchführung in Fallbeispielen, 11. Aufl., Stuttgart. • Pellens, B./Fülbier, R. U./Gassen, J./Sellhorn, T. (2011): Internationale Rechnungslegung: IFRS 1 bis 9, IAS 1 bis 41, IFRIC-Interpretationen, Standardentwürfe Mit Beispielen, Aufgaben und Fallstudie 8. Aufl., Stuttgart. • Brealey, R.A./Myers, S.C./Allen, F. (2020): Principles of Corporate Finance, 13e, New York: McGraw-Hill. • Wöhe, G./Döring, U. (2010): Einführung in die allgemeine Betriebswirtschaftslehre, 24. Aufl., München. • Berk, J./DeMarzo, P. (2017): Corporate Finance, 5e, Boston: Pearson. 3. Gesetzestexte/Standards: • Handelsgesetzbuch (HGB) (Achtung: BilMoG!), teilw. Aktiengesetz (AktG) http://www.gesetze-im-internet.de/hgb/index.html

Course L3054: Management Accounting and Capital Budgeting	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Matthias Meyer
Language	DE
Cycle	WiSe
Content	• Cost type accounting: Cost concepts, recognition and evaluation of resources • Cost center accounting: Expense distribution, stepladder method, equation method, indirect cost apportionment • Costing: Causer-pays and marginal principle, output costing, equivalence number costing, overhead calculation, charge rate calculation • Cost unit accounting: unit-of-output costing, cost unit period costing, total cost accounting, cost of sales accounting • Standard cost accounting: Cost resolution, fixed and flexible planned cost calculation, marginal costing • Breakeven analysis: Direct costing, multi-level fixed cost absorption, bottleneck-related contribution margin in operational production program planning • Modern cost management: Relevance Lost, activity-based costing, target costing • Valuation and capital budgeting (e.g., time value of money, valuing stocks and corporate bonds, discounted cash flow, net present value and other criteria, making capital investment decisions) **Exercise:** Both parts of the lecture include an exercise. For the Management Accounting part there are also Web-based exercises for self-testing.
Literature	**Mandatory literature:** Brealey, R.A./Myers, S.C./Marcus, A.J (2020): Fundamentals of Corporate Finance, 10e, New York: McGraw-Hill. **Additional literature:** Brealey, R.A./Myers, S.C./Allen, F. (2020): Principles of Corporate Finance, 13e, New York: McGraw-Hill. Berk, J./DeMarzo, P. (2017): Corporate Finance, 5e, Boston: Pearson. Eun, C.S./Resnick, B.G. (2018): International Financial Management, 8e, New York: McGraw-Hill. Ross, S./Westerfield, R./Jaffe, J./Jordan, B. (2016): Corporate Finance, 11e, New York: McGraw-Hill. Ross, S.A./Westerfield, R.W./Jaffe, J./Jordan, B. (2018): Corporate Finance: Core Principles and Applications, 5e, New York: McGraw-Hill.

Module M0554: Quantitative Methods - Statistics and Operations Research

Courses

Title	Typ	Hrs/wk	CP
Quantitative Methods - Statistics and Operations Research (L0127)	Lecture	3	4
Quantitative Methods - Statistics and Operations Research (L0250)	Recitation Section (small)	2	2

Module Responsible	Prof. Kathrin Fischer
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of Mathematics on the Bachelor Level. Relevant previous knowledge is taught and tested by an online module.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know • different methods from the field of descriptive statistics and can explain them and their importance for Business Analytics; • different forecasting methods as, e.g., moving averages or linear regression; • different discrete and continuous distribution functions and can explain their meaning and their areas of application; • the laws of probability theory as, e.g. the Bayes rule, and can explain them; • different methods of inferential statistics - e.g. confidence intervals, hypothesis testing and regression analysis - and can explain their theoretical background; • fields of research in which statistical methods are applied; • the history and relevance of Operations Research; • linear programming methods for solving planning problems, and can explain them; • selected methods of transportation and network optimization, and can explain them; • integer programming models and methods, e.g. for location planning; • appropriate software for solving these problems; • relevant areas of OR research.
Skills	Students are able to • collect empirical data by appropriate methods, to aggregate, classify and analyze the data and to draw conclusions from them also in complex and realistic situations, e.g. for time series; • recognize different distribution functions and to apply them in the solution of Business problems; • apply laws of probability, as e.g. the Bayes rule, to construct solutions for Business and Engineering problems; • select appropriate methods of inferential statistics, apply them to Business problems and evaluate the results of their analysis; • construct appropriate quantitative - linear or integer - models for Business and Engineerig planning situations; • apply methods from linear and integer programming and interpret and evaluate the results; • apply methods from transport and network planning and interpret and evaluate the results; • solve the problems with appropriate software, carry out sensitivity analyses and evaluate the results; • develop a critical judgement of the different methods and their applicability; • use models and methods from Statistics and OR to analyse problems from the areas of business and engineering and to evaluate the results; • apply their theoretical knowledge of the different methods to practical problems, in particular in international value chains and also to apply their knowledge to specific research problems.
Personal Competence	
Social Competence	Students are able to • engage in scientific discussions on topics from the fields of Statistics and OR; • present the results of their work to specialists; • work successfully and respectfully in a team.
Autonomy	Students are able to • carry out complex data analyses independently, individually or in a team; • solve complex Business planning problems independently or in a team, selecting and using appropriate software; • gather knowledge in the area independently and research-based, and to apply their knowledge also in new and unknown situations; • critically evaluate the results of their work and the consequences.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 2.5 % / Excercises Yes / 47.5 % / Midterm
Examination	Written exam
Examination duration and scale	3 hours
Assignment for the Following Curricula	International Management and Engineering: Core Qualification: Compulsory

Course L0127: Quantitative Methods - Statistics and Operations Research	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Kathrin Fischer
Language	EN
Cycle	WiSe
Content	**Statistics** • Descriptive Statistics: Graphical representations, calculation of relevant measures of central tendency etc., also by using a computer; application of methods for large data sets, analysis and comparison of results, critical discussion and evaluation of methods and their use in scientific projects and business practice • Probability theory: important laws, dependent probabilities, Bayes Rule; application to practical problems • Use and application of probability distributions , as e.g. Binomial and Normal distribution to Management and Engineering problems • Methods of inferential statistics: confidence intervals: theoretical background and applications; hypothesis testing: theoretical background and application to business problems; regression analysis: theoretical background and application in research practice. **Operations Research** • Linear Programming: Modelling business decision situations, solving problems by Simplex method and by using software, theoretical background of Simplex procedure, Dual Simplex procedure and blocked variables, special cases (degeneracy etc.); sensitivity analysis and interpretation • Transportation planning: Modellung transportation and transshipment problems in global networks; Solving transportation problems using software • Network Optimization problems: modelling production and transportation networks, solving planning problems in networks, Network Planning as a research topic • Integer Programming: Models using integer variables, e.g. in location decisions, branch and bound procedure
Literature	Ausgewählte Bücher: D.R. Anderson / D.J. Sweeney / T.A. Williams / Martin: Quantitative Methods for Business. 11th Edition, Thomson, South Western 2008. Bluman, Alan G.: Elementary Statistics - A brief version. Third Edition, McGrawHill 2006. Bowerman, Bruce L. and O'Connell, Richard T.: Business Statistics in Practice, 8th edition, McGraw-Hill 2016. Domschke, W., Drexl, A.: Einführung in Operations Research, 9. Auflage, Springer, Berlin et al. 2015. Domschke, W. / A. Drexl / R. Klein / A. Scholl / S. Voß: Übungen und Fallbeispiele zum Operations Research, 8. Auflage, Springer, Berlin et al. 2015 Hillier, F.S., Lieberman, G.J.: Introduction to Operations Research. 11th Edition, McGraw-Hill, 2014. Schira, J.: Statistische Methoden der VWL und BWL - Theorie und Praxis. 5. Auflage, Pearson Verlag 2016. Zudem: Skript und Unterlagen, die zur Vorlesung herausgegeben werden.

Course L0250: Quantitative Methods - Statistics and Operations Research	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kathrin Fischer
Language	EN
Cycle	WiSe
Content	**Statistics** • Descriptive Statistics: Graphical representations, calculation of relevant measures of central tendency etc., also by using a computer; application of methods for large data sets, analysis and comparison of results, critical discussion and evaluation of methods and their use in scientific projects and business practice • Probability theory: important laws, dependent probabilities, Bayes Rule; application to practical problems • Use and application of probability distributions , as e.g. Binomial and Normal distribution to Management and Engineering problems • Methods of inferential statistics: confidence intervals: theoretical background and applications; hypothesis testing: theoretical background and application to business problems; regression analysis: theoretical background and application in research practice. **Operations Research** • Linear Programming: Modelling business decision situations, solving problems by Simplex method and by using software, theoretical background of Simplex procedure, Dual Simplex procedure and blocked variables, special cases (degeneracy etc.); sensitivity analysis and interpretation • Transportation planning: Modellung transportation and transshipment problems in global networks; Solving transportation problems using software • Network Optimization problems: modelling production and transportation networks, solving planning problems in networks, Network Planning as a research topic • Integer Programming: Models using integer variables, e.g. in location decisions, branch and bound procedure
Literature	Ausgewählte Bücher: D.R. Anderson / D.J. Sweeney / T.A. Williams / Martin: Quantitative Methods for Business. 11th Edition, Thomson, South Western 2008. Bluman, Alan G.: Elementary Statistics - A brief version. Third Edition, McGrawHill 2006. Bowerman, Bruce L. and O’Connell, Richard T.: Business Statistics in Practice, 8th edition, McGraw-Hill 2016. Domschke, W., Drexl, A.: Einführung in Operations Research, 9. Auflage, Springer, Berlin et al. 2015. Domschke, W. / A. Drexl / R. Klein / A. Scholl / S. Voß: Übungen und Fallbeispiele zum Operations Research, 8. Auflage, Springer, Berlin et al. 2015 Hillier, F.S., Lieberman, G.J.: Introduction to Operations Research. 11th Edition, McGraw-Hill, 2014. Schira, J.: Statistische Methoden der VWL und BWL - Theorie und Praxis. 5. Auflage, Pearson Verlag 2016. Zudem: Skript und Unterlagen, die zur Vorlesung herausgegeben werden.

Module M0820: International Business

Courses

Title	Typ	Hrs/wk	CP
Business-to-Business Marketing (L0762)	Lecture	2	2
Intercultural Management and Communication (L0846)	Lecture	2	2
International Management (L0157)	Lecture	2	2

Module Responsible: Prof. Christian Lüthje

Admission Requirements: None

Recommended Previous Knowledge: Bachelor-level knowledge in marketing and (international) strategic management; basic understanding of market segmentation, modes of market entry, strategic management, pricing theory and marketing instruments.

The previous knowledge which is required for this module is taught by e-learning modules. Students receive access data and information regarding the online learning module after enrolment at TUHH.

Educational Objectives: After taking part successfully, students have reached the following learning results

Professional Competence

Knowledge

The students will develop a thorough understanding of the following:

- Selling to organizations and marketing strategies in B2B markets
- Relevant theories, methods and tools for operational B2B marketing
- Relevant theories for intercultural communication
- Theoretical knowledge of
    - the importance of globalization for firms and the challenges facing companies in the context of their international operations;
    - methods of measuring the internationalization degree of companies and the resulting practical implications;
    - target market strategies, market entry strategies and foreign operation modes and allocation strategies;
    - different types of international organizational structures (e.g. global organization, network organization, transnational organization);
    - "culture" and its impact on human interaction;
    - important aspects of (intercultural) communication issues.
    - methods of analysis and assessment of market entry risks by applying modern theories such as the “Innovator’s Dilemma” framework;
    - modes of cooperation such as prime contractor and consortium models and their industrial cooperation related advantages and disadvantages;
    - special methods of assessment of specific country risks;

Skills

The students will be able to apply this knowledge to

- identify and systematically address relevant partners when selling to business organizations;
- place, price and communicate industrial products with the help state-of-the-art B2B marketing tools;
- define the specifics of global industries and respond to them deriving appropriate practical recommendations (global competitors, regional consumers, local and global suppliers, etc.);
- derive advantages and disadvantages of different target market, market entry, timing and allocation strategies;
- apply the theoretical knowledge to business cases or real examples (e.g. internationalization processes of well-known hotel chains or franchise companies, etc.);
- interpret symbols, rituals and gestures appropriately in an intercultural context.

Based on these skills, the students will be able to

- analyze market-entry options and market positioning in B2B markets;
- systematically analyze, work up and present information needed for making the decision for or against internationalization of company’s operations and regarding HOW, WHEN and WHAT;
- analyze and evaluate risks in the context of international business operations;
- decide which mode of market entry (e.g. franchising) yields most potential;
- make methodically based internationalization decisions as well as master the specifics of strategic management in an international context and apply concrete planning processes;
- develop strategies when approaching international client companies and manage relationships with complex client entities;
- develop sophisticated market-entry strategies and to position innovative industrial goods in global business-to-business markets;
- develop communication strategies in the domain of industrial goods, develop pricing plans by applying state-of-the-art tools like Vickrey-auctions to measure willingness-to-pay and methods such as tender-bidding models.
- solve complex operating planning tasks independently or in a team applying appropriate methods and comprehensibly present the results of their analysis;
- identify problems and resolve cultural issues in multi-cultural teams and in intercultural collaborations
- successfully manage cultural diversity.

Personal Competence

Social Competence

The students will be able to

- have fruitful professional discussions;
- present and defend the results of their work in a group of students;
- work successfully in multi-cultural teams
- communicate and collaborate successfully and respectfully with others, also on an intercultural basis.

Autonomy	The students will be able to • acquire knowledge in the specific context independently and to map this knowledge onto other new complex problem fields.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** **Bonus** **Form** **Description** Yes 5 % Excercises
Examination	Subject theoretical and practical work
Examination duration and scale	3 written tests during the semester
Assignment for the Following Curricula	International Management and Engineering: Core Qualification: Compulsory

Course L0762: Business-to-Business Marketing	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Christian Lüthje
Language	EN
Cycle	WiSe
Content	**Contents** Business-to-business (B2B) markets play an important role in most economies. At the same time, B2B markets differ strongly from consumer goods markets. For example, companies' buying decisions follow different rules than those of consuming individuals. Consequently, marketing mix decisions in B2B markets need to follow the specific circumstances in such markets. The aim of this lecture is to enable students to understand the specifics of marketing in B2B markets. At the beginning, students learn which strategic marketing decisions may be most appropriate in industrial markets. Following that, the lecture will focus more on different options to design marketing mix elements - Pricing, Communication and Distribution - in B2B markets. We extend the student's basic knowhow in marketing and focus on the specific requirements in B2B markets. Topics • The importance, specific characteristics and developments of B2B markets today • Organizational buying behavior and the corporate buying process • B2B marketing strategies regarding modes and time of market entry with focus on innovative industrial products • Types of project-related cooperation in the B2B project business • Specific operational marketing methods in communication (success factors of fares and exhibitions, importance of public relations for B2B markets); pricing (measuring willingness-to-pay via auctions; value-based pricing in industrial markets, bidding models and auctioning); distribution and channel strategies for B2B markets • Marketing in complex value chains: Solving the problem of direct customers' unwillingness to adopt innovative products by directly addressing indirect customers **Knowledge** The students will develop a thorough understanding of: • How organizations and firms buy • How marketing can be performed in complex value chains • Promising market and competitive strategies in B2B markets • Modes of cooperation in B2B markets • Marketing-Mix decisions in B2B marketing (communication, pricing, distribution) **Skills** • analyzing the advantages and disadvantages of different target market, market entry, timing and allocation strategies; • identifying and systematically address relevant partners when selling to business organizations; • developing context-specific market-entry and timing strategies; • making appropriate decisions for the pricing and communication of industrial products; • applying the theoretical knowledge to business cases or real examples **Social Competence** The students will be able to • having fruitful professional discussions; • presenting and defending the results of their work in groupwork; **Self-reliance** • acquiring knowledge in the specific context independently and to map this knowledge onto other new complex problem fields. **Assessment** Written examination & Class participation in interactive elements (presentations, homework)
Literature	Blythe, J., Zimmerman, A. (2005) Business-to-Business Marketing: A global perspective, London, Thomson Monroe, K. B. (2002). Pricing: Making Profitable Decisions, 3 rd Edition Morris, M., Pitt, L., Honeycutt, E. (2001), Business-to-Business Marketing, New York, Sage Publishing, 3rd Edition Nagle, T., Hogan, J., Zale, J. (2009), Strategy and Tactics of Pricing, New York, Prentice Hall, 5th Edition

Course L0846: Intercultural Management and Communication	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Christian Lüthje
Language	EN
Cycle	WiSe
Content	Globalization of business processes and the revolution in information and communication technologies (ICT) have resulted in distributed workflows across geographic boundaries. These developments as well as increased immigration emanating, for example, as a consequence of a shortage of skilled labour in many industrialized nations, have led to the creation of (virtual) multi-cultural, multi-ethnic teams with diverse cultural backgrounds. Such diversity generally has a positive impact on creativity and innovativeness, as many empirical studies confirm. Nevertheless, varying cultural practices, communication styles, and contextual sensibilities have the potential to disturb or even disrupt collaborative work processes, if left unmanaged. This course focuses on inter-cultural management from both, theoretical as well as practical, points of view to provide a solid fundament to students enabling them to operate successfully in cross-cultural settings. Case studies and guest lecture(s) will be used to provide added practical relevance to the course. In addition, where practicable, student assignments will be used to foster autonomous learning. Some of the main topics covered in this course include: • Understanding “culture” and its impact on human interaction • Verbal and non-verbal communication • High and low context communication • Role of formality and non-formality in communication • Varying interpretations of symbols, rituals & gestures • Managing diversity in domestic settings
Literature	• Bartlett, C.A. / Ghoshal, S. (2002): Managing Across Borders: The Transnational Solution, 2nd edition, Boston • Deresky, H. (2006): International Management: Managing Across Borders and Cultures, 3rd edition, Upper Saddle River • French, R. (2010): Cross-cultural Management in Work Organisations, 2nd edition, London • Hofstede, G. (2003): Culture's Consequences : Comparing Values, Behaviors, Institutions and Organizations across Nations, 2nd edition, Thousand Oaks • Hofstede, G. / Hofstede, G.J. (2006): Cultures and Organizations: Software of the mind, 2nd edition, New York

Course L0157: International Management	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Thomas Wrona
Language	EN
Cycle	WiSe
Content	Growing internationalization of companies and increased globalization require dealing with operations and specifics of international management as well as creating an understanding of intercultural differences. In order to help the students to understand these specifics and challenges accompanying international companies, the course will be divided in the following parts: • Important Aspects in International Management • Theories of Internationalization • Specific characteristics of international companies and their strategies • Organizational Structure and Leadership in international companies During the course, the content will be covered from a theoretical as well as a practical point of view by using examples of different companies. In order to provide practical relevance to the course, a guest speaker from a well-known international company will be invited or alternatively a company visit will be organized as well as an analysis of a case study will take place.
Literature	1. Course notes and materials provided before the lecture. 2. Selected books: ◦ Bartlett/Ghoshal (2002): Managing Across Borders, The Transnational Solution, 2nd edition, Boston ◦ Buckley, P.J./Ghauri, P.N. (1998), The Internationalization of the Firm, 2nd edition ◦ Czinkota, Ronkainen, Moffett, Marinova, Marinov (2009), International Business, Hoboken ◦ Dunning, J.H. (1993), The Globalization of Business: The Challenge of the 1990s, London ◦ Ghoshal, S. (1987), Global Strategy: An Organizing Framework, Strategic Management Journal, p. 425-440 ◦ Praveen Parboteeah, K.,Cullen, J.B. (2011) , Strategic International Management, International 5th Edition ◦ Rugman, A.M./Collinson, S. (2012): International Business, 6th Edition, Essex 2012

Module M1002: Production and Logistics Management

Courses

Title	Typ	Hrs/wk	CP
Operative Production and Logistics Management (L1198)	Lecture	2	2
Strategic Production and Logistics Management (L1089)	Lecture	2	2
Strategic Production and Logistics Management (L3152)	Project-/problem-based Learning	1	2

Module Responsible	Prof. Wolfgang Kersten
Admission Requirements	None
Recommended Previous Knowledge	Introduction to Business and Management The previous knowledge, that is necessary for the successful participation in this module is accessable via e-learning. Log-in and additional information will be distributed during the admission process.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will be able - to differentiate between strategic and operational production and logistics management, - to describe the areas of production and logistics management, - understand the difference between traditional and new concepts of production planning and control, - to describe and explain the actual challenges and research areas of production and logistics management, esp. in an international context.
Skills	Based on the acquired knowledge students are capable of - Applying methods of production and logistics management in an international context, - Selecting sufficient methods of production and logistics management to solve practical problems, - Selecting appropriate methods of production and logistics management also for non-standardized problems, - Making a holistic assessment of areas of decision in production and logistics management and relevant influence factors, - Design a production and logistics strategy and a global manufacturing footprint systematically.
Personal Competence	
Social Competence	After completion of the module students can - lead discussions and team sessions, - arrive at work results in groups and document them, - develop joint solutions in mixed teams and present them to others, - present solutions to specialists and develop ideas further.
Autonomy	After completion of the module students can - assess possible consequences of their professional activity, - define tasks independently, acquire the requisite knowledge and use suitable means of implementation, - define and carry out research tasks bearing in mind possible societal consequences.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 2.5 % / Excercises / Online-Modul No / 15 % / Subject theoretical and practical work / PBL
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory

Course L1198: Operative Production and Logistics Management	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Thorsten Blecker
Language	DE
Cycle	WiSe
Content	• Further knowledge of operational production management • Traditional production planning and control concepts • Recent production planning and control concepts • Understanding and application of quantitative methods • Further concepts regarding operational production management
Literature	Corsten, H.: Produktionswirtschaft: Einführung in das industrielle Produktionsmanagement, 12. Aufl., München 2009. Dyckhoff, H./Spengler T.: Produktionswirtschaft: Eine Einführung, 3. Aufl., Berlin Heidelberg 2010. Heizer, J./Render, B: Operations Management, 10. Auflage, Upper Saddle River 2011. Kaluza, B./Blecker, Th. (Hrsg.): Produktions- und Logistikmanagement in Virtuellen Unternehmen und Unternehmensnetzwerken, Berlin et al. 2000. Kaluza, B./Blecker, Th. (Hrsg.): Erfolgsfaktor Flexibilität. Strategien und Konzepte für wandlungsfähige Unternehmen, Berlin 2005. Kurbel, K.: Produktionsplanung und -steuerung, 5., Aufl., München - Wien 2003. Schweitzer, M.: Industriebetriebslehre, 2. Auflage, München 1994. Thonemann, Ulrich (2005): Operations Management, 2. Aufl., München 2010. Zahn, E./Schmid, U.: Produktionswirtschaft I: Grundlagen und operatives Produktionsmanagement, Stuttgart 1996 Zäpfel, G.: Grundzüge des Produktions- und Logistikmanagement, 2. Aufl., München - Wien 2001

Course L1089: Strategic Production and Logistics Management	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Wolfgang Kersten
Language	DE
Cycle	WiSe
Content	• Identification of the scope of production, operations and logistics management • Understanding of actual challenges concerning production and logistics strategy • Understanding operations as a competitive weapon • Identification and design of the main elements of an operations strategy (level of vertical integration, technology strategy, location strategy, capacity strategy) of a company • Understanding of international conditions for the development of a production and logistics strategy • In depth discussion of different roles and design elements of a global manufacturing footprint • Evaluation of operation strategies of different companies and industrial sectors • In depth discussion of methods and concepts of production and logistics management • In depth discussion of lean management: Main goals and measures of lean management and lean production concepts, impact of lean management on production and logistics strategies • Analysis of the impact of digitalization on production and logistics strategies • Presentation and discussion of current research topics in the field of production and logistics management • Integration of Problem-Based-Learning sessions in order to enhance teamworking and problem solving skills as well as presentation skills
Literature	Arvis, J.-F. et al. (2018): Connecting to Compete - Trade Logistics in the Global Economy, Washington, DC, USA: The World Bank Group, Download: https://openknowledge.worldbank.org/handle/10986/29971 Corsten, H. /Gössinger, R. (2016): Produktionswirtschaft - Einführung in das industrielle Produktionsmanagement, 14. Auflage, Berlin/ Boston: De Gruyter/ Oldenbourg. Heizer, J./ Render, B./ Munson, Ch. (2016): Operations Management (Global Edition), 12. Auflage, Pearson Education Ltd.: Harlow, England. Kersten, W. et al. (2017): Chancen der digitalen Transformation. Trends und Strategien in Logistik und Supply Chain Management, Hamburg: DVV Media Group Nyhuis, P./ Nickel, R./ Tullius, K. (2008): Globales Varianten Produktionssystem - Globalisierung mit System, Garbsen: Verlag PZH Produktionstechnisches Zentrum GmbH. Porter, M. E. (2013): Wettbewerbsstrategie - Methoden zur Analyse von Branchen und Konkurrenten, 12. Auflage, Frankfurt/Main: CampusVerlag. Schröder, M./ Wegner, K., Hrsg. (2019): Logistik im Wandel der Zeit - Von der Produktionssteuerung zu vernetzten Supply Chains, Wiesbaden: Springer Gabler Slack, N./ Lewis, M. (2017): Operations Strategy, 5/e Pearson Education Ltd.: Harlow, England. Swink, M./ Melnyk, S./ Cooper, M./ Hartley, J. (2011): Managing Operations across the Supply Chain, New York u.a. Wortmann, J. C. (1992): Production management systems for one-of-a-kind products, Computers in Industry 19, S. 79-88 Womack, J./ Jones, D./ Roos, D. (1990): The Machine that changed the world; New York. Zahn, E. /Schmid, U. (1996): Grundlagen und operatives Produktionsmanagement, Stuttgart: Lucius & Lucius Zäpfel, G.(2000): Produktionswirtschaft: Strategisches Produktions-Management, 2. Aufl., München u.a.

Course L3152: Strategic Production and Logistics Management	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Wolfgang Kersten
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1759: Linking theory and practice (dual study program, Master's degree)

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical modules as part of the dual Bachelor’s course • Module "interlinking theory and practice as part of the dual Master’s course"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... ... can describe and classify selected classic and current theories, concepts and methods • related to project management and • change and transformation management ... and apply them to specific situations, processes and plans in a personal, professional context.
Skills	Dual students ... • ... anticipate typical difficulties, positive and negative effects, as well as success and failure factors in the engineering sector, evaluate them and consider promising strategies and courses of action. • ... develop specialised technical and conceptual skills to solve complex tasks and problems in their professional field of activity/work.
Personal Competence	
Social Competence	Dual students ... • ... can responsibly lead interdisciplinary teams within the framework of complex tasks and problems. • ... engage in sector-specific and cross-sectoral discussions with experts, stakeholders and staff, representing their approaches, points of view and work results.
Autonomy	Dual students ... • ... define, reflect and evaluate goals and measures for complex application-oriented projects and change processes. • ... shape their professional area of responsibility independently and sustainably. • ... take responsibility for their actions and for the results of their work.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Studienbegleitende und semesterübergreifende Dokumentation: Die Leistungspunkte für das Modul werden durch die Anfertigung eines digitalen Lern- und Entwicklungsberichtes (E-Portfolio) erworben. Dabei handelt es sich um eine fortlaufende Dokumentation und Reflexion der Lernerfahrungen und der Kompetenzentwicklung im Bereich der Personalen Kompetenz.

Course L2890: Responsible Project Management in Engineering (for Dual Study Program)

Typ	Seminar
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Henning Haschke, Heiko Sieben
Language	DE
Cycle	WiSe/SoSe
Content	• Theories and methods of project management • Innovation management • Agile project management • Fundamentals of classic and agile methods • Hybrid use of classic and agile methods • Roles, perspectives and stakeholders throughout the project • Initiating and coordinating complex engineering projects • Principles of moderation, team management, team leadership, conflict management • Communication structures: in-house, cross-company • Public information policy • Promoting commitment and empowerment • Sharing experience with specialists and managers from the engineering sector • Documenting and reflecting on learning experiences
Literature	Seminarapparat

Course L2891: Responsible Change and Transformation Management in Engineering (for Dual Study Program)	
Typ	Seminar
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Henning Haschke, Heiko Sieben
Language	DE
Cycle	WiSe/SoSe
Content	• Basic concepts, opportunities and limits of organisational change • Models and methods of organisational design and development • Strategic orientation and change, and their short-, medium- and long-term consequences for individuals, organisations and society as a whole • Roles, perspectives and stakeholders in change processes • Initiating and coordinating change measures in engineering • Phase models of organisational change (Lewin, Kotter, etc.) • Change-oriented information policy and dealing with resistance and uncertainty • Promoting commitment and empowerment • Successfully handling change and transformation: personally, as an employee, as a manager (personal, professional, organisational) • Company-level and globally (systemic) • Sharing experience with specialists and managers from the engineering sector • Documenting and reflecting on learning experiences
Literature	Seminarapparat

Module M1756: Practical module 1 (dual study program, Master's degree)

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Practical term 1 (dual study program, Master's degree) (L2887)		0	10

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of a compatible dual B.Sc. at TU Hamburg or comparable practical work experience and competences in the area of interlinking theory and practice • Course D from the module on interlinking theory and practice as part of the dual Master's course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... combine their knowledge of facts, principles, theories and methods gained from previous study content with acquired practical knowledge - in particular their knowledge of practical professional procedures and approaches, in the current field of activity in engineering. • ... have a critical understanding of the practical applications of their engineering subject.
Skills	Dual students ... • ... apply technical theoretical knowledge to complex, interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. • ... implement the university's application recommendations with regard to their current tasks. • ... develop solutions as well as procedures and approaches in their field of activity and area of responsibility.
Personal Competence	
Social Competence	Dual students ... • ... work responsibly in project teams within their working area and proactively deal with problems within their team. • ... represent complex engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders.
Autonomy	Dual students ... • ... define goals for their own learning and working processes as engineers. • ... reflect on learning and work processes in their area of responsibility. • ... reflect on the relevance of subject modules specialisations and specialisation for work as an engineer, and also implement the university's application recommendations and the associated challenges to positively transfer knowledge between theory and practice.
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Credit points	10
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory Aeronautics: Core Qualification: Compulsory Materials Science and Engineering: Core Qualification: Compulsory Materials Science: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Core Qualification: Compulsory Microelectronics and Microsystems: Core Qualification: Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Water and Environmental Engineering: Core Qualification: Compulsory

Course L2887: Practical term 1 (dual study program, Master's degree)	
Typ	
Hrs/wk	0
CP	10
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe/SoSe
Content	**Company onboarding process** • Assigning a professional field of activity as an engineer (B.Sc.) and associated fields of work • Establishing responsibilities and authorisation of the dual student within the company as an engineer (B.Sc.) • Working independently in a team and on selected projects - across departments and, if applicable, across companies • Scheduling the current practical module with a clear correlation to work structures • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: Responsibility as an engineer (B.Sc.) in their own area of work, coordinating team and project work, dealing with complex contexts and unsolved problems, developing and implementing innovative solutions • Subject specialisation (corresponding to the chosen course [M.Sc.]) in the field of activity • Systemic skills • Implementing the university’s application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • Creating an e-portfolio • Importance of course contents (M.Sc.) when working as an engineer • Importance of development and innovation when working as an engineer
Literature	• Studierendenhandbuch • Betriebliche Dokumente • Hochschulseitige Handlungsempfehlungen zum Theorie-Praxis-Transfer

Module M0750: Economics

Courses

Title	Typ	Hrs/wk	CP
International Economics (L0700)	Lecture	2	2
Main Theoretical and Political Concepts (L0641)	Lecture	2	2
Economics (L2714)	Project-/problem-based Learning	1	2

Module Responsible	Prof. Timo Heinrich
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of economics is expected. The prior knowledge in the field of economics required for successful completion of this module is imparted as an e-learning offering. Students will receive access and further information on the associated online learning module when they enroll. By taking an associated online test, the student can acquire points that are added to the result of the final examination of the Economics module.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know • the most important principles of individual decision making in a national and international context, • different market structures, • types of market failure, • the functioning of a single economy (including money market, financial and goods markets, labor market), • the difference between and the interdependence of short and long run equilibria, • the significance of expectations on the effects of economic policy, • the various links between economies and • different economic policies and their effects on the economy.
Skills	The students are able to model analytically or graphically • the most important principles of individual decision making in a national and international context, • the market results of different market structures and market failure, • the welfare effects of the market results, • the functioning of an economy (including money market, financial and goods markets, labor market), • links between economies and • the effects of economic policies.
Personal Competence	
Social Competence	The students are able • to anticipate expectations and decisions of individuals or groups of individuals. These may be inside or outside of the own firm, • to take these decisions into account while deciding themselves and • to understand the behavior of markets and to assess the opportunities and risks with respect to the own business activities.
Autonomy	With the methods taught the students will be able • to analyze empirical phenomena in single economies and the world economy and to reconcile them with the studied theoretical concepts and • to design, analyze and evaluate micro- and macroeconomic policies against the background of different models.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 5 % / Excercises / No / 15 % / Presentation /
Examination	Written exam
Examination duration and scale	60 min
Assignment for the Following Curricula	International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Elective Compulsory Mechanical Engineering and Management: Specialisation Management: Elective Compulsory

Course L0700: International Economics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Timo Heinrich
Language	EN
Cycle	SoSe

Content	• International Trade Theory and Policy:
	  ◦ Comparative Advantage - the Ricardian Model
	  ◦ The Heckscher-Ohlin Model
	  ◦ The Standard Trade Model
	  ◦ Intrasectoral Trade
	  ◦ International Trade Policy

Literature	• Mankiw/Taylor: Economics, Cengage, 5th ed., 2020 • Krugman/Obstfeld/Mehlitz: International Economics, Pearson, 11th ed. 2018 • The CORE Team: The Economy: Economics for a Changing World, Oxford University Press, 2017

Course L0641: Main Theoretical and Political Concepts	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Timo Heinrich
Language	EN
Cycle	SoSe

Content	• Introduction: Ten Principles of Economics
	• Microeconomics:
	  ◦ Theory of the Household
	  ◦ Theory of the Firm
	  ◦ Competitive Markets in Equilibrium
	  ◦ Market Failure: Monopoly and External Effects
	  ◦ Government Policies
	• Macroeconomics:
	  ◦ A Nation’s Real Income and Production
	  ◦ The Real Economy in the Long Run: Capital and Labour Market
	  ◦ Money and Prices in the Long Run
	  ◦ Aggregate Demand and Supply: Short-Run Economic Fluctuations
	  ◦ Monetary and Fiscal Policy in the Short and the Long Run

Literature	• Mankiw/Taylor: Economics, Cengage, 5th ed., 2020 • Pindyck/Rubinfeld: Microeconomics, Prentice Hall International, 7th ed. 2010 • The CORE Team: The Economy: Economics for a Changing World, Oxford University Press, 2017

Course L2714: Economics	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Timo Heinrich
Language	EN
Cycle	SoSe
Content	Students work in teams on in-depth questions related to the contents of the lectures and present the results.
Literature	• Mankiw/Taylor: Economics, Cengage, 5th ed., 2020 • Krugman/Obstfeld/Mehlitz: International Economics, Pearson, 11th ed. 2018 • Pindyck/Rubinfeld, Microceconomics, Pearson, 9th ed., 2018 • The CORE Team: The Economy: Economics for a Changing World, Oxford University Press, 2017

Module M1734: Organization and IT of international companies and supply chains

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Logistics and Information Technology (L0065)	Lecture	2	3
Organization and Process Management (L1217)	Project-/problem-based Learning	3	3

Module Responsible	Prof. Thorsten Blecker
Admission Requirements	None
Recommended Previous Knowledge	Foundations of business administration and foundations of logistics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students acquire knowledge of: • Information systems in logistics and supply chain management as well as critical appraisal of potentials against the background of solid theoretical knowledge • Case studies and new technical developments in IT from practice • Relevance of information in international companies and supply chains • Theoretical knowledge and application of Radio Frequency Identification (RFID) • Basics and examples of a process-oriented company organization • Design possibilities of the process-oriented structure of organizations for the efficient design of company processes; transfer to nationally and internationally operating practical companies • Possibilities of structuring internal and cross-company forms of organization as well as transfer of the theoretically acquired knowledge to examples of international corporate practice; discussion of their applicability in the company as well as considerations of success • Possibilities of co-determination on the part of employees and employers in the company; critical discussion and reflection on the legal basis using current examples in corporate practice to promote responsible action • Basics on the topics of corporate culture and knowledge management as well as possibilities for shaping them in company practice • Digitalization and associated opportunities and challenges for the organization and process management of international companies and supply chains
Skills	Students acquire the following skills: • Apply theoretical content, approaches and models of organizational theory and process management • Analyze potentials and challenges of digitalization on the organization of international companies and supply chains • Evaluate national and international empirical studies in relation to organization and IT in companies and their supply chains • Evaluation of the relevance of the availability of information in international companies and supply chains • Design and analysis of the process-oriented structure of organizations for the efficient design of corporate processes; transfer to nationally and internationally operating practical companies • Weighing up the advantages and disadvantages of process management; developing approaches for its optimization • Discussion of practical issues on the basis of theoretical findings or creation of a practical reference through examples and case studies • Identification and tracking of technical developments from practice as well as assessment with reference to international companies and supply chains • Independent analysis of case studies relevant to the lecture; joint elaboration and development of problem-solving proposals within the framework of intercultural teamwork; preparation of results with the aid of modern presentation media
Personal Competence	
Social Competence	Students are able to • work out and develop joint problem-solving proposals within the framework of intercultural teamwork and prepare the results with the help of modern presentation media; • to lead subject-specific and interdisciplinary discussions; • to represent work results, also in English.
Autonomy	Students are able to • independently acquire subject-specific knowledge from the literature, discuss its applicability in the company and weigh up the prospects of success.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min
Assignment for the Following Curricula	International Management and Engineering: Core Qualification: Elective Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Elective Compulsory

Course L0065: Logistics and Information Technology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Thorsten Blecker
Language	DE
Cycle	SoSe
Content	• Basics of Logistics and Supply Chain Management • Basis of Information Management • Basics of Information Systems • Empirical Studies Related to IT in Supply Chains • Relevance of Information in the Supply Chain • Logistics Information Systems • Radio Frequency Identification (RFID) • E-Logistics • Electronic Sourcing • E-Supply Chains • Case Studies and New Technical Developments
Literature	• Kummer, S./Einbock, M., Westerheide, C.: RFID in der Logistik - Handbuch für die Praxis, Wien 2005. Pepels, W. (Hsg.): E-Business-Anwendungen in der Betriebswirtschaft, Herne/Berlin 2002. Reindl, M./Oberniedermaier, G.: eLogistics: Logistiksysteme und -prozesse im Internetzeitalter, München et al. 2002. Schulte, C.: Logistik, 5. Auflage, München 2009 Wildemann, H.: Logistik Prozessmanagement, 4. Aufl., München 2009. Wildemann H. (Hsg.): Supply Chain Management, München 2000.

Course L1217: Organization and Process Management	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Wolfgang Kersten
Language	DE
Cycle	SoSe
Content	• Fundamentals of a process-oriented company organization • Analysis of process-oriented business structures for efficient configuration of operational workflows; application to national and international examples from the industry • Description and comparative analysis of possible organizational forms and transfer into the international practice; opportunities to organize a company in practice; pros and cons of different organizational forms • Analysis of possible cooperation forms between companies and applications in the industry • Development of different participation types for employers and employees within the company; discussion and reflection of legal principles based on practical examples • Description of the basics concerning corporate culture and knowledge management, as well as options for the practical implementation • Weighing up the pros and cons of process management; development of optimization options • Digitalization and process management, related requirements for change management • Digitalization and corporate culture including an analysis of different international preconditions • Integration of problem based learning sessions to work on relevant case studies; joint development of possible problem solving solutions within intercultural teams; preparation of the results with modern presentation methods
Literature	• Becker, J. / Kugeler, M. / Rosemann, M. (2012): Prozessmanagement: Ein Leitfaden zur prozessorientierten Organisationsgestaltung, 7. Aufl., Berlin. • Bullinger, H.-J. / Warnecke, H. J. (2003): Neue Organisationsformen im Unternehmen, 2. Auflage, Berlin. • Corsten, H., Gössinger, R., Spengler, Th. (Hrsg., 2018): Handbuch Produktions- und Logistikmanagement in Wertschöpfungsnetzwerken, Berlin/Boston • Eversheim, W. (2005): Integrierte Produkt- und Prozessgestaltung, Heidelberg. • Gaitanides, M. (2007): Prozessorganisation: Entwicklung, Ansätze und Programme des Managements von Geschäftsprozessen, 2. Auflage, München. • Hopfenbeck, W. (2002): Allgemeine Betriebswirtschafts- und Managementlehre - das Unternehmen im Spannungsfeld zwischen ökonomischen, sozialen und ökologischen Interessen, 14. Auflage, München. • Kersten, W.; Koller, H.; Lödding, H. (Hrsg.): Industrie 4.0. Wie intelligente Vernetzung und kognitive Systeme unsere Arbeit verändern. Berlin 2014 • Kersten, W. et al. (2017): Chancen der digitalen Transformation. Trends und Strategien in Logistik und Supply Chain Management, Bremen • Obermaier, Robert (Hrsg., 2019): Handbuch Industrie 4.0 und Digitale Transformation: Betriebswirtschaftliche, technische und rechtliche Herausforderungen, Wiesbaden • Porter, M. (1999): Wettbewerbsstrategie (competitive strategy): Methoden zur Analyse von Branchen und Konkurrenten, 10. Auflage, Frankfurt. • Schreyögg, G. (2008): Organisation. Grundlagen moderner Organisationsgestaltung. 5. Auflage. GWV Fachverlag. Wiesbaden • Wöhe, G. (2020): Einführung in die Allgemeine Betriebswirtschaftslehre, 27. Aufl., München.

Module M1733: Foundations in Organizational Design and Human Resource Management

Courses

Title	Typ	Hrs/wk	CP
Foundations in Organizational Design and Human Resource Management (Seminar) (L2800)	Seminar	2	3
Foundations in Organizational Design and Human Resource Management (Lecture) (L2799)	Lecture	2	3

Module Responsible	Prof. Christian Ringle
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge on academic writing as well as principles and concepts in business administration.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will be able to... • Explain the core elements and practices of an effective organizational design; • Describe key components of human resource management (e.g., personnel planning, employee testing, training & development) throughout national and international organizations; • Comprehend the meaning and importance of managing human resources in multinational companies and its relation to organizational designs and strategies; • Use adequate data and quantitative methods for decision making in organizational design and human resource management; • Identify critical success in organizations and conduct human resource analytics.
Skills	Students will be able to... • Apply theoretical knowledge to practical examples; • Write a scientific seminar thesis; • Appropriately present results of their work to others, both in terms of a thesis and oral presentations.
Personal Competence	
Social Competence	The students will be able to... • Respectfully work in teams; • Have fruitful group discussions; • Present their results in written form and oral presentations.
Autonomy	The students will be able to... • Independently gather knowledge on specific topics; • Critically evaluate and discuss this information; • Transfer the acquired knowledge to practical applications.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Thesis with presentation and assignments during the semester
Assignment for the Following Curricula	International Management and Engineering: Core Qualification: Elective Compulsory

Course L2800: Foundations in Organizational Design and Human Resource Management (Seminar)	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Ringle
Language	EN
Cycle	SoSe
Content	This course is structured as a lecture and a seminar. The lecture focuses on gaining an understanding of the fundamentals of human resource management and organizational design. The lecture also introduces quantitative and business analytics methods for decision making in the field. In the lecture, the basic theoretical concepts are explained and discussed, whereas they are applied through the preparation of a seminar thesis in the seminar. Organizational Design & Human Resource Management • The processes of developing organizational structures for small and mid-sized corporations as well as for large multinational enterprises; • The adaptation of organizations and their structures to the competitive environment, with special focus on international operating organizations and global markets; • Introduction to human resource management from a strategic and international perspective (incl. the typical challenges of international organizations); • Key elements of human resource management (incl. design of work, employee recruitment, development, separation & retention); • Introduction of methods and models for decision making in organizational design and human resource management. Possible Applications of the Theoretical Concepts • Big data in organizations and human resource analytics; • Business analytics and machine learning methods (e.g., factor analysis, regression analysis, and structural equation modeling); • Models for the management of organizations and human resource management (e.g., job satisfaction and turnover intention, motivation and organizational commitment).
Literature	This course is structured as a lecture and a seminar. The lecture focuses on gaining an understanding of the fundamentals of human resource management and organizational design. The lecture also introduces quantitative and business analytics methods for decision making in the field. In the lecture, the basic theoretical concepts are explained and discussed, whereas they are applied through the preparation of a seminar thesis in the seminar. Organizational Design & Human Resource Management • The processes of developing organizational structures for small and mid-sized corporations as well as for large multinational enterprises; • The adaptation of organizations and their structures to the competitive environment, with special focus on international operating organizations and global markets; • Introduction to human resource management from a strategic and international perspective (incl. the typical challenges of international organizations); • Key elements of human resource management (incl. design of work, employee recruitment, development, separation & retention); • Introduction of methods and models for decision making in organizational design and human resource management. Possible Applications of the Theoretical Concepts • Big data in organizations and human resource analytics; • Business analytics and machine learning methods (e.g., factor analysis, regression analysis, and structural equation modeling); • Models for the management of organizations and human resource management (e.g., job satisfaction and turnover intention, motivation and organizational commitment).

Course L2799: Foundations in Organizational Design and Human Resource Management (Lecture)	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Ringle
Language	EN
Cycle	SoSe
Content	This course is structured as a lecture and a seminar. The lecture focuses on gaining an understanding of the fundamentals of human resource management and organizational design. The lecture also introduces quantitative and business analytics methods for decision making in the field. In the lecture, the basic theoretical concepts are explained and discussed, whereas they are applied through the preparation of a seminar thesis in the seminar. Organizational Design & Human Resource Management • The processes of developing organizational structures for small and mid-sized corporations as well as for large multinational enterprises; • The adaptation of organizations and their structures to the competitive environment, with special focus on international operating organizations and global markets; • Introduction to human resource management from a strategic and international perspective (incl. the typical challenges of international organizations); • Key elements of human resource management (incl. design of work, employee recruitment, development, separation & retention); • Introduction of methods and models for decision making in organizational design and human resource management. Possible Applications of the Theoretical Concepts • Big data in organizations and human resource analytics; • Business analytics and machine learning methods (e.g., factor analysis, regression analysis, and structural equation modeling); • Models for the management of organizations and human resource management (e.g., job satisfaction and turnover intention, motivation and organizational commitment).
Literature	Textbooks • Bernardin, H. J. (2006): Human Resource Management: An Experiential Approach, 4e, New York, NY: McGraw-Hill. • Cascio, W. (2015): Managing Human Resources: Productivity, Quality of Work Life, Profits, revised edition, New York, NY: McGraw-Hill. • Dessler, G. (2012): A Framework for Human Resource Management, 7 ed., Upper Saddle River, NJ: Prentice Hall. • French, W., Bell, C. H., Zawacki, R. A. (2004): Organization Development and Transformation: Managing Effective Change, 6e, Chicago, IL: McGraw-Hill. • Gibson, J. L., Ivancevich, J. M., Donnelly, J. H., & Konopaske, R. (2011): Organizations: Behavior, Structure, Processes, 14 ed., New York, NY: McGraw-Hill. • Jones, G. R. (2012): Organizational Theory, Design, and Change, 7 ed., Upper Saddle River, NJ: Prentice Hall. • Noe, R. A., Hollenbeck, J. R., Gerhart, B., Wright, P. M. (2021): Human Resource Management: Gaining a Competitive Advantage, 12 ed., New York, NY: McGraw-Hill. Methods • Hair, J. F., Black, W. C., Babin, B. J. and Anderson, R. E. (2018): Multivariate Data Analysis, Mason, OH: Cengage. • Hair, J. F., Hult, G. T. M., Ringle, C. M. and Sarstedt, M. (2021); A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM), 3 ed., Thousand Oaks, CA: Sage. Academic writing • Davis, M., Davis K. J., & Dunagan, M. M. (2013): Scientific Papers and Presentations. Academic Press. • Katz, M. J. (2009): From Research to Manuscript: A Guide to Scientific Writing. Dordrecht: Springer.

Module M1757: Practical module 2 (dual study program, Master's degree)

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Practical term 2 (dual study program, Master's degree) (L2888)		0	10

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical module 1 as part of the dual Master's course • course D from the module on interlinking theory and practice as part of the dual Master's course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... combine their knowledge of facts, principles, theories and methods gained from previous study content with acquired practical knowledge - in particular their knowledge of practical professional procedures and approaches, in the current field of activity in engineering. • ... have a critical understanding of the practical applications of their engineering subject.
Skills	Dual students ... • ... apply technical theoretical knowledge to complex, interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. • ... implement the university's application recommendations with regard to their current tasks. • ... develop (new) solutions as well as procedures and approaches in their field of activity and area of responsibility - including in the case of frequently changing requirements (systemic skills).
Personal Competence	
Social Competence	Dual students ... • ... work responsibly in cross-departmental and interdisciplinary project teams and proactively deal with problems within their team. • ... represent complex engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders and develop these further together.
Autonomy	Dual students ... • ... define goals for their own learning and working processes as engineers. • ... reflect on learning and work processes in their area of responsibility. • ... reflect on the relevance of subject modules specialisations and specialisation for work as an engineer, and also implement the university's application recommendations and the associated challenges to positively transfer knowledge between theory and practice.
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Credit points	10
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory Aeronautics: Core Qualification: Compulsory Materials Science and Engineering: Core Qualification: Compulsory Materials Science: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Core Qualification: Compulsory Microelectronics and Microsystems: Core Qualification: Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Water and Environmental Engineering: Core Qualification: Compulsory

Course L2888: Practical term 2 (dual study program, Master's degree)	
Typ	
Hrs/wk	0
CP	10
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe/SoSe
Content	**Company onboarding process** • Assigning a professional field of activity as an engineer (B.Sc.) and associated fields of work • Establishing responsibilities and authorisation of the dual student within the company as an engineer (B.Sc.) • Taking personal responsibility within a team and on selected projects - across departments and, if applicable, across companies • Scheduling the current practical module with a clear correlation to work structures • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: Responsibility as an engineer (B.Sc.) in their own area of work, coordinating team and project work, dealing with complex contexts and unsolved problems, developing and implementing innovative solutions • Subject specialisation (corresponding to the chosen course [M.Sc.]) in the field of activity • Systemic skills • Implementing the university's application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • Updating their e-portfolio • Importance of course contents (M.Sc.) when working as an engineer • Importance of development and innovation when working as an engineer
Literature	• Studierendenhandbuch • Betriebliche Dokumente • Hochschulseitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

Module M0916: Project Seminar IWI

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Project Seminar IWI (L1064)	Project Seminar	3	6

Module Responsible	Prof. Kathrin Fischer
Admission Requirements	None
Recommended Previous Knowledge	Prior knowledge in the relevant area from the relevant Management modules.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The knowledge and the skills which are gained in this module differ depending on the topic of the seminar. In all cases, in-depth knowledge of a certain scientific area and the respective skills are developed by the students, e.g. in-depth knowledge of complexity management in production, in-depth knowledge of the application of simulations in Controlling or in-depth knowledge of specific problems in Strategic Management or Marketing, and the respective skills, e.g. the ability to judge and select different approaches to certain strategic planning problems and to apply them successfully. Hence, the seminar is strongly research oriented.
Skills	Students are able to • independently acquire the relevant knowledge to handle their project • independently carry out a (pre-defined) complex research task and/or solve a complex problem • select and use the relevant literature and critically evaluate it • aggregate their knowledge and results and present it to others • write a scientific report on the project / problem at hand, individually or in a team.
Personal Competence	
Social Competence	Students are able to • work respectfully and successfully in a team, organize the team, and solve complex tasks in a team in a given timeframe • analyse a problem in a team and develop a solution for the problem • present the results of their work to specialists.
Autonomy	Students are able to • define the scope of their project • independently acquire relevant scientific knowledge • independently carry out a (pre-defined) complex research task • independently prepare a presentation of the relevant aspects of the project.
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	To be announced in seminar.
Assignment for the Following Curricula	International Management and Engineering: Core Qualification: Compulsory

Course L1064: Project Seminar IWI	
Typ	Project Seminar
Hrs/wk	3
CP	6
Workload in Hours	Independent Study Time 138, Study Time in Lecture 42
Lecturer	Prof. Kathrin Fischer
Language	DE/EN
Cycle	WiSe/SoSe
Content	Contents differ, depending on the institute which organizes the respective seminar. Topics are always announced at the start of the term.
Literature	Wird je nach Thema angegeben; in der Regel handelt es sich um wissenschaftliche Fachartikel und Publikationen, vorwiegend in englischer Sprache.

Module M1758: Practical module 3 (dual study program, Master's degree)

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Practical term 3 (dual study program, Master's degree) (L2889)		0	10

Module Responsible	Dr. Henning Haschke
Admission Requirements	None
Recommended Previous Knowledge	• Successful completion of practical module 2 as part of the dual Master's course • course E from the module on interlinking theory and practice as part of the dual Master's course
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... combine their comprehensive and specialised engineering knowledge acquired from previous study contents with the strategy-oriented practical knowledge gained from their current field of work and area of responsibility. • ... have a critical understanding of the practical applications of their engineering subject, as well as related fields when implementing innovations.
Skills	Dual students ... • ... apply specialised and conceptual skills to solve complex, sometimes interdisciplinary problems within the company, and evaluate the associated work processes and results, taking into account different possible courses of action. • ... implement the university's application recommendations with regard to their current tasks. • ... develop new solutions as well as procedures and approaches to implement operational projects and assignments - even when facing frequently changing requirements and unpredictable changes (systemic skills). • ... can use academic methods to develop new ideas and procedures for operational problems and issues, and to assess these with regard to their usability.
Personal Competence	
Social Competence	Dual students ... • ... work responsibly in cross-departmental and interdisciplinary project teams and proactively deal with problems within their team. • ... can promote the professional development of others in a targeted manner. • ... represent complex and interdisciplinary engineering viewpoints, facts, problems and solution approaches in discussions with internal and external stakeholders and develop these further together.
Autonomy	Dual students ... • ... reflect on learning and work processes in their area of responsibility. • ... define goals for new application-oriented tasks, projects and innovation plans while reflecting on potential effects on the company and the public. • ... reflect on the relevance of areas of specialisation and research for work as an engineer, and also implement the university's application recommendations and the associated challenges to positively transfer knowledge between theory and practice.
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Credit points	10
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Documentation accompanying studies and across semesters: Module credit points are earned by completing a digital learning and development report (e-portfolio). This documents and reflects individual learning experiences and skills development relating to interlinking theory and practice, as well as professional practice. In addition, the partner company provides proof to the dual@TUHH Coordination Office that the dual student has completed the practical phase.
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory Computer Science: Core Qualification: Compulsory Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Compulsory Environmental Engineering: Core Qualification: Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory Computer Science in Engineering: Core Qualification: Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Core Qualification: Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Compulsory Aeronautics: Core Qualification: Compulsory Materials Science and Engineering: Core Qualification: Compulsory Materials Science: Core Qualification: Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Core Qualification: Compulsory Microelectronics and Microsystems: Core Qualification: Compulsory

	Product Development, Materials and Production: Core Qualification: Compulsory Renewable Energies: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Core Qualification: Compulsory Water and Environmental Engineering: Core Qualification: Compulsory

Course L2889: Practical term 3 (dual study program, Master's degree)	
Typ	
Hrs/wk	0
CP	10
Workload in Hours	Independent Study Time 300, Study Time in Lecture 0
Lecturer	Dr. Henning Haschke
Language	DE
Cycle	WiSe/SoSe
Content	**Company onboarding process** • Assigning a future professional field of activity as an engineer (M.Sc.) and associated fields of work • Extending responsibilities and authorisation of the dual student within the company up to the intended first assignment after completing their studies • Working responsibly in a team; project responsibility within own area - as well as across divisions and companies if necessary • Scheduling the final practical module with a clear correlation to work structures • Internal agreement on a potential topic or innovation project for the Master’s dissertation • Planning the Master’s dissertation within the company in cooperation with TU Hamburg • Scheduling the examination phase/subsequent study semester **Operational knowledge and skills** • Company-specific: dealing with change, project and team development, responsibility as an engineer in their future field of work (M.Sc.), dealing with complex contexts, frequent and unpredictable changes, developing and implementing innovative solutions • Specialising in one field of work (final dissertation) • Systemic skills • Implementing the university’s application recommendations (theory-practice transfer) in corresponding work and task areas across the company **Sharing/reflecting on learning** • E-portfolio • Relevance of study content and personal specialisation when working as an engineer • Relevance of research and innovation when working as an engineer
Literature	• Studierendenhandbuch • betriebliche Dokumente • Hochschulseitige Anwendungsempfehlungen zum Theorie-Praxis-Transfer

Specialization I. Electives Management

Module M0855: Marketing (Sales and Services / Innovation Marketing)

Courses

Title	Typ	Hrs/wk	CP
Marketing of Innovations (L2009)	Lecture	4	4
PBL Marketing of Innovations (L0862)	Project-/problem-based Learning	1	2

Module Responsible	Prof. Christian Lüthje
Admission Requirements	None
Recommended Previous Knowledge	• Module International Business • Basic understanding of business administration principles (strategic planning, decision theory, project management, international business) • Bachelor-level Marketing Knowledge (Marketing Instruments, Market and Competitor Strategies, Basics of Buying Behavior) • Unerstanding the differences beweetn B2B and B2C marketing • Understanding of the importance of managing innovation in global industrial markets • Good English proficiency; presentation skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will have gained a deep understanding of • Specific characteristics in the marketing of innovative poroducts and services • Approaches for analyzing the current market situation and the future market development • The gathering of information about future customer needs and requirements • Concepts and approaches to integrate lead users and their needs into product and service development processes • Approaches and tools for ensuring customer-orientation in the development of new products and innovative services • Marketing mix elements that take into consideration the specific requirements and challenges of innovative products and services • Pricing methods for new products and services • The organization of complex sales forces and personal selling • Communication concepts and instruments for new products and services
Skills	Based on the acquired knowledge students will be able to: • Design and to evaluate decisions regarding marketing and innovation strategies • Analyze markets by applying market and technology portfolios • Conduct forecasts and develop compelling scenarios as a basis for strategic planning • Translate customer needs into concepts, prototypes and marketable offers and successfully apply advanced methods for customer-oriented product and service development • Use adequate methods to foster efficient diffusion of innovative products and services • Choose suitable pricing strategies and communication activities for innovations • Make strategic sales decisions for products and services (i.e. selection of sales channels) • Apply methods of sales force management (i.e. customer value analysis)
Personal Competence	
Social Competence	The students will be able to • have fruitful discussions and exchange arguments • develop original results in a group • present results in a clear and concise way • carry out respectful team work
Autonomy	The students will be able to • Acquire knowledge independently in the specific context and to map this knowledge on other new complex problem fields. • Consider proposed business actions in the field of marketing and reflect on them.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Written elaboration, excercises, presentation, oral participation
Assignment for the Following Curricula	Global Technology and Innovation Management & Entrepreneurship: Core Qualification: Compulsory International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory Mechanical Engineering and Management: Specialisation Management: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Compulsory

Course L2009: Marketing of Innovations	
Typ	Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Prof. Christian Lüthje
Language	EN
Cycle	SoSe
Content	I. Introduction • Innovation and service marketing (importance of innovative products and services, model, objectives and examples of innovation marketing, characteristics of services, challenges of service marketing) II. Methods and approaches of strategic marketing planning • patterns of industrial development, patent and technology portfolios III. Strategic foresight and scenario analysis • objectives and challenges of strategic foresight, scenario analysis, Delphi method IV. User innovations • Role of users in the innovation process, user communities, user innovation toolkits, lead users analysis V. Customer-oriented Product and Service Engineering • Conjoint Analysis, Kano, QFD, Morphological Analysis, Blueprinting VII. Pricing • Basics of Pricing, Value-based pricing, Pricing models VIII. Sales Management • Basics of Sales Management, Assessing Customer Value, Planning Customer Visits IX. Communications • Diffusion of Innovations, Communication Objectives, Communication Instruments
Literature	**Mohr, J., Sengupta, S., Slater, S. (2014). Marketing of high-technology products and innovations, third edition, Pearson education. ISBN-10: 1292040335 . Chapter 6 (188-210), Chapter 7 (227-256), Chapter 10 (352-365), Chapter 12 (419-426).** Crawford, M., Di Benedetto, A. (2008). New products management, 9th edition, McGrw Hill, Boston et al., 2008 Christensen, C. M. (1997). Innovator's Dilemma: When New Technologies Cause Great Firms to Fail, Harvard Business Press, Chapter 1: How can great firms fail?,pp. 3-24. Hair, J. F., Bush, R. P., Ortinau, D. J. (2009). Marketing research. 4th edition, Boston et al., McGraw Hill Tidd; J. & Hull, Frank M. (Editors) (2007) Service Innovation, London Von Hippel, E.(2005). Democratizing Innovation, Cambridge: MIT Press

Course L0862: PBL Marketing of Innovations	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Christian Lüthje
Language	EN
Cycle	SoSe
Content	This PBL course is seggregated into two afternoon sessions. This cours aims at enhancing the students' practical skills in (1) forecasting the future development of markets and (2) making appropriate market-related decisions (particularly segmentation, managing the marketing mix). The students will be prompted to use the knowledge gathered in the lecture of this module and will be invited to (1) Conduct a scenario analysis for an innovative product category and (2) Engage in decision making wtihin a market simulation game.
Literature	

Module M0996: Supply Chain Management

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Supply Chain Management (L1218)	Project-/problem-based Learning	3	4
Value-Adding Networks (L1190)	Lecture	2	2

Module Responsible	Prof. Thorsten Blecker
Admission Requirements	None
Recommended Previous Knowledge	no
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Current developments in international business activities such as outsourcing, offshoring, internationalization and globalization and emerging markets illustrated by examples from practice. • Theoretical Approaches and methods in logistics and supply chain management and use in practice. • to identify fields of decision in SCM . • reasons for the formation of networks based on various theories from institutional economics (transaction cost theory, principal-agent theory, property-right theory) and the resource-based view. • Selected approaches to explain the development of networks. • to illustrate phases of network formation. • to understand the functional mechanisms of inter-organizational and international network relationships. • to explain and categorize relationships within networks. • to categorize sourcing concepts and explain motives/ barriers or advantages and disadvantages. • advantages and disadvantages of offshoring and outsourcing and to illustrate the distinction between the two terms . • to state criteria/ factors/ parameters that influence production location decisions at the global level (total network costs). • to explain methods for location finding/evaluation. • to interpret phenotypes of production networks. • recognize relationships between R & D and production and their locations and to describe coherent models. • to solve sub-problems with the configuration of logistics networks (distribution and spare parts networks) by the use of appropriate approaches. • to categorise special waste logistics including their duties & objectives and to state and describe practical examples of good networking.
Skills	• to asses trends and challenges in national and international supply chains and logistics networks and their consequences for companies. • to evaluate, anaylse and systematise networks and network relations based on the lecture. • to anaylse partners and their suitability for co-operation in collaborations and cooperative relations. • to select sourcing concepts for specific products / product components based on the lecture as well as advantages and disadvantages of each approach. • to evaluate location decisions for production and R & D based on concepts. • to recognize relationships between R & D and production as well as their locations and to evaluate the suitability of specific models for different situations. • to transfer the analyzed concepts to international practices. • to analyse and evaluate the product development processes. • to anaylse concepts of Information and communication management in logistics. • to design subcontracting, procurement, production and disposal as well as R & D networks to shape, • to plan reorganise efficient and flow-oriented enterprise networks. • to adopt methods of complexity management and risk management in logistics.
Personal Competence	
Social Competence	• to evaluate intercultural and international relationships based on discussed case studies. • advance planning and design of network formation and their objectives based on content discussed in the lecture. • definition of procurement strategies for individual parts using the gained knowledge of procurement networks. • design of the procurement network (external/internal/modules etc.) based on the sourcing concepts and core competencies, as well as on the findings of the case studies. • to make decision of location for production taking into account global contexts, evaluation methods and buying/selling markets, which were also discussed in the case studies and their dependence on R & D. • Decision on R & D locations based on the insights gained from case studies / practical examples and the selection of an appropriate model.
Autonomy	After completing the module students are capable to work independently on the subject of Supply Chain Management and transfer the acquired knowledge to new problems.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** No; **Bonus** 15 %; **Form** Subject theoretical practical work; **Description** andim Rahmen der Lehrveranstaltung "Supply Chain Management"
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory

Course L1218: Supply Chain Management	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Christian Thies
Language	DE
Cycle	SoSe
Content	• Vermittlung eines tiefgreifenden Verständnisses von Logistik und Supply Chain Management • Vermittlung umfassender theoretischer Ansätze und Methoden in der Logistik und im Supply Chain Management; Übertragung der analysierten Konzepte auf Praxisbeispiele • Ausarbeitung und kritische Diskussion unterschiedlicher Supply Chain Konfigurationen sowie strategischer Supply Chain Ansätze (z.B. Effizienz vs. Reaktionsfähigkeit) • Einführung in die Managementprozesse des SCOR-Modells; Vermittlung von Konzepten der Bereiche Planung, Beschaffung/Einkauf und Distribution • Vermittlung von Grundlagen des Supply Chain Risikomanagements; Übertragung der Konzepte auf Praxisbeispiele • Einführung in die digitale Transformation; Identifikation von Trends und Strategien in der Logistik und Supply Chain Management; Ableitung von Chancen der digitalen Transformation in der Logistik und Supply Chain Management • Einführung in die Datenanalyse und -visualisierung mithilfe eines Tools; Anwenden der Kenntnisse auf Themengebiete in der Logistik und Supply Chain Management; Aufbereitung der Ergebnisse mit Hilfe moderner Präsentationsmedien
Literature	Bowersox, D. J., Closs, D. J. und Cooper, M. B. (2010): Supply chain logistics management, 3 rd edition, Boston [u.a.]: McGraw-Hill/Irwin. Chopra, S. und Meindl, P. (2016): Supply chain management: strategy, planning, and operation, 6 th edition, Boston [u.a.]: Pearson. Corsten, H., Gössinger, R. (2007): Einführung in das Supply Chain Management, 2. Aufl., München/Wien: Oldenbourg. Corsten, H., Gössinger, R., Spengler, Th. (Hrsg., 2018): Handbuch Produktions- und Logistikmanagement in Wertschöpfungsnetzwerken, Berlin/Boston. Heiserich O., Helbig, K. und Ullmann, W. (2011): Logistik, 4. vollständig überarbeitete und erweiterte Auflage, Wiesbaden: Gabler Verlag/ Springer Fachmedien. Heizer, J., Render, B., Munson, Ch. (2020): Principles of Operations Management, 11 th edition, Boston: Pearson. Hugos, M. (2018): Essentials of Supply Chain Management, Wiley. Fisher, M. (1997): What is the right supply chain for your product?, Harvard Business Review, Vol. 75, No. pp., S. 105-117. Kersten, W. Seiter, M., von See, B, and Hackius, N. und Maurer, T. (2017): Trends und Strategien in Logistik und Supply Chain Management: Chancen der digitalen Transformation, DVV Media Group GmbH: Hamburg. Kuhn, A. und Hellingrath, B. (2002): Supply Chain Management: optimierte Zusammenarbeit in der Wertschöpfungskette, Berlin [u.a.]: Springer. Larson, P., Poist, R. and Halldórsson, Á. (2007): Perspectives on logistics vs. SCM: a survey of SCM professionals, in: Journal of Business Logistics, Vol. 28, No. 1, S. 1-24. Kummer, S., Grün, O. und Jammernegg, W. (2018): Grundzüge der Beschaffung, Produktion und Logistik, 4. aktualisierte Auflage, München: Pearson Studium. Obermaier, Robert (Hrsg., 2019): Handbuch Industrie 4.0 und Digitale Transformation: Betriebswirtschaftliche, technische und rechtliche Herausforderungen, Wiesbaden. Porter, M. (1986): Changing Patterns of International Competition, California Management Review, Vol. 28, No. 2, S. 9-40. Schröder, M./ Wegner, K., Hrsg. (2019): Logistik im Wandel der Zeit - Von der Produktionssteuerung zu vernetzten Supply Chains, Wiesbaden: Springer Gabler Simchi-Levi, D., Kaminsky, P. und Simchi-Levi, E. (2008): Designing and managing the supply chain: concepts, strategies and case studies, 3rd edition, Boston [u.a.]: McGraw-Hill/Irwin. Supply Chain Council (2014): Supply Chain Operations Reference (SCOR) model: Overview - Version 11.0. Swink, M., Melnyk, S. A., Cooper, M. B. und Hartley, J. L. (2011): Managing Operations - Across the Supply Chain. 2 nd edition, New York, NY: McGraw-Hill/Irwin. Weele , A. J. v. (2005): Purchasing & supply chain management, 4th edition, London [u.a.]: Thomson Learning.

Course L1190: Value-Adding Networks	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Thorsten Blecker
Language	DE
Cycle	SoSe
Content	• Introduction: Overview of current trade flows and development of global business cooperation • Networks explanations using neo institutional approaches as a theoretical basis • Networks organization and functioning • Development stages of networks • Presentation of different network types such as supplier, production, disposal and logistics network as well as their respective requirements, peculiarities and characteristics
Literature	• **Ballou, R.** Business Logistics/Supply Chain Management, Upper Saddle River 2004. • **Bellmann, K.** (Hrsg.): Kooperations- und Netzwerkmanagement, Berlin 2001. • **Bretzke, W.R.**: Logistische Netzwerke, Berlin Heidelberg 2008. • **Blecker, Th. / Gemünden, H. G.** (Hrsg.): Wertschöpfungsnetzwerke, Berlin 2006. • **Kaluza, B. / Blecker, Th.** (Hrsg.): Produktions- und Logistikmanagement in virtuellen Unternehmen und Unternehmensnetzwerken, Berlin et al. 2000. • **Sydow, J. / Möllering**: Produktion in Netzwerken, Berlin 2009. • **Willibald A. G.** (Hrsg.): Neue Wege in der Automobillogistik, Berlin Heidelberg 2007.

Module M1034: Technology Entrepreneuship

Courses

Title	Typ	Hrs/wk	CP
Creation of Business Opportunities (L1280)	Project-/problem-based Learning	3	3
Entrepreneurship (L1279)	Lecture	2	3

Module Responsible	Prof. Christoph Ihl
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in business economics obtained in the compulsory modules as well as an interest in new technologies and the pursuit of new business opportunities either in corporate or startup contexts.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Wissen (subject-related knowledge and understanding): • develop a working knowledge and understanding of the entrepreneurial perspective • understand the difference between a good idea and scalable business opportunity • understand the process of taking a technology idea and finding a high-potential commercial opportunity • understand the components of business models • understand the components of business opportunity assessment and business plans

Skills	• Fertigkeiten (subject-related skills):
	  ◦ identify and define business opportunities
	  ◦ assess and validate entrepreneurial opportunities
	  ◦ create and verify a business model of how to sell and market an entrepreneurial opportunity
	  ◦ formulate and test business model assumptions and hypotheses
	  ◦ conduct customer and expert interviews regarding business opportunities
	  ◦ prepare business opportunity assessment
	  ◦ create and verify a plan for gathering resources such as talent and capital
	  ◦ pitch a business opportunity to your classmates and the teaching team

Personal Competence	
Social Competence	Sozialkompetenz (Social Competence): • team work • communication and presentation • give and take critical comments • engaging in fruitful discussions
Autonomy	Selbständigkeit (Autonomy): • autonomous work and time management • project management • analytical skills
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Three presentations on the respective project status
Assignment for the Following Curricula	Global Technology and Innovation Management & Entrepreneurship: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory Logistics, Infrastructure and Mobility: Core Qualification: Elective Compulsory Mechanical Engineering and Management: Specialisation Management: Elective Compulsory

Course L1280: Creation of Business Opportunities	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Christoph Ihl
Language	EN
Cycle	SoSe
Content	Important note: This course is part of an 6 ECTS module consisting of two courses "Entrepreneurship" & "Creation of Business Opportunities", which have to be taken together in one semester. Startups are temporary, team-based organizations, which can form both within and outside of established companies, to pursue one central objective: taking a new venture idea to market by designing a business model that can be scaled to a full-grown company. In this course, students will form startup teams around self-selected ideas and run through the process just like real startups would do in the first three months of intensive work. Startup Engineering takes an incremental and iterative approach, in that it favors variety and alternatives over one detailed, linear five-year business plan to reach steady state operations. From a problem solving and systems thinking perspective, student teams create different possible versions of a new venture and alternative hypotheses about value creation for customers and value capture vis-à-vis competitors. We will draw on recent scientific findings about international success factors of new venture design. To test critical hypotheses early on, student teams engage in scientific, evidence-based, experimental trial-and-error learning process that measures real progress. Upon completion of this course, students will be able to: · Apply a modern innovation toolkit relevant in both the corporate & startup world · Analyze given business opportunities in terms of its constituent elements · Design new business models by gathering and combining relevant ideas, facts and information · Evaluate business opportunities and derive judgment about next steps & decisions Course language is English, but participants can decide to give their graded presentations in German. Students are invited to apply to this course module already with a startup idea and/ or team, but this is not a requirement! We will form teams and ideas in the beginning of the course. Class meetings have alternate intervals of lecture inputs, teamwork, mentoring, and peer feedback. Attendance is mandatory for at least 80% of class time due to large proportion of teamwork sessions. Student teams give three presentations and submit them with backup analyses. Grading scheme: · Startup discovery presentation after 5 weeks: 30% · Startup validation presentation after 10 weeks: 30% · Final startup pitches after 13 weeks: 40%
Literature	• Blank, S. & Dorf, B. (2012). The startup owner's manual. • Gans, J. & Stern, S. (2016). Entrepreneurial Strategy. • Osterwalder, A. & Yves, P. (2010). Business model generation. • Maurya, A. (2012). Running lean: Iterate from plan A to a plan that works. • Maurya, A. (2016). Scaling lean: Mastering the Key Metrics for Startup Growth. • Wilcox, J. (2016). FOCUS Framework: How to Find Product-Market Fit.

Course L1279: Entrepreneurship	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christoph Ihl
Language	EN
Cycle	SoSe
Content	Important note: This course is part of an 6 ECTS module consisting of two courses "Entrepreneurship" & "Creation of Business Opportunities", which have to be taken together in one semester. Startups are temporary, team-based organizations, which can form both within and outside of established companies, to pursue one central objective: taking a new venture idea to market by designing a business model that can be scaled to a full-grown company. In this course, students will form startup teams around self-selected ideas and run through the process just like real startups would do in the first three months of intensive work. Startup Engineering takes an incremental and iterative approach, in that it favors variety and alternatives over one detailed, linear five-year business plan to reach steady state operations. From a problem solving and systems thinking perspective, student teams create different possible versions of a new venture and alternative hypotheses about value creation for customers and value capture vis-à-vis competitors. We will draw on recent scientific findings about international success factors of new venture design. To test critical hypotheses early on, student teams engage in scientific, evidence-based, experimental trial-and-error learning process that measures real progress. Upon completion of this course, students will be able to: · Apply a modern innovation toolkit relevant in both the corporate & startup world · Analyze given business opportunities in terms of its constituent elements · Design new business models by gathering and combining relevant ideas, facts and information · Evaluate business opportunities and derive judgment about next steps & decisions Course language is English, but participants can decide to give their graded presentations in German. Students are invited to apply to this course module already with a startup idea and/ or team, but this is not a requirement! We will form teams and ideas in the beginning of the course. Class meetings have alternate intervals of lecture inputs, teamwork, mentoring, and peer feedback. Attendance is mandatory for at least 80% of class time due to large proportion of teamwork sessions. Student teams give three presentations and submit them with backup analyses. Grading scheme: · Startup discovery presentation after 5 weeks: 30% · Startup validation presentation after 10 weeks: 30% · Final startup pitches after 13 weeks: 40%
Literature	• Blank, S. & Dorf, B. (2012). The startup owner's manual. • Gans, J. & Stern, S. (2016). Entrepreneurial Strategy. • Osterwalder, A. & Yves, P. (2010). Business model generation. • Maurya, A. (2012). Running lean: Iterate from plan A to a plan that works. • Maurya, A. (2016). Scaling lean: Mastering the Key Metrics for Startup Growth. • Wilcox, J. (2016). FOCUS Framework: How to Find Product-Market Fit.

Module M0558: Business Optimization - Advanced Operations Research

Courses

Title	Typ	Hrs/wk	CP
Business Optimization and Operations Research (L0155)	Lecture	2	2
Project: Modelling in Operations Research (L1793)	Project-/problem-based Learning	1	1
Seminar Operations Research (L0156)	Seminar	2	3

Module Responsible Prof. Kathrin Fischer

Admission Requirements None

Recommended Previous Knowledge Knowledge from the module "Quantitative Methods": Linear Programming, Network Optimization and basics of Integer Programming.

Educational Objectives After taking part successfully, students have reached the following learning results

Professional Competence

Knowledge After taking this module, students have an in-depth knowledge of the following areas: They are able to

- explain complex quantitative models for applications, e.g. production models with integrated inventory holding over time, portfolio models, revenue management models
- Discuss advanced topics in linear programming, e.g, duality theory and its application, special structures as upper/lower bounds for variables; revised simplex method etc.
- Analyze problems with multiple objectives and under uncertainty, i.e. the adaption of linear programming models to realistic applications as e.g. international humanitarian logistics problems (distribution of relief goods);
- Discuss advanced topics in integer programming: complex problems, e.g. from vehicle routing, and logical constraints; advanced solutions procedures as branch and bound, cutting-plane procedures etc.
- Examine dynamic and non-linear programming problems and applications in Management;
- Solve OR problems using appropriate software;
- Understand and explain OR reserach projects they learn about in the course.

Skills Students have in-depth abilities in the following areas: They are able to

- formulate complex quantitative models for applications, e.g. production models with integrated inventory holding over time, portfolio models, revenue management models
- Apply duality theory in linear programming and analyze special structures as upper/lower bounds for variables; use the revised simplex method etc.
- Analyze problems with multiple objectives and under uncertainty, i.e. the adaption of linear programming models to realistic applications
- Set up advanced models in integer programming and solve them, e.g. problems from vehicle routing, or logical constraints
- Analyze dynamic and non-linear programming problems and applications in Management
- to understand a specified planning problem of OR research, to implement a solution and to document and explain their approach in a concise way.

Personal Competence

Social Competence Students are able to

- work successfully in a team, organize the team, and solve complex tasks in a team in a given time frame
- give structured feedback, following feedback rules, and also accept deeback from their fellow students
- lead discussions on problems from the field of OR
- present the results of their work to specialists.

Autonomy Students are able to

- independently acquire relevant scientific knowledge from the literature
- independently carry out a (pre-defined) complex research task
- aggregate their knowledge and results and present it to others
- apply their knowledge and experience also to new problems and unknown situations.

Workload in Hours Independent Study Time 110, Study Time in Lecture 70

Credit points 6

Course achievement

Compulsory	Bonus	Form	Description
Yes	5 %	Group discussion	

Examination Subject theoretical and practical work

Examination duration and scale To be announced in Lecture

Assignment for the Following Curricula International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory
Logistics, Infrastructure and Mobility: Core Qualification: Elective Compulsory

Course L0155: Business Optimization and Operations Research	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kathrin Fischer
Language	DE
Cycle	SoSe
Content	• Complex quantitative models for applications, e.g. production models with integrated inventory holding over time, portfolio models, revenue management models • Advanced topics in linear programming, e.g, duality theory and its application, special structures as upper/lower bounds for variables; revised simplex method etc. • Problems with multiple objectives and under uncertainty: adaption of linear programming models to realistic applications • Topics from current OR research, e.g. from the field of humanitarian logistics and revenue management • Advanced topics in integer programming: Modelling complex problems, e.g. from vehicle routing, and logical constraints; advanced solutions procedures as branch and bound, cutting-plane procedures etc. • Dynamic and non-linear programming and its applications in Management • Applications of models and methods in the area of supply chain management and logistics, e.g. in location planning etc.
Literature	Bücher: Albright, C., Winston, W.: Management Science Modeling. Revised Third Edition, South-Western 2009. Eiselt, H.A., Sandblom, C.-L.: Linear Programming and its Applications, Springer 2007. Eiselt, H.A., Sandblom, C.-L.: Integer Programming and Network Models, Springer 2000. Eiselt, H.A., Sandblom, C.-L.: Decision Analysis, Location Models, and Scheduling Problems, Springer 2004. Suhl, L., Mellouli, T.: Optimierungssysteme. Springer, Berlin et al., 2. Auflage, 2009. Williams, H.P.: Model Building in Mathematical Programming. 5th edition, Wiley & Sons, 2013. Winston, W., Venkataramanan, M.: Mathematical Programming. Operations Research, Volume 1, 4th Edition, Thomson, London et al. 2003. Sowie ein Skript, das zur Vorlesung herausgegeben wird.

Course L1793: Project: Modelling in Operations Research	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Kathrin Fischer
Language	DE
Cycle	SoSe
Content	In this course, students develop a computer-based realization for a business application problem in a team of students. In particular, they are required to carry out the following steps: • Modeling the planning situation • Implementation and documentation • Generation of appropriate test data • Testing the implementation, sensitivity analyses etc. • Documentation of results and critical evaluation
Literature	Siehe Vorlesung Operations Research

Course L0156: Seminar Operations Research	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Kathrin Fischer
Language	DE
Cycle	SoSe
Content	Special topics from different areas of the lecture are discussed in the seminar. Students are required to use current publications from highly esteemed journals in their assignment and to write an essay on a relevant OR topic. Moreover, they have to prepare and give a talk on that topic. The seminar is research-oriented and focuses on relevant research topics from the field. Students get a first-hand experience in carrying out a research project in a well-defined, limited area of OR. There is a limitation of the number of seminar participants (36 students). If necessary, selection of participants will be based on the results in the Quantitative Methods module which is a prerequisite for this course.
Literature	Fachartikel (Journal Papers), die zu Beginn des Seminars bekanntgegeben werden.

Module M0866: EIP and Productivity Management

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Elements of Integrated Production Systems (L0927)	Project-/problem-based Learning	2	3
Productivity Management (L0928)	Project-/problem-based Learning	2	2
Productivity Management (L0931)	Recitation Section (small)	1	1

Module Responsible	Prof. Hermann Lödding
Admission Requirements	None
Recommended Previous Knowledge	Basic lecture in Production Organization or Production Management
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	not available
Skills	not available
Personal Competence	
Social Competence	not available
Autonomy	Students are able to define research-related tasks, to acquire the requisite knowledge and to apply it to a problem.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes · **Bonus** None · **Form** Excercises · **Description**
Examination	Written exam
Examination duration and scale	180 Minuten
Assignment for the Following Curricula	International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory

Course L0927: Elements of Integrated Production Systems

Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Hermann Lödding
Language	DE
Cycle	SoSe
Content	not available
Literature	Harris, R.; Harris, C.; Wilson, E.: Making Materials Flow, Lean Enterprise Institute, Cambridge, 2003. Ohno, T.: Das Toyota-Produktionssystem, Campus-Verlag, Frankfurt et al, 1993. Rother, M.: Die Kata des Weltmarktführers. Toyotas Erfolgsmethoden, Campus-Verlag, Frankfurt et al, 2009. Rother, M.; Shook, J.: Sehen lernen: Mit Wertstromdesign die Wertschöpfung erhöhen und Verschwendung beseitigen, Lean Management Institut, Aachen, 2006. Rother, M.; Harris, R.: Creating Continuous Flow, Lean Enterprise Institute, Brookline, 2001. Shingo, S.: A Revolution in Manufacturing. The SMED System, Productivity Press, 2006. Womack, J. P. et al: Die zweite Revolution in der Autoindustrie, Frankfurt/New York, Campus Verlag, 1992.

Course L0928: Productivity Management	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Hermann Lödding, Christopher Mundt
Language	DE
Cycle	SoSe
Content	• Principles of productivity management • Shop floor management and standardisation • Takt analysis and design of manual operations • Maintenance Principles • Total Productive Maintenance (TPM) • Optimisation of set-up operations • Analysis of interlinked production systems
Literature	Bokranz, R.; Landau, K.:Produktivitätsmanagement von Arbeitssystemen. Schäffer-Poeschel, Stuttgart, 2006. Takeda, H.: Das synchrone Produktionssystem: Just-in-Time für das ganze Unternehmen. 5. Aufl., mi-Wirtschaftsbuch, FinanzBuch Verlag, München, 2006. Nakajima, S.: Management der Produktionseinrichtungen (Total Productive Maintenance). Campus Verlag, New York, 1995. Shingo, S.: A Revolution in Manufacturing: The SMED System. Productivity, Inc., 1985

Course L0931: Productivity Management	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Hermann Lödding
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0697: Management Control

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Management Control (L0496)	Lecture	3	3
Management Control (L0495)	Seminar	2	3

Module Responsible	Prof. Matthias Meyer
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of financial and cost accounting
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	On successful completion of this module, the students will know about: • Important concepts of German-language controlling research; • International differences and traditions in corporate management • Central controlling tasks such as the provision of information, planning and control as well as coordination • Differences between data, information and knowledge and they can explain them; • Digitization and impact on controlling • Instruments of operational, tactical and strategic planning; • Selected concepts of game theory, information economics and principal-agent theory; • Performance measures and coordination; • The concept of value-based management and key value-oriented key performance indicators; • Functions and methods for determining transfer prices; • Risk and project controlling instruments and concepts; • Monte Carlo simulation method, also as a research method;
Skills	On successful completion of this module, the students will be able to: • Explain the origin and nature of controlling in practice and to locate it internationally; • Explain important concepts of German-language controlling research; • Assess essential areas of responsibility of and requirements for controllers; • Explain various key figures and systems and classify their advantages and disadvantages; • Explain and apply the levers of reporting design; • Derive design recommendations for the supply of information; • Apply and evaluate essential (planning) instruments of controlling; • Comprehend tactical and strategic issues within companies; • Carry out game theoretical modelling and evaluation of decision-making problems; • Carry out a Monte Carlo simulation and interpret its results • Design and assess transfer prices according to different procedures; • Help shape the process of risk management and to be able to calculate and interpret aggregated risk measures; • Assign psychological theories to individual controlling problems and to derive design recommendations from them.
Personal Competence	
Social Competence	On successful completion of this module, the students can: • Take over controlling tasks and to successfully transfer the theoretical knowledge into operational practice and apply it there; • Decide independently which controlling instruments can and must be used for which problem; • Work together with other team members, to discuss and come to a result together; • Apply concepts from psychology, game theory, information economics and principal-agent theory to new questions; • Present the results of their analyses in an understandable manner, also in English; • Solve business management problems within Controlling and its sub-areas independently and in a team; • Take on complex planning tasks in international companies, also in a managerial capacity.
Autonomy	The students are able... • To acquire knowledge by themselves and to transfer the knowledge acquired to new problems. • To argue the case for their findings (including in English). • develop their own critical understanding of research results
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** No · **Bonus** 8.3 % · **Form** Excercises · **Description**
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory

Course L0496: Management Control	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Matthias Meyer
Language	DE
Cycle	SoSe
Content	Information provision: Ratios and ratio systems, balanced scorecard, reporting, information supply design • Operative planning: Budgeting, operative production planning • Operative controlling: Deviation analysis and forecasting • Tactical planning: Quantitative and qualitative business planning • Strategic planning: Portfolio analysis, SWOT analysis, resource-based view, experience curve concept • Coordination: Economies of scope, value-oriented business ratios, transfer pricing, incentive systems, principal-agent theory • Risk controlling: Value at risk, risk analysis, risk aggregation, risk management, risk control • Project controlling
Literature	1. Skript und Unterlagen, die zur Vorlesung und Übung herausgegeben werden. 2. Ausgewählte Bücher: 3. Balakrishnan, R./Sivaramakrishnan, K./Sprinkle, G. (2009): Managerial Accounting, Hoboken. 4. Ewert, R./Wagenhofer, A. (2008): Interne Unternehmensrechnung, 7. Aufl., Berlin. 5. Merchant, K./Van der Stede, W. (2012): Management Control Systems: Performance Measurement, Evaluation, and Incentives, London. 6. Weber, J./Schäffer, U. (2011): Einführung in das Controlling, 13. Aufl., Stuttgart.

Course L0495: Management Control	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Matthias Meyer
Language	DE
Cycle	SoSe
Content	
Literature	1. Skript und Aufgaben, die zur Vertiefung herausgegeben werden. 2. Weiterführende Literatur, die jeweils mit Blick auf die gesetzten Themenschwerpunkte spezifiziert wird

Module M0543: Advanced Topics in Management, Organization, and Human Resource Management

Courses

Title	Typ	Hrs/wk	CP
Advanced Topics in Management, Organization, and Human Resource Management (L0110)	Lecture	2	3
Advanced Topics in Management, Organization, and Human Resource Management (L0111)	Seminar	2	3

Module Responsible	Prof. Christian Ringle
Admission Requirements	None
Recommended Previous Knowledge	Foundations in Organizational Design and Human Resource Management Basic knowledge on academic writing as well as principles and concepts in business administration and foundations in organizational design and human resource management.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to... • Explain the different organizational designs and strategies in an international environment with a focus on selected forms of cooperation (e.g., virtual organizations or strategic alliances) to compete in global business; • Map the need of organizational changes in light of new business lines, strategies, altering employees' attitudes, and international competition; • Explain the models and approaches for appropriately measuring employee relations (e.g., job satisfaction models), incl. the development and estimation of causal models.
Skills	The students are able to... • Work with empirical data, apply business process management and multivariate techniques to the data collected using standard software, and critically evaluate and interpret the results; • Critically rethink theoretical concepts and gain analytical abilities in organization management and human resource management; • Use their practical knowledge of the analytical toolset to successfully tackle the management challenges in organization and human resource management in internationally acting companies; • Present their results in written and oral form.
Personal Competence	
Social Competence	The students are able to... • Respectfully work in teams; • Have fruitful group discussions; • Present their results in written form and oral presentations.
Autonomy	The students are able to... • Acquire further relevant information independently; • Critically reflect and evaluate this information; • Transfer the acquired knowledge to practical applications.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** Yes · **Bonus** 20 % · **Form** Presentation · **Description**
Examination	Subject theoretical and practical work
Examination duration and scale	Thesis with presentation and assignments during the semester
Assignment for the Following Curricula	International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory Mechanical Engineering and Management: Specialisation Management: Elective Compulsory

Course L0110: Advanced Topics in Management, Organization, and Human Resource Management	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Ringle
Language	EN
Cycle	WiSe
Content	This lecture focuses on multinational firms and advanced issues of management, organizations, and human resource management. This course is structured as a lecture and a seminar. In the lecture, the advanced theoretical concepts are explained and discussed, whereas they are applied in the seminar through the preparation of a seminar thesis. The students learn about the process and structure of a scientific article, and further deepen their knowledge, while working in groups. Example topics: • Management: change management and corporate social responsibility; • Organization: exploration & exploitation, networks, and organizational identity; • Human Resource Management: human resource metrics & analytics and recruitment & selection.
Literature	The students will be provided with selected journal articles. Bernardin, H.J. (2006): Human Resource Management: An Experiential Approach, 4e, New York: McGraw-Hill. Cascio, W. (2015): Managing Human Resources: Productivity, Quality of Work Life, Profits, revised edition, New York: McGraw-Hill. French, W./Bell, C.H./Zawacki, R.A. (2004): Organization Development and Transformation: Managing Effective Change, 6e, Chicago: McGraw-Hill. Hitt, M.A./Ireland, R.D./Hoskisson, R.E. (2014): Strategic Management: Competitiveness and Globalization, 11e, Ohio: Cengage Learning. Lynch, R. (2015): Strategic Management, 7e, Harlow: Prentice Hall.

Course L0111: Advanced Topics in Management, Organization, and Human Resource Management	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christian Ringle
Language	EN
Cycle	WiSe
Content	This course focuses on multinational firms and advanced issues of management, organizations, and human resource management. The students learn about the process and structure of a scientific article and deepen their knowledge while working in groupds. Selected topics focus, for example, on: • Human Resource Management: aging workforce, e-human resource management, generation X, Y, Z, human resource metrics/ analytics, recruitment/ selection/ hiring • Organisation: employee voice, exploration/ exploitation, networks, organisational identity, trust measurement • Management: change management, corporate social responsibility, firm performance measurement, gender, innovation management
Literature	The students will be provided with selected journal articles. Bernardin, H.J. (2006): Human Resource Management: An Experiential Approach, 4e, New York: McGraw-Hill. Cascio, W. (2015): Managing Human Resources: Productivity, Quality of Work Life, Profits, revised edition, New York: McGraw-Hill. French, W./Bell, C.H./Zawacki, R.A. (2004): Organization Development and Transformation: Managing Effective Change, 6e, Chicago: McGraw-Hill. Hitt, M.A./Ireland, R.D./Hoskisson, R.E. (2014): Strategic Management: Competitiveness and Globalization, 11e, Ohio: Cengage Learning. Lynch, R. (2015): Strategic Management, 7e, Harlow: Prentice Hall.

Module M0559: Strategic Management

Courses

Title	Typ	Hrs/wk	CP
Strategic Management (L0158)	Lecture	4	6

Module Responsible	Prof. Thomas Wrona
Admission Requirements	None
Recommended Previous Knowledge	Basic principles in International and Intercultural Management
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will accumulate extensive knowledge about different aspects of strategic management after having participated in this module. Apart from strategic planning, students will be able to discern different contingency factors in strategic decision making and apply various strategies accordingly. Students will gain competences in the following areas: • The historical and theoretical development of strategic management • Different forms of strategy formation • Content and process view of strategic management • Formulation and implementation of strategic options • Management systems and their influence on strategies • The origins of competitive advantage
Skills	• Students are able to analyze and interpret external and internal information in the context of strategic choice • Students are able to differentiate environmental contingencies and assess risk potentials • Students are able to evaluate the attractiveness of different industries • Students are able to evaluate the pros and cons of strategic options and adequately select strategies during implementation • In essence, students are able to conceptually and theoretically “design” strategic decision processes and considers industry and corporate peculiarities during strategic planning Those skills refer to competences in information seeking and analysis, the consolidation of data and their presentation in teams. These skills will be continuously shaped… • During case studies and strategic role plays, where students identify, develop and implement solutions for strategic problems • During complex data analyses, which are performed in groups and discussed in class • By making educated guesses about (yet unknown) corporate phenomena and decision makers attitudes, which are based on prior theoretical knowledge
Personal Competence	
Social Competence	After attending the module students will be able… • To interact and share own thoughts with group members during case study sessions or strategic role plays • To lead and take part in strategy-related discussions • To present results, both in written and verbal form
Autonomy	After attending the module students will be able… • To accumulate knowledge about specified strategic problems and transfer it to other related areas of interest • To identify related literature and integrate relevant findings during problem solution • To present existing and new knowledge about strategic phenomena in own conceptual ways
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 20 % / Subject theoretical and practical work /
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory

Course L0158: Strategic Management	
Typ	Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Thomas Wrona
Language	DE
Cycle	WiSe
Content	• Introduction - Basic concepts and objects within the area of strategic management • Objectives, corporate strategies, mission statements and management systems as an object of strategic management • Theoretical perspectives of strategic management • Analysis and design of selected strategies • Strategic (planning) processes • Integrative application of knowledge based on a number of selected case studies Theoretical, conceptual parts are devoted to the processing and discussion of theoretical contributions from current management research, which are practically applied in case studies and simulations.
Literature	Bamberger, I./Wrona, T. (2012): Strategische Unternehmensführung. Strategien - Systeme - Prozesse, 2. überarbeitete und erweiterte Auflage, München 2012 Bamberger, I./Wrona, T. (2012): Strategische Unternehmensberatung, 6. erweiterte Auflage, Wiesbaden 2012 Bamberger, I./Wrona, T. (1996): Der Ressourcenansatz und seine Bedeutung für die Strategische Unternehmensführung, in: Schmalenbachs Zeitschrift für betriebswirtschaftliche Forschung (zfbf), 2/1996, S. 130-153 Bowman, E.H./Singh, H./Thomas, H. (2006): The domain of strategic management: History and evolution, in: Pettigrew, A./Thomas, H./Whittington, R. (Hrsg.): Handbook of strategy and management, London u.a. 2006, S. 31-54 Johnson, G./Whittington, R./Scholes, K./Angwin, D./Regnér, D. (2017): Exploring strategy. Text and Cases, 11. Aufl., Harlow 2017 Kreikebaum, H./Gilbert, D. U./Behnam, M. (2018): Strategisches Management, Stuttgart. Mintzberg, H./Ahlstrand, B./Lampel, J. (2002): Strategy Safari, New York 2002 (in deutscherSprache: Dies. (2012): Strategy Safari: Der Wegweiser durch den Dschungel des strategischen Managements, 2. Aufl., München 2012) Porter, M. E. (2013): Wettbewerbsstrategie. Methoden zur Analyse von Branchen und Konkurrenten, 12. Aufl., Frankfurt 2013 zu Knyphausen-Aufseß, D. (2012): Theoretische Perspektiven des strategischen Managements, in: Welge, M.K./Al-Laham, A./Kajüter, P. (Hrsg.): Praxis des strategischen Managements, Wiesbaden 2012, S. 39-70 Skripte und Textdokumente, die während der Vorlesung herausgegeben werden:

Module M0815: Product Planning

Courses

Title	Typ	Hrs/wk	CP
Product Planning (L0851)	Lecture	3	3
Product Planning Seminar (L0853)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Cornelius Herstatt
Admission Requirements	None
Recommended Previous Knowledge	Good basic-knowledge of Business Administration
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	

Knowledge	Students will gain insights into:
	• Product Planning
	  ◦ Process
	  ◦ Methods
	• Design thinking
	  ◦ Process
	  ◦ Methods
	  ◦ User integration

Skills	Students will gain deep insights into:
	• Product Planning
	  ◦ Process-related aspects
	  ◦ Organisational-related aspects
	  ◦ Human-Ressource related aspects
	  ◦ Working-tools, methods and instruments
	  ◦

Personal Competence	
Social Competence	• Interact within a team • Raise awareness for globabl issues
Autonomy	• Gain access to knowledge sources • Interpret complex cases • Develop presentation skills
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 20 % / Subject theoretical and practical work /
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Global Innovation Management: Core Qualification: Compulsory International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory Mechanical Engineering and Management: Specialisation Management: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L0851: Product Planning	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Cornelius Herstatt
Language	EN
Cycle	WiSe
Content	Product Planning Process This integrated lecture is designed to understand major issues, activities and tools in the context of systematic product planning, a key activity for managing the front-end of innovation, i.e.: • Systematic scanning of markets for innovation opportunities • Understanding strengths/weakness and specific core competences of a firm as platforms for innovation • Exploring relevant sources for innovation (customers, suppliers, Lead Users, etc.) • Developing ideas for radical innovation, relying on the creativeness of employees, using techniques to stimulate creativity and creating a stimulating environment • Transferring ideas for innovation into feasible concepts which have a high market attractively Voluntary presentations in the third hour (articles / case studies) - Guest lectures by researchers - Lecture on Sustainability with frequent reference to current research - Permanent reference to current research Examination: In addition to the written exam at the end of the module, students have to attend the PBL-exercises and prepare presentations in groups in order to pass the module. Additionally, students have the opportunity to present research papers on a voluntary base. With these presentations it is possible to gain a bonus of max. 20% for the exam. However, the bonus is only valid if the exam is passed without the bonus.
Literature	Ulrich, K./Eppinger, S.: Product Design and Development, 2nd. Edition, McGraw-Hill 2010

Course L0853: Product Planning Seminar	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Cornelius Herstatt
Language	EN
Cycle	WiSe
Content	Seminar is integrative part of the Module Product Planning (for content see lecture) and can not be choosen independantly.
Literature	See lecture information "Product Planning".

Module M0994: Information Technology in Logistics

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Informationtechnology in Logsitics (L1197)	Practical Course	6	6

Module Responsible	Prof. Thorsten Blecker
Admission Requirements	None
Recommended Previous Knowledge	Knowledge from the module "Production and Logistics Management"; Interest in new technologies and their application in logistics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• on the relationship between logistics and IT, and representation and describtion in depth; • information systems and information management, and the application of information systems and information management to logistical issues; • using information technologies that are currently used in logistics, such as RFID, e-logistics and electronic sourcing.
Skills	• to assess the use of information technology in logistics issues and to implement appropriate technologies; • to be able to deal critically with the current developments in IT and logistics and to assess them critically; • analyse in depth relevant issues arising from the thematic field of "IT in Logistics" at a scientific level; • to independently work on current topics from the field of "IT in Logistics"; • analyse the relationship between logistics and IT; • implementing information technology in logistics successfully • to transfer the theoretical knowledge of information technologies to real situations and to give recommendations of action for solving new tasks; • to solve logistical problems using information technology
Personal Competence	
Social Competence	• to conduct subject-specific and interdisciplinary discussions; • oral and written presentation of results • respectful team work
Autonomy	• work independently on a subject and transfer the acquired knowledge to new problems.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	-
Assignment for the Following Curricula	International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory

Course L1197: Informationtechnology in Logsitics	
Typ	Practical Course
Hrs/wk	6
CP	6
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Lecturer	Prof. Thorsten Blecker
Language	DE
Cycle	WiSe
Content	• In the beginning the students get insight of the functionality of a service-oriented architecture. • Then the students will get a logistic problem to solve in small groups. • The elaborations result shall be one or more programmed services/module that together with the other groups result completes a total application.
Literature	Skripte und Textdokumente, die während der Vorlesung herausgegeben werden

Module M1003: Management Control Systems for Operations

Courses

Title	Typ	Hrs/wk	CP
Management Control Systems for Operations (L1219)	Lecture	2	2
Management Control Systems for Operations (Seminar) (L2967)	Seminar	2	3
Management Control Systems for Operations (Exercise) (L1224)	Recitation Section (small)	1	1

Module Responsible Prof. Wolfgang Kersten

Admission Requirements None

Recommended Previous Knowledge Introduction to Business and Management

Educational Objectives After taking part successfully, students have reached the following learning results

Professional Competence

Knowledge Students have acquired in depth knowledge in the following areas and can

- explain the function and the requirements of management control systems,
- explain the targets and the tasks of production and supply chain comtrolling,
- understand management control systems for production in an international context,
- explain the major aspects of investment planning and control,
- explain the major aspects of cost management,
- explain and understand the procedures of budgeting,
- present and give a detailed explanation of methods and tools of management control systems for production and supply chains,
- describe opportunities and risks of digitalization for the design of management control systems for production and supply chains,
- give an overview of relevant research topics for management control systems for production and supply chains.

Skills Based on the acquired knowledge students are capable of

- Applying methods of managerial accounting in production and logistics in an international context,
- Selecting sufficient methods of managerial accounting in production and logistics to solve practical problems,
- Selecting appropriate methods of managerial accounting in production and logistics also for non-standardized problems,
- Making a holistic assessment of areas of decision in management control systems for production and logistics and relevant influence factors.

Personal Competence

Social Competence After completion of the module students can

- lead discussions and team sessions,
- arrive at work results in groups and document them,
- develop joint solutions in mixed teams and present them to others,
- present solutions to specialists and develop ideas further.

Autonomy After completion of the module students can

- assess possible consequences of their professional activity,

- define tasks independently, acquire the requisite knowledge and use suitable means of implementation,

- define and carry out research tasks bearing in mind possible societal consequences.

Workload in Hours Independent Study Time 110, Study Time in Lecture 70

Credit points 6

Course achievement

Compulsory	Bonus	Form	Description
Yes	20 %	Subject theoretical and practical work	

Examination Written exam

Examination duration and scale 90 min

Assignment for the Following Curricula Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory
International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory
Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory

Course L1219: Management Control Systems for Operations	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Wolfgang Kersten
Language	DE
Cycle	WiSe
Content	• Identification of missions and changing requirements on controlling • Differentiating managerial accounting, production management, logistics and supply chain controlling • Considering global dispersed supply chain networks in production management and supply chain controlling • Analyzing investment projects and resulting effects (investment control, risk management in investment) • In depth knowledge in planning, realizing and controlling investments • Developing characteristics of differentiation for cost and activity accounting (aim, purpose, opportunities in structuring etc.) • In depth knowledge in cost management (cost types and units) • Budgeting in practice; Analysis of existing methods • Development of an approach in activity based costing • Application of target costing • Knowing the importance and method of life cycle costing • Applying performance figures in production and logistics • Discussion of opportunities and risks of digitalization for the design of management control systems for production and supply chains • Developing recommendations for problem solving by using research oriented problem based learning sessions for relevant actual topics and cases; thereby preparing and presenting results in intercultural teams
Literature	Altrogge, G. (1996): Investition, 4. Aufl., Oldenbourg, München Arvis, J.-F. et al. (2018): Connecting to Compete - Trade Logistics in the Global Economy, The World Bank Group, Washington, DC, USA; Download: https://openknowledge.worldbank.org/handle/10986/29971 Betge, P. (2000): Investitionsplanung: Methoden, Modelle, Anwendungen, 4. Aufl., Vahlen, München. Christopher, M. (2005): Logistics and Supply Chain Management, 3. Aufl., Pearson Education, Edinburgh. Corsten, H., Gössinger, R., Spengler, Th. (Hrsg., 2018): Handbuch Produktions- und Logistikmanagement in Wertschöpfungsnetzwerken, Berlin/Boston. Eversheim, W., Schuh, G. (2000): Produktion und Management. Betriebshütte: 2 Bde., 7. Aufl., Springer Verlag, Berlin. Friedl, G., Hofmann, C., Pedell, B. (2017): Kostenrechnung - Eine entscheidungsorientierte Einführung, 3. Aufl., Vahlen, München. Günther, H.-O., Tempelmeier, H. (2005): Produktion und Logistik, 6. Aufl., Springer Verlag, Berlin. Hahn, D. Horváth, P., Frese, E. (2000): Operatives und strategisches Controlling, in: Eversheim, W., Schuh, G. (Hrsg.): Produktion und Management. Betriebshütte: 2 Bde. Springer Verlag, Berlin. Hansmann, K.-W. (1987): Industriebetriebslehre, 2. Aufl., Oldenbourg, München. Hoitsch, H.-J. (1993): Produktionswirtschaft: Grundlagen einer industriellen Betriebswirtschaftslehre, 2. Aufl., Vahlen, München. Horváth, P./ Gleich, R./ Seiter, M. (2020): Controlling, 14. Aufl., Vahlen, München. Kersten, W. et al. (2017): Chancen der digitalen Transformation. Trends und Strategien in Logistik und Supply Chain Management, DVV Media Group, Hamburg. Kruschwitz, L. (2009): Investitionsrechnung, 12. Aufl., Oldenbourg, München. Obermaier, Robert (Hrsg., 2019): Handbuch Industrie 4.0 und Digitale Transformation: Betriebswirtschaftliche, technische und rechtliche Herausforderungen, Wiesbaden Preißler, P. R. (2000): Controlling. 12. Aufl., Oldenbourg Wissenschaftsverlag, München. Weber, J./ Wallenburg, C. M. (2010): Logistik- und Supply Chain Controlling, 6. Auflage, Schaeffer Poeschel Verlag, Stuttgart. Wildemann, H. (1987): Strategische Investitionsplanung, Methoden zur Bewertung neuer Produktionstechnologien, Gabler, Wiesbaden. Wildemann, H. (2001): Produktionscontrolling: Systemorientiertes Controlling schlanker Produktionsstrukturen, 4. Aufl. TCW, München.

Course L2967: Management Control Systems for Operations (Seminar)	
Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Wolfgang Kersten
Language	DE
Cycle	WiSe
Content	
Literature	Die angewandte Fachliteratur ist von den jeweils gewählten Themen abhängig und wird passend zu den Semesterthemen aktualisiert. Darüberhinaus steht die Fachliteratur der korrespondierenden Vorlesung zur Verfügung.

Course L1224: Management Control Systems for Operations (Exercise)	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Wolfgang Kersten
Language	DE
Cycle	WiSe
Content	• Identification of missions and changing requirements on controlling • Differentiating managerial accounting, production management, logistics and supply chain controlling • Considering global dispersed supply chain networks in production management and supply chain controlling • Analyzing investment projects and resulting effects (investment control, risk management in investment) • In depth knowledge in planning, realizing and controlling investments • Developing characteristics of differentiation for cost and activity accounting (aim, purpose, opportunities in structuring etc.) • In depth knowledge in cost management (cost types and units) • Budgeting in practice; Analysis of existing methods • Development of an approach in activity based costing • Application of target costing • Knowing the importance and method of life cycle costing • Applying performance figures in production and logistics • Developing recommendations for problem solving by using problem based learning sessions for case studies; thereby preparing and presenting results in intercultural teams
Literature	Altrogge, G. (1996): Investition, 4. Aufl., Oldenbourg, München Betge, P. (2000): Investitionsplanung: Methoden, Modelle, Anwendungen, 4. Aufl., Vahlen, München. Christopher, M. (2005): Logistics and Supply Chain Management, 3. Aufl., Pearson Education, Edinburgh. Eversheim, W., Schuh, G. (2000): Produktion und Management. Betriebshütte: 2 Bde., 7. Aufl., Springer Verlag, Berlin. Günther, H.-O., Tempelmeier, H. (2005): Produktion und Logistik, 6. Aufl., Springer Verlag, Berlin. Hahn, D. Horváth, P., Frese, E. (2000): Operatives und strategisches Controlling, in: Eversheim, W., Schuh, G. (Hrsg.): Produktion und Management. Betriebshütte: 2 Bde. Springer Verlag, Berlin. Hansmann, K.-W. (1987): Industriebetriebslehre, 2. Aufl., Oldenbourg, München. Hoitsch, H.-J. (1993): Produktionswirtschaft: Grundlagen einer industriellen Betriebswirtschaftslehre, 2. Aufl., Vahlen, München. Horváth, P. (2011): Controlling, 12. Aufl., Vahlen, München. Kruschwitz, L. (2009): Investitionsrechnung, 12. Aufl., Oldenbourg, München. Martinich, J. S. (1997): Production and operations management: an applied modern approach. Wiley. Preißler, P. R. (2000): Controlling. 12. Aufl., Oldenbourg Wissenschaftsverlag, München. Weber, J. (2002): Logistik- und Supply Chain Controlling, 5. Auflage, Schaeffer-Poeschel Verlag, Stuttgart. Wildemann, H. (1987): Strategische Investitionsplanung, Methoden zur Bewertung neuer Produktionstechnologien, Gabler, Wiesbaden. Wildemann, H. (2001): Produktionscontrolling: Systemorientiertes Controlling schlanker Produktionsstrukturen, 4. Aufl. TCW, München.

Module M1035: Entrepreneurial Finance

Courses

Title	Typ	Hrs/wk	CP
Entrepreneurial Finance: Case Studies (L1282)	Seminar	3	4
Entrepreneurial Finance: Lecture (L1281)	Lecture	2	2

Module Responsible	Prof. Christoph Ihl
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in business economics and finance obtained in the compulsory modules and participation in the module “Technology Entrepreneurship” is highly recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Wissen (subject-related knowledge and understanding): • understand the structure of a financial plan for a new venture • understand the procedures, pros and cons of different valuation methods • understand the design of financial contracts and term sheets • understand the interests of venture capital funds • understand the pros and cons of different growth and exit options
Skills	Fertigkeiten (subject-related skills): • prepare a financial plan for a new venture • value a new venture in financial terms • apply different valuation methods • evaluate the attractiveness of financial contracts • design VC term sheets • design employee contracts in terms of financial compensation • design financial contracts and conduct financial negotiations • assess and justify possible growth and exit options
Personal Competence	
Social Competence	Sozialkompetenz (Social Competence): • team work • communication and presentation • give and take critical comments • engaging in fruitful discussions
Autonomy	Selbständigkeit (Autonomy): • autonomous work and time management • project management • analytical skills
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 20 % / Group discussion
Examination	Subject theoretical and practical work
Examination duration and scale	Presentations and case study work
Assignment for the Following Curricula	Global Innovation Management: Core Qualification: Elective Compulsory Global Technology and Innovation Management & Entrepreneurship: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory Mechanical Engineering and Management: Specialisation Management: Elective Compulsory

Course L1282: Entrepreneurial Finance: Case Studies	
Typ	Seminar
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Christoph Ihl
Language	EN
Cycle	WiSe
Content	Entrepreneurial finance is at the center of a clash of two very distant worlds: that of entrepreneurship and that of finance. Finance is disciplined, based on numbers and logical thinking and looking for proven track records. Entrepreneurship is messy, based on intuition and experimentation and treading off the beaten track. Entrepreneurial finance is the provision of funding to young, innovative, growth-oriented companies. Entrepreneurial companies are young, typically less than ten years old, and introduce innovative products or business models. The younger are called “startups,” and are typically less than five years old. There is a variety of investors who can finance entrepreneurial companies: family and friends, business angels, accelerators and incubators, crowdfunding platforms, venture capital firms, corporate investors, etc. The course provides a thorough understanding of what motivates them, of the way they invest, and of what support they can provide to a company at what stage in the fundraising cycle. The course addresses the following key questions: How much money can and should be raised? When should it be raised and from whom? What is a reasonable valuation of the company? How should funding, employment contracts and exit decisions be structured? Thus, the course provides an understanding of the whole fundraising cycle, from the moment the entrepreneur conceived her idea to the moment investors exit the company and move on. We examine the entrepreneur's signalling to investors of the qualities of the venture, the investors' evaluation of the venture, the various dimensions of contracting (cash flow rights, control rights, compensation, and other clauses), the negotiation of a deal and the provision of corporate governance, the process of staged financing, the financing through debt, and the exit process though liquidity events such as initial public offering, sale or merger. The following topics will be covered with specific case studies: 1. Introduction: Evaluating Venture Opportunities 2. Financial Planning 3. Ownership and Returns 4. Valuation Methods 5. Term Sheets 6. Structuring Deals 7. Corporate Governance 8. Staged Financing 9. Debt Financing 10. Exits 11. Early Stage & Venture Capital Investors 12. Ecosystems
Literature	Da Rin, Marco, and Thomas Hellmann. Fundamentals of Entrepreneurial Finance. Oxford University Press, 2020.

Course L1281: Entrepreneurial Finance: Lecture	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Christoph Ihl
Language	EN
Cycle	WiSe
Content	Entrepreneurial finance is at the center of a clash of two very distant worlds: that of entrepreneurship and that of finance. Finance is disciplined, based on numbers and logical thinking and looking for proven track records. Entrepreneurship is messy, based on intuition and experimentation and treading off the beaten track. Entrepreneurial finance is the provision of funding to young, innovative, growth-oriented companies. Entrepreneurial companies are young, typically less than ten years old, and introduce innovative products or business models. The younger are called “startups,” and are typically less than five years old. There is a variety of investors who can finance entrepreneurial companies: family and friends, business angels, accelerators and incubators, crowdfunding platforms, venture capital firms, corporate investors, etc. The course provides a thorough understanding of what motivates them, of the way they invest, and of what support they can provide to a company at what stage in the fundraising cycle. The course addresses the following key questions: How much money can and should be raised? When should it be raised and from whom? What is a reasonable valuation of the company? How should funding, employment contracts and exit decisions be structured? Thus, the course provides an understanding of the whole fundraising cycle, from the moment the entrepreneur conceived her idea to the moment investors exit the company and move on. We examine the entrepreneur's signalling to investors of the qualities of the venture, the investors' evaluation of the venture, the various dimensions of contracting (cash flow rights, control rights, compensation, and other clauses), the negotiation of a deal and the provision of corporate governance, the process of staged financing, the financing through debt, and the exit process though liquidity events such as initial public offering, sale or merger. The following topics will be covered in lectures: 1. Introduction: Evaluating Venture Opportunities 2. Financial Planning 3. Ownership and Returns 4. Valuation Methods 5. Term Sheets 6. Structuring Deals 7. Corporate Governance 8. Staged Financing 9. Debt Financing 10. Exits 11. Early Stage & Venture Capital Investors 12. Ecosystems
Literature	Da Rin, Marco, and Thomas Hellmann. Fundamentals of Entrepreneurial Finance. Oxford University Press, 2020.

Module M1683: Project and Negotiation Management

Courses

Title	Typ	Hrs/wk	CP
Open Project Exercise (L2798)	Recitation Section (small)	1	1
Project Management (L0709)	Lecture	2	2
Negotiation Management (L2669)	Project-/problem-based Learning	3	3

Module Responsible	Prof. Christian Lüthje
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results

Professional Competence

Knowledge

Students will be familiar with...

Project management

- characteristics and critical success factors of projects,
- typical phases in projects, corresponding tasks and challenges,
- advanced methods and tools, which can be applied in special phases of a project (such as cost-benefit analyses, scheduling techniques, business process modeling techniques, change management approaches),
- important soft factors influencing a project's success (such as cultural aspects, team dynamics, and leadership approaches),
- different project management approaches (classic vs. agile vs. hybrid),
- practical cases of international project management,
- theories, strategies, and advanced methods of negotiation (such as game theory, decision theory, and negotiation analysis).

Negotiation management

- the theory basics of negotiations (e.g. game theory, behavioral theories)
- the types and the pros and cons of different negotiation strategies
- the process of negotiation including goal formulation, preparation/planning, execution and evaluation
- about some key issues impacting negotiations (e.g. team building and roles, barriers to reaching a deal, cognitive biases, multi-phase negotiations)

Skills

Students will be able to...

Project Management

- conduct stakeholder and industry analyses,
- critically analyze industries and multinational firms (e.g., in terms of their competitive situation and their strengths and weaknesses),
- systematically implement project management techniques to international projects (e.g., plan international projects, deal with uncertainty, and establish, harmonize and track quality, time, and cost objectives),
- apply project management techniques to complex business cases (e.g., optimize the target setting process, develop work breakdown structures, schedules and action plans, monitor project progress, manage risk throughout the project, and do the project controlling),
- apply strategies and methods of negotiation to complex business cases,
- internalize the components of an effective negotiation and practice their use,
- successfully apply strategies and methods of negotiation in business practice in an international context (e.g., expose and overcome typical barriers to an agreement, deal with typical hardball tactics, and avoid cognitive traps),
- work target-oriented on exercises to solve case studies,
- apply scientific standards to academic writing,
- appropriately present results of their work to others.

Negotiation Management

- simultaneously considering multiple factors in negotiation situations and taking reasoned actions when preparing and conducting negotiations.
- Analyzing and handling the key challenges of uncertainty, risk, intercultural differences, and time pressure in realistic negotiation situations.
- assessing the typical barriers to an agreement (e.g. lack of trust), dealing with hardball tactics (e.g. good cop, bad cop; lowball, highball; intimidation), and avoiding cognitive traps (e.g. unchecked emotions, overconfidence).
- reflecting on their decision-making in uncertain negotiation situations and derive actions for future decisions.

Personal Competence

Social Competence

The students will be able to...

- lead fruitful group discussions,
- provide appropriate feedback,
- present their results in written form and by oral presentations,
- collaborate respectfully in multicultural teams,
- be reflective on their own behavior in negotiations.

Autonomy

The students will be able to...

- independently acquire further relevant information and critically evaluate this information,
- independently gather knowledge,
- improve management techniques and adapt these to new situations in international business practice.

Workload in Hours	Independent Study Time 96, Study Time in Lecture 84

Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Negotiation Strategies: Preparation and reviewing problem-based learning sessions; Projektmanagement: tbd
Assignment for the Following Curricula	International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory

Course L2798: Open Project Exercise	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Carlos Jahn
Language	EN
Cycle	WiSe
Content	In the lecture Project Management, the most important phases of a project and the use of the project management software Open Project are taught. In the group exercise, example projects are worked on in small groups and these project phases are run through. The project is planned and documented with Open Project.
Literature	

Course L0709: Project Management	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Carlos Jahn
Language	EN
Cycle	WiSe
Content	The lecture “project management” aims at characterizing typical phases of projects. Important contents are: possible tasks, organization, techniques and tools for initiation, definition, planning, management and finalization of projects. This will also be deepened by exercises within the framework of the event. The following topics will be covered in the lecture: • SMART, Work Breakdown Structure, Operationalization, Goals relation matrix • Metra-Potential Method (MPM), Critical-Path Method (CPM), Program evaluation and review technique (PERT) • Milestone Analysis, Earned Value Analyis (EVA) • Progress reporting, Tracing of project goals, deadlines and costs, Project Management Control Loop, Maturity Level Assurance (MLA) • Risk Management, Failure Mode and Effects Analysis (FMEA), Risk Matrix
Literature	Project Management Institute (2017): A Guide to the Project Management Body of Knowledge (PMBOK® Guide) 6. Aufl. Newtown Square, PA, USA: Project Management Institute. DeMarco, Tom (1997). The Deadline: A Novel About Project Management. DIN Deutsches Institut für Normung e.V. (2009). Projektmanagement - Projektmanagementsysteme - Teil 5: Begriffe. (DIN 69901-5) Frigenti, Enzo and Comninos, Dennis (2002). The Practice of Project Management. Haberfellner, Reinhard (2015). Systems Engineering: Grundlagen und Anwendung Harrison, Frederick and Lock, Dennis (2004). Advanced Project Management: A Structured Approach. Heyworth, Frank (2002). A Guide to Project Management. ISO - International Organization for Standardization (2012). Guidance on Project Management. (21500:2012(E)) Kerzner, Harold (2013). Project Management: A Systems Approach to Planning, Scheduling, and Controlling. Lock, Dennis (2018). Project Management. Martinelli, Russ J. and Miloševic, Dragan (2016). Project Management Toolbox: Tools and Techniques for the Practicing Project Manager. Murch, Richard (2011). Project Management: Best Practices for IT Professionals. Patzak, Gerold and Rattay, Günter (2009). Projektmanagement: Leitfaden zum Management von Projekten, Projektportfolios, Programmen und projektorientierten Unternehmen.

Course L2669: Negotiation Management	
Typ	Project-/problem-based Learning
Hrs/wk	3

CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Christian Lüthje
Language	EN
Cycle	WiSe
Content	**General description of course content and course goals** We negotiaate everday in privat and professional contexts. Leading negotiations successfully has a significant impact on future careers. Yet, we tend to have limited knowledge about the theory and empirical evidence regarding successful negotiating. Many people approach negotiations in a rather intuitive and unplanned way which often results in sub-optimal negotiation outcomes. The purpose of this interactive and problem-based course is to theortically understand the strategies and process of negotiation as practiced in a variety of business-related settings (e.g. negotiations about working conditions, negotiations with customers and suppliers). The course will highlight the components of an effective negotiation (strategy, perparation, execution, evaluation) and offer the students the opportunity to analyze their own behavior in negotiations in order to improve. The course structure is experiential and problem-based, combining lectures, class discussion, mini-cases and small erxercises, and more comprehensive negotiation practices in longer sessions. Through participation in negotiation exercises, students will have the opportunity to practice their communication and persuasion skills and to experiment with a variety of negotiating strategies and tactics. Students will apply the lessons learned to ongoing, real-world negotiations. **Content:** The students will find answers to the following fundamental questions of negotiation strategies in theory and practice: • How do negotiations influence everyday life and business processes? • What are key features of negotiations? • What are different forms of negotiations? What kinds of negotiation can be distinguished? • Which theoretical approaches to a theory of negotiation can be distinguished? • How can game theory be applied to negotiation? • What makes an effective negotiator? • Which factors should be considered when planning negotiations? • What steps must be followed to reach a deal? • Are there specific negotiation tactics? • What are the typical barriers to an agreement and how to deal with them? • What are possible cognitive (mental) errors and how to correct them? **Knowledge** Students know... • the theory basics of negotiations (e.g. game theory, behavioral theories) • the types and the pros and cons of diffrent negotiation strategies • the process of negotiation, inlcuding goal formulation, preparation/planning, execution and evaluation • about some key issues impacting negotiations (e.g. team building and roles, barriers to reaching a deal, cognitive biases, multi-phase negotiations) **Skills** Students are capable of... • simultaneously considering multiple factors in negotiation situations and taking reasoned actions when preparing and conducting negotiations. • Analyzing and handling the key challenges of uncertainty, risk, intercultural differences, and time pressure in realistic negotiation situations. • assessing the typical barriers to an agreement (e.g. lack of trust), dealing with hardball tactics (e.g. good cop, bad cop; lowball, highball; intimidation), and avoiding cognitive traps (e.g. unchecked emotions, overconfidence). • reflecting on their decision-making in uncertain negotiation situations and derive actions for future decisions. **Social Competence** Students can... • provide appropriate feedback and handle feedback on their own performance constructively. • constructively interact with their team members in role playing in negotiations sessions • develop joint solutions in mixed teams and present them to others in real-world negotiation situatio **Self-Reliance** Students are able to... ◦ assess possible consequences of their own negotiation behavior ◦ define own positions and tasks in the negotiation preparation process. ◦ justify and make elaborated decisions in authentic negotiation situations.
Literature	R.J. Lewicki / B. Barry / D.M. Saunders: Negotiation. Sixth Edition, McGraw-Hill, Boston, 2010.

	H. Raiffa: Negotiation analysis. Belknap Press of Harvard Univ. Press, Cambridge, Mass, 2007. R. Fisher / W. Ury: Getting to yes. Third edition. Penguin, New York, 2011. M. Voeth / U. Herbst: Verhandlungsmanagement: Planung, Steuerung und Analyse. Schäffer-Poeschel, Stuttgart, 2009.

Module M1701: Digital Economics

Courses

Title	Typ	Hrs/wk	CP
Digital Economics (L2715)	Lecture	2	3
Digital Economics (L2716)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Timo Heinrich
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of economics as taught in the Economics module is expected.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know • basic concepts of game theory, auction theory and mechanism design, • the properties of online advertising markets and matching markets, • basic concepts of social choice, • models of belief formation, • how trust is established in online interactions, • current models of behavioral economics as well as • empirical results concerning these topics.
Skills	On the basis of the knowledge acquired, students will be able to • analyze and model behavior in digital networks and markets, • understand and discuss current empirical research on the topic and • develop their own empirical research questions.
Personal Competence	
Social Competence	Students will be able to • participate in subject-specific and interdisciplinary discussions on the topics of the course, • present and discuss their work results from empirical studies and • cooperate successfully and respectfully in a team.
Autonomy	Students will be able to • identify empirical research questions from the areas of the courses and analyze and answer them independently and in a team, • acquire knowledge about the subject area independently and transfer the acquired knowledge to new questions as well as • critically evaluate the results of their work.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	10- to 15-page elaboration
Assignment for the Following Curricula	International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory

Course L2715: Digital Economics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Timo Heinrich
Language	EN
Cycle	WiSe
Content	• Experimental economics • Game theory • Auction theory • Mechanism design • Online advertising markets • Matching markets • Social choice • Belief formation • Reputation systems
Literature	• Parkes/Seuken: Algorithmic Economics: A Design Approach, Unpublished, 2020 • Easley/Kleinberg: Networks, Crowds and Markets, Cambridge University Press, 2010 • Weimann/Brosig-Koch: Methods in Experimental Economics, Springer, 2019 • Pass: A Course in Networks and Markets: Game-theoretic Models and Reasoning, MIT Press, 2019

Course L2716: Digital Economics	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Timo Heinrich
Language	EN
Cycle	WiSe
Content	Students examine existing empirical studies on topics covered in the lecture and develop their own research questions and study designs.
Literature	• Parkes/Seuken: Algorithmic Economics: A Design Approach, Unpublished, 2020 • Easley/Kleinberg: Networks, Crowds and Markets, Cambridge University Press, 2010 • Weimann/Brosig-Koch: Methods in Experimental Economics, Springer, 2019 • Pass: A Course in Networks and Markets: Game-theoretic Models and Reasoning, MIT Press, 2019

Module M0814: Technology Management

Courses

Title	Typ	Hrs/wk	CP
Technology Management (L0849)	Lecture	3	3
Technology Management Seminar (L0850)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Cornelius Herstatt
Admission Requirements	None
Recommended Previous Knowledge	Bachelor knowledge in business management
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	

Knowledge	Students will gain deep insights into:
	• International R&D-Management
	• Technology Timing Strategies
	  ◦ Technology Strategies and Lifecycle Management (I/II)
	  ◦ Technology Intelligence and Planning
	• Technology Portfolio Management
	  ◦ Technology Portfolio Methodology
	  ◦ Technology Acquisition and Exploitation
	  ◦ IP Management
	• Organizing Technology Development
	  ◦ Technology Organization & Management
	  ◦ Technology Funding & Controlling

Skills	The course aims to: • Develop an understanding of the importance of Technology Management - on a national as well as international level • Equip students with an understanding of important elements of Technology Management (strategic, operational, organizational and process-related aspects) • Foster a strategic orientation to problem-solving within the innovation process as well as Technology Management and its importance for corporate strategy • Clarify activities of Technology Management (e.g. technology sourcing, maintenance and exploitation) • Strengthen essential communication skills and a basic understanding of managerial, organizational and financial issues concerning Technology-, Innovation- and R&D-management. Further topics to be discussed include: • Basic concepts, models and tools, relevant to the management of technology, R&D and innovation • Innovation as a process (steps, activities and results)
Personal Competence	
Social Competence	• Interact within a team • Raise awareness for globabl issues
Autonomy	• Gain access to knowledge sources • Discuss recent research debates in the context of Technology and Innovation Management • Develop presentation skills • Discussion of international cases in R&D-Management
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Global Innovation Management: Core Qualification: Compulsory International Management and Engineering: Specialisation I. Electives Management: Elective Compulsory Mechanical Engineering and Management: Specialisation Management: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Compulsory

Course L0849: Technology Management	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Cornelius Herstatt
Language	EN
Cycle	WiSe
Content	The role of technology for the competitive advantage of the firm and industries; Basic concepts, models and tools for the management of technology; managerial decision making regarding the identification, selection and protection of technology (make or buy, keep or sell, current and future technologies). Theories, practical examples (cases), lectures, interactive sessions and group study. This lecture is part of the Module Technology Management and can not separately choosen.
Literature	Leiblein, M./Ziedonis, A.: Technology Strategy and Inoovation Management, Elgar Research Collection, Northhampton (MA) 2011

Course L0850: Technology Management Seminar	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Cornelius Herstatt
Language	EN
Cycle	WiSe
Content	Beside the written exam at the end of the module, students have to give one presentation (RE) on a research paper and two presentations as part of a group discussion (GD) in the seminar in order to pass. With these presentations it is possible to gain a bonus of max. 20% for the exam. However, the bonus is only valid if the exam is passed without the bonus.
Literature	see lecture Technology Management.

Specialization II. Civil Engineering

Module M0998: Statics and Dynamics of Structures

Courses

Title	Typ	Hrs/wk	CP
Structural Dynamics (L1202)	Lecture	2	2
Structural Dynamics (L1203)	Recitation Section (large)	2	2
Fracture mechanics and fatigue in steel structures (L0564)	Lecture	1	1
Fracture mechanics and fatigue in steel structures (L0565)	Recitation Section (large)	1	1

Module Responsible	Prof. Bastian Oesterle
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of linear structural analysis of statically determinate and indeterminate structures; Mechanics I/II, Mathematics I/II, Differential equations I
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After successful completion of this module, the student can explain the basic aspects of dynamic effects on structures and the respective methods.
Skills	After successful completion of this module, the students will be able to predict the response of material and structures to dynamics loading using the appropriate computational approaches and methods.
Personal Competence	
Social Competence	Students can • participate in subject-specific and interdisciplinary discussions, • defend their own work results in front of others • promote the scientific development of colleagues • Furthermore, they can give and accept professional constructive criticism
Autonomy	Students are able to gain knowledge of the subject area from given and other sources and apply it to new problems. Furthermore, they are able to structure the solution process for problems in the area of Structural Analysis.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	150 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Civil Engineering: Specialisation Computational Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory

Course L1202: Structural Dynamics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Bastian Oesterle
Language	DE
Cycle	SoSe
Content	• mechanical background of dynamics • harmonic vibrations, damped and undamped free and forced vibrations • frequency and time domain • modelling aspects • principle of d'Alembert • systems with multiple degrees of freedom • consistent and lumped mass matrices • finite elements for dynamics problems • impact problems • eigenvalue problems and modal analysis • direct time integration schemes, transient analyses
Literature	• Vorlesungsmanuskript • Clough, R.W., Penzien, J.: Dynamics of Structures. 2. Aufl., McGraw-Hill, New York, 1993.

Course L1203: Structural Dynamics	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Bastian Oesterle
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0564: Fracture mechanics and fatigue in steel structures	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Jürgen Priebe
Language	DE
Cycle	SoSe
Content	• basics of fatigue stress and fatigue resistance and determination of fatigue strength, • determination anduse of S-N-curves and classification of notch effects, • set up of determination of fatigue strength under dynamic load using the accumulation formula by Palmgren-Miner, • set up of determination of fatigue strength in different examples, • basics of construction and design regarding the problem of material fatigue, • basics of linear elastic fracture mechanics under static and dynamic load, • determination of lifetime of steel construction based on linear elastic fracture mechanics in different examples.
Literature	• Seeßelberg, C.; Kranbahnen - Bemessung und konstruktive Gestaltung; 3. Auflage; Bauwerk-Verlag; Berlin 2009 • Kuhlmann, Dürr, Günther; Kranbahnen und Betriebsfestigkeit; in Stahlbau Kalender 2003; Verlag Ernst & Sohn; Berlin 2003 • Deutscher Stahlbau-Verband (Hrsg.); Stahlbau Handbuch Band 1 Teil B; 3. Auflage; Stahlbau-Verlagsgesellschaft; Köln 1996 • Petersen, C.; Stahlbau; 3. überarb. und erw. Auflage; Vieweg-Verlag; Braunschweig 1993 • DIN V ENV 1993-1-1: Eurocode 3; Bemessung und Konstruktion von Stahlbauwerken; Teil 1-1: Allgemeine Bemessungsregeln, Bemessungsregeln für den Hochbau; 1993 • DIN V ENV 1993-6: Eurocode 3; Bemessung und Konstruktion von Stahlbauwerken; Teil 6: Kranbahnen; 2001 • DIN-Fachbericht 126. Richtlinie zur Anwendung von DIN V ENV 1993-6; Nationales Anwendungsdokument (NAD); Berlin 2002

Course L0565: Fracture mechanics and fatigue in steel structures	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Jürgen Priebe
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0723: Design of Prestressed Structures and Concrete Bridges

Courses

Title	Typ	Hrs/wk	CP
Design of Prestressed Structures and Concreet Bridges (L0603)	Lecture	3	4
Design of Prestressed Structures and Concreet Bridges (L0604)	Recitation Section (large)	2	2

Module Responsible	Prof. Günter Rombach
Admission Requirements	None
Recommended Previous Knowledge	Detailed knowledge on the design of concrete structures. Modules: Reinforced Concrete Structures I+II, Structural Analysis I+II, Mechanics I+II, Concrete Structures
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know the main bridge types, their applications and the various loads. They can explain the basic design methods. They can explain the design of a prestressed bridge.
Skills	The students are able to design reinforced or prestressed concrete bridges.
Personal Competence	
Social Competence	The students can design in teamwork a real concrete bridge.
Autonomy	The students are able to design a prestressed concrete bridge and discuss the problems and results with other students.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 minutes
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Computational Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory

Course L0603: Design of Prestressed Structures and Concreet Bridges	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Günter Rombach
Language	DE
Cycle	SoSe
Content	prestressed structures • basis of prestressed structures, field of application • differences between reinforced and prestressed concrete structures • history of prestressing • construction materials: concrete, tendons, ducts, anchorage systems • construction: prestressing methods • prestressing forces and member forces (friction, elongation) • tendon layout • time dependant prestressing losses • design of prestressed structures • design of anchorage region • non-bonded prestressing • prestressed flat slabs Concrete bridges • history of bridges • design of bridges • loads on bridges • member forces for slab, T-beam, hollow box, frame and arch bridges • precast bridges - precast segmental bridges • bearings • abutments, columns • construction methods • damages - checking of bridges
Literature	• Vorlesungsumdruckim STUDiP • Rombach, G. (2003): Spannbetonbau. Ernst & Sohn, Berlin • Wicke, M. (2002): Anwendung des Spannbetons. Betonkalender 2002, Teil II, S. 113-180, Verlag Ernst & Sohn, Berlin • Leonhardt, F. (1980): Vorlesungen über Massivbau. Teil 5: Spannbeton. Berlin • Mehlhorn, G. (2007): Handbuch Brücken, Springer Verlag • Schäfer, H.; Kaufeld, K. (1997): Massivbrücken. Betonkalender Teil II, S. 443ff, Ernst & Sohn, Berlin • Menn, Ch. (1986): Stahlbetonbrücken. Springer Verlag, Wien

Course L0604: Design of Prestressed Structures and Concreet Bridges	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Günter Rombach
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0977: Construction Logistics and Project Management

Courses

Title	Typ	Hrs/wk	CP
Construction Logistics (L1163)	Lecture	1	2
Construction Logistics (L1164)	Recitation Section (small)	1	2
Project Development and Management (L1161)	Lecture	1	1
Project Development and Management (L1162)	Project-/problem-based Learning	1	1

Module Responsible	Prof. Heike Flämig
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can... • give definitions of the main terms of construction logistics and project development and management • name advantages and disadvantages of internal or external construction logistics • explain characteristics of products, demand and production of construction objects and their consequences for construction specific supply chains • differentiate constructions logistics from other logistics systems
Skills	Students can... • carry out project life cycle assessments • apply methods and instruments of construction logistics • apply methods and instruments of project development and management • apply methods and instruments of conflict management • design supply and waste removal concepts for a construction project
Personal Competence	
Social Competence	Students can... • hold presentations in and for groups • apply methods of conflict solving skills in group work and case studies
Autonomy	Students can... • solve problems by holistic, systemic and flow oriented thinking • improve their creativity, negotiation skills, conflict and crises solution skills by applying methods of moderation in case studies
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Two written papers with presentations
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L1163: Construction Logistics	
Typ	Lecture
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heike Flämig
Language	DE
Cycle	SoSe
Content	The lecture gives deeper insight how important logistics are as a competetive factor for construction projects and which issues are to be adressed. The following toppics are covered: • competetive factor logistics • the concept of systems, planning and coordination of logistics • material, equipment and reverse logistics • IT in construction logistics • elements of the planning model of construction logistics and their connections • flow oriented logistics systems for construction projects • logistics concepts for ready to use construction projects (especially procurement and waste removel logistics) • best practice examples (construction logistics Potsdamer Platz, recent case study of the region) Contents of the lecture are deepened in special exercises.
Literature	Flämig, Heike: Produktionslogistik in Stadtregionen. In: Forschungsverbund Ökologische Mobilität (Hrsg.) Forschungsbericht Bd. 15.2. Wuppertal 2000. Krauss, Siri: Die Baulogistik in der schlüsselfertigen Ausführung, Bauwerk Verlag GmbH Berlin 2005. Lipsmeier, Klaus: Abfallkennzahlen für Neubauleistungen im Hochbau : Verlag Forum für Abfallwirtschaft und Altlasten, 2004. Schmidt, Norbert: Wettbewerbsfaktor Baulogistik. Neue Wertschöpfungspotenziale in der Baustoffversorgung. In: Klaus, Peter: Edition Logistik. Band 6. Deutscher Verkehrs-Verlag. Hamburg 2003. Seemann, Y.F. (2007): Logistikkoordination als Organisationseinheit bei der Bauausführung Wissenschaftsverlag Mainz in Aachen, Aachen. (Mitteilungen aus dem Fachgebiet Baubetrieb und Bauwirtschaft (Hrsg. Kuhne, V.): Heft 20)

Course L1164: Construction Logistics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heike Flämig
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1161: Project Development and Management	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Heike Flämig, Dr. Anton Worobei
Language	DE
Cycle	SoSe
Content	Within the lecture, the main aspects of project development and management are tought: • Terms and definitions of project management • Advantages and disadvantages of different ways of project handling • organization, information, coordination and documentation • cost and fincance management in projects • time- and capacity management in projects • specific methods and instruments for successful team work Contents of the lecture are deepened in special exercises.
Literature	Projektmanagement-Fachmann. Band 1 und Band 2. RKW-Verlag, Eschborn, 2004.

Course L1162: Project Development and Management	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Heike Flämig, Dr. Anton Worobei
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0860: Harbour Engineering and Harbour Planning

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Harbour Engineering (L0809)	Lecture	2	2
Harbour Engineering (L1414)	Project-/problem-based Learning	1	2
Port Planning and Port Construction (L0378)	Lecture	2	2

Module Responsible	Prof. Peter Fröhle
Admission Requirements	None
Recommended Previous Knowledge	Basics of coastal engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to define in details and to choose design approaches for the functional design of a port and apply them to design tasks. They can design the fundamental elements of a port.
Skills	The students are able to select and apply appropriate approaches for the functional design of ports.
Personal Competence	
Social Competence	The students are able to deploy their gained knowledge in applied problems such as the functional design of ports. Additionaly, they will be able to work in team with engineers of other disciplines.
Autonomy	The students will be able to independently extend their knowledge and apply it to new problems.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	The duration of the examination is 150 min. The examination includes tasks with respect to the general understanding of the lecture contents and calculations tasks.
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory

Course L0809: Harbour Engineering

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Peter Fröhle
Language	DE
Cycle	SoSe

Content	• Fundamentals of harbor engineering
	  ◦ Maritime transportation and waterways engineering
	  ◦ Ships
	• Elements of harbors
	  ◦ Harbor approaches and water-side harbor areas
	  ◦ Terminal design and handling of cargo
	  ◦ Quay-walls and piers
	  ◦ Equipment of harbors
	  ◦ Sluices and other special constructions
	• Connection to inland transportation / inland waterway transportation
	• Protection of harbors
	  ◦ Breakwaters and Jetties
	  ◦ Wave protection of harbors
	• Fishery and other small harbors

Literature	Brinkmann, B.: Seehäfen, Springer 2005

Course L1414: Harbour Engineering

Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Peter Fröhle
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0378: Port Planning and Port Construction	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Frank Feindt
Language	DE
Cycle	SoSe
Content	• Planning and implementation of major projects • Market analysis and traffic relations • Planning process and plan • Port planning in urban neighborhood • Development of the logistics center "Port of Hamburg" in the metropolis • Quays and waterfront structure • Special planning Law Harbor - securing of a flexible use of the port • Dimensioning of quays • Flood protection structures • Port of Hamburg - Infrastructure and development • Preparation of areas • Scour formation in front of shore structures
Literature	Vorlesungsumdruck, s. www.tu-harburg.de/gbt

Module M0581: Water Protection

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Water Protection and Wastewater Management (L0226)	Lecture	3	3
Water Protection and Wastewater Management (L2008)	Project Seminar	3	3

Module Responsible	Prof. Ralf Otterpohl
Admission Requirements	None
Recommended Previous Knowledge	• Basic knowledge in water management; • Good knowledge in urban drainage; • Good knowledge of wastewater treatment techniques; • Good knowledge of pollutants (e.g. COD, BOD, TS, N, P) and their properties;
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can describe the basic principles of the regulatory framework related to the international and European water sector. They can explain limnological processes, substance cycles and water morphology in detail. They are able to assess complex problems related to water protection, such as ecosystem service and wastewater treatment with a special focus on innovative solutions, remediation measures as well as conceptual approaches.
Skills	Students can accurately assess current problems and situations in a country-specific or local context. They can suggest concrete actions to contribute to the planning of tomorrow's urban water cycle. Furthermore, they can suggest appropriate technical, administrative and legislative solutions to solve these problems.
Personal Competence	
Social Competence	The students can work together in international groups.
Autonomy	Students are able to organize their work flow to prepare presentations and discussions. They can acquire appropriate knowledge by making enquiries independently.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Presentation
Examination duration and scale	Term paper plus presentation
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Environmental Engineering: Specialisation Water Quality and Water Engineering: Elective Compulsory Environmental Engineering: Specialisation Water: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Compulsory

Course L0226: Water Protection and Wastewater Management	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Ralf Otterpohl
Language	EN
Cycle	WiSe
Content	The lecture focusses on: • Regulatory Framework (e.g. WFD) • Main instruments for the water management and protection • In depth knowledge of relevant measures of water pollution control • Urban drainage, treatment options in different regions on the world • Rainwater management, improved management of heavy rainfalls, downpours, rainwater harvesting, rainwater infiltration • Case Studies and Field Trips
Literature	The literature listed below is available in the library of the TUHH. • Water and wastewater technology Hammer, M. J. 1., & . (2012). (7. ed., internat. ed.). Boston [u.a.]: Pearson Education International. • Water and wastewater engineering : design principles and practice: Davis, M. L. 1. (2011). . New York, NY: McGraw-Hill. • Biological wastewater treatment: (2011). C. P. Leslie Grady, Jr. (3. ed.). London, Boca Raton, Fla. [u.a.]: IWA Publ.

Course L2008: Water Protection and Wastewater Management	
Typ	Project Seminar
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Ralf Otterpohl
Language	EN
Cycle	WiSe
Content	
Literature	

Module M0595: Examination of Materials, Structural Condition and Damages

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Examination of Materials, Structural Condition and Damages (L0260)	Lecture	3	4
Examination of Materials, Structural Condition and Damages (L0261)	Recitation Section (small)	1	2

Module Responsible	Prof. Frank Schmidt-Döhl
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge about building materials or material science, for example by the module Building Materials and Building Chemistry.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to describe the rules for trading, use and marking of construction products in Germany. They know which methods for the testing of building material properties are usable and know the limitations and characterics of the most important testing methods.
Skills	The students are able to responsibly discover the rules for trading and using of building products in Germany. They are able to chose suitable methods for the testing and inspection of construction products, the examination of damages and the examination of the structural conditions of buildings. They are able to conclude from symptons to the cause of damages. They are able to describe an examination in form of a test report or expert opinion.
Personal Competence	
Social Competence	The students can describe the different roles of manufacturers as well as testing, supervisory and certification bodies within the framework of material testing. They can describe the different roles of the participants in legal proceedings.
Autonomy	The students are able to make the timing and the operation steps to learn the specialist knowledge of a very extensive field.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory Materials Science and Engineering: Specialisation Engineering Materials: Elective Compulsory Materials Science: Specialisation Engineering Materials: Elective Compulsory

Course L0260: Examination of Materials, Structural Condition and Damages

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Frank Schmidt-Döhl
Language	DE
Cycle	WiSe
Content	Materials testing and marking process of construction products, testing methods for building materials and structures, testing reports and expert opinions, describing the condition of a structure, from symptons to the cause of damages
Literature	Frank Schmidt-Döhl: Materialprüfung im Bauwesen. Fraunhofer irb-Verlag, Stuttgart, 2013.

Course L0261: Examination of Materials, Structural Condition and Damages

Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Frank Schmidt-Döhl
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0603: Nonlinear Structural Analysis

Courses

Title	Typ	Hrs/wk	CP
Nonlinear Structural Analysis (L0277)	Lecture	3	4
Nonlinear Structural Analysis (L0279)	Recitation Section (small)	1	2

Module Responsible	Prof. Alexander Düster
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of partial differential equations is recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to + give an overview of the different nonlinear phenomena in structural mechanics. + explain the mechanical background of nonlinear phenomena in structural mechanics. + to specify problems of nonlinear structural analysis, to identify them in a given situation and to explain their mathematical and mechanical background.
Skills	Students are able to + model nonlinear structural problems. + select for a given nonlinear structural problem a suitable computational procedure. + apply finite element procedures for nonlinear structural analysis. + critically verify and judge results of nonlinear finite elements. + to transfer their knowledge of nonlinear solution procedures to new problems.
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups. + present and discuss their results in front of others. + give and accept professional constructive criticism.
Autonomy	Students are able to + assess their knowledge by means of exercises and E-Learning. + acquaint themselves with the necessary knowledge to solve research oriented tasks. + to transform the acquired knowledge to similar problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Computational Engineering: Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Ship and Offshore Technology: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0277: Nonlinear Structural Analysis	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Alexander Düster
Language	DE/EN
Cycle	WiSe
Content	1. Introduction 2. Nonlinear phenomena 3. Mathematical preliminaries 4. Basic equations of continuum mechanics 5. Spatial discretization with finite elements 6. Solution of nonlinear systems of equations 7. Solution of elastoplastic problems 8. Stability problems 9. Contact problems
Literature	[1] Alexander Düster, Nonlinear Structrual Analysis, Lecture Notes, Technische Universität Hamburg-Harburg, 2014. [2] Peter Wriggers, Nonlinear Finite Element Methods, Springer 2008. [3] Peter Wriggers, Nichtlineare Finite-Elemente-Methoden, Springer 2001. [4] Javier Bonet and Richard D. Wood, Nonlinear Continuum Mechanics for Finite Element Analysis, Cambridge University Press, 2008.

Course L0279: Nonlinear Structural Analysis	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Alexander Düster
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0858: Coastal Hydraulic Engineering I

Courses

Title	Typ	Hrs/wk	CP
Basics of Coastal Engineering (L0807)	Lecture	3	4
Basics of Coastal Engineering (L1413)	Project-/problem-based Learning	1	2

Module Responsible	Prof. Peter Fröhle
Admission Requirements	None
Recommended Previous Knowledge	Basics of hydraulic engineering, hydrology and hydromechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to define and explain the basic concepts of coastal engineering and port engineering. They are able to apply the concepts to selected practical problems of coastal engineering. Students can define and determine the basics for design and dimensioning of coastal engineering constructions.
Skills	The students are capable to apply basic design approaches to selected and pre-defined design tasks in coastal engineering.
Personal Competence	
Social Competence	The students are able to deploy their gained knowledge in applied problems such as the design of coastal protection structures. Additionaly, they will be able to work in team with engineers of other disciplines, for instance designing of coastal breakwaters.
Autonomy	The students will be able to independently extend their knowledge and applyit to new problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	The duration of the examination is 2 hours. The examination includes tasks with respect to the general understanding of the lecture contents and calculations tasks.
Assignment for the Following Curricula	Civil Engineering: Specialisation Coastal Engineering: Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Compulsory Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Environmental Engineering: Specialisation Environment and Climate: Elective Compulsory Environmental Engineering: Specialisation Water Quality and Water Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory

Course L0807: Basics of Coastal Engineering

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Peter Fröhle
Language	EN
Cycle	SoSe

Content

- Basics of planning and design
  - Water levels
  - Currents
  - Waves
  - Ice
- Planning and Design in Coastal Engineering
  - Functional and constructional design
  - Determination of design parameters
  - Design-approaches
    - Filter
    - Rubble mound constructions
    - Piles
    - Vertical constructions

Literature

Coastal Engineering Manual, CEM

Vorlesungsumdruck

Course L1413: Basics of Coastal Engineering	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Peter Fröhle
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0699: Geotechnics III

Courses

Title	Typ	Hrs/wk	CP
Numerical Methods in Geotechnics (L0375)	Lecture	3	3
Advanced Foundation Engineering (L0497)	Lecture	2	2
Advanced Foundation Engineering (L0498)	Recitation Section (large)	1	1

Module Responsible	Prof. Jürgen Grabe
Admission Requirements	None
Recommended Previous Knowledge	Geotechnics I and II, Mathematics I-III
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After successfully completing the module, students will be able to • describe individual procedures for the geotechnical monitoring of civil engineering measures, • reproduce exploration and investigation methods of the subsoil, • select suitable types of field and laboratory tests for subsoil investigation and evaluate their results, • state the differences between various stress and deformation states and the physical significance of invariants of the stress and distortion tensor, • outline the standard and special soil mechanics tests used to determine the stress-strain behavior of soil, • describe continuum models and the resulting boundary value problems, • as well as define boundary value problems from the field of geotechnical engineering in such a way that they can be solved unambiguously.
Skills	Students will be able to • dimension vertical drains for soil improvement of soft soils, • calculate depth compaction using various appropriate methods, • apply principles of horizontal bearing capacity of piles, • verify the internal and external stability of fluid-supported diaphragm walls, • evaluate the boundary conditions for the design of a deep excavation and design the individual components of the excavation, • perform, evaluate and interpret tests for the description and classification of soils according to applicable standards, • computationally implement numerical algorithms to solve boundary value problems, • select and apply the types of analyses depending on the degree of saturation, the impact, and the material behavior • determine appropriate model parameters for different possibilities and limitations of material models for the grain structure of soils.
Personal Competence	
Social Competence	Students can work in groups and support each other in finding solutions.
Autonomy	Students are able to assess their own strengths and weaknesses and, based on this, organize their time and learning management and think in terms of processes.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Compulsory Civil Engineering: Specialisation Coastal Engineering: Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Civil Engineering: Specialisation Computational Engineering: Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory

Course L0375: Numerical Methods in Geotechnics	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Dr. Hans Mathäus Stanford
Language	DE
Cycle	WiSe
Content	Topics: • numerical simulations • numerical algorithms • finite element method • application of finite element method in geomechanics • constitutive models for soils • contact models for soil structure interaction • selected applications
Literature	• Wriggers P. (2001): Nichtlineare Finite-Elemente-Methoden, Springer Verlag, Berlin • Bathe Klaus-Jürgen (2002): Finite-Elemente-Methoden. Springer Verlag, Berlin

Course L0497: Advanced Foundation Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Jürgen Grabe
Language	DE
Cycle	WiSe
Content	• Vertical drains • Piles • Ground improvement (Deep Compaction, Soil mixing) • Vibration driving • Jet grouting • Slurry wall • Deep excavation
Literature	• EAK (2002): Empfehlungen für Küstenschutzbauwerke • EAU (2004): Empfehlungen des Arbeitsausschusses Uferbauwerke • EAB (1988): Empfehlungen des Arbeitskreises Baugruben • Grundbau-Taschenbuch, Teil 1-3, (1997), Ernst & Sohn Verlag

Course L0498: Advanced Foundation Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Jürgen Grabe
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0962: Sustainability and Risk Management

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Safety, Reliability and Risk Assessment (L1145)	Seminar	2	3
Environment and Sustainability (L0319)	Lecture	2	3

Module Responsible	Prof. Kerstin Kuchta
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe single techniques and to give an overview for the field of safety and risk assessment as well as environmental and sustainable engineering, in detail: • basics in safety and reliability of technical facilities • safety and reliability analysis methods • risk assessment • Production and usage of bio-char • energy production and supply • sustainable product design
Skills	Students are able apply interdisciplinary system-oriented methods for risk assessment and sustainability reporting. They can evaluate the effort and costs for processes and select economically feasible treatment concepts.
Personal Competence	
Social Competence	
Autonomy	Students can gain knowledge of the subject area from given sources and transform it to new questions. Furthermore, they can define targets for new application or research-oriented duties in for risk management and sustainability concepts accordance with the potential social, economic and cultural impact.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Elaboration and presentation (45 minutes in groups)
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Water and Environmental Engineering: Core Qualification: Compulsory

Course L1145: Safety, Reliability and Risk Assessment

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Marco Ritzkowski
Language	DE
Cycle	WiSe
Content	An introduction in safety and risk assessment is given and some typical problems of structural and environmental engineering are treated: • basics in safety and reliability of technical facilities • safety and reliability analysis methods • risk assessment • practical examples and excursions • discussions and presentations
Literature	- Vorlesungsunterlagen - Schneider, J., Schlatter, H.P.: Sicherheit und Zuverlässigkeit im Bauwesen. www.risksafety.ch/files/**sicherheit**_und_zuverlaessigkeit.pdf

Course L0319: Environment and Sustainability	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	WiSe
Content	This course presents actual methodologies and examples of environmental relevant, sustainable technologies, concepts and strategies in the field of energy supply, product design, water supply, waste water treatment or mobility. The following list show examples. Production and Usage of Bio-char Engergy production with algae Environmental product design Clean Development mechanism (CDM) Democracy and Energy New Concepts for a sustainable Energy Supply Recycling of Wind Turbines Alternative Mobility Disposal of Nuclear Wastes Waste2Energy Offshore Wind energy
Literature	Wird in der Veranstaltung bekannt gegeben.

Module M0963: Steel and Composite Structures

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Steel and Composite Structures (L1204)	Lecture	2	2
Steel and Composite Structures (L1205)	Recitation Section (large)	2	2
Steel Bridges (L1097)	Lecture	2	2

Module Responsible	Prof. Marcus Rutner
Admission Requirements	None
Recommended Previous Knowledge	Basics of steel construction (i.e. Steel Structures I and II, BUBC)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After successful completition, students can • describe the phenomenon of local buckling • explain warping torsion • illustrate the behaviour of composite structures • specify the principles in design of composite sttructures • sketch the contructions of steel and composite bridges
Skills	After successful participation students are able to • check stiffened and unstiffened plated structures • recognize and verify warping tosion in strucures • design composite structures • design bridges and o perform the detailing
Personal Competence	
Social Competence	--
Autonomy	--
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Civil Engineering: Specialisation Computational Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory

Course L1204: Steel and Composite Structures

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Marcus Rutner
Language	DE
Cycle	WiSe
Content	• Local-buckling of plated structures • Warping torsion • Composite-girders, -columns, -slabs, -bridges • Principles in composite constructions • Bridge-design and -construction
Literature	Petersen, C.: Stahlbau, 4.Auflage 2013, Springer-Vieweg Verlag Minnert, J. Wagenknecht, G.: Verbundbau-Praxis - Berechnung und Konstruktion nach Eurocode 4, 2.Auflage 2013, Bauwerk Beuth Verlag

Course L1205: Steel and Composite Structures	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Marcus Rutner
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1097: Steel Bridges	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Yves Freundt
Language	DE
Cycle	WiSe
Content	**Lecture Contents ‚Steel Bridge Construction'** **Dr.-Ing. Jörg Ahlgrimm** - From tendering and contracting to completion - the development of a steel bridge - Contents of a bridge static - structural details, examples of analysis in detail: -> effective width in regard to the longitudinal stiffeners -> Bearing point, bearing stiffener -> Crossbeam breakthrough, crossbeam reinforcement -> Analysis of the Rib-to-Floorbeam (RF) connection (web-tooth of the floorbeam between trapezoidal shaped Ribs) - Steel grades, -designation, testing methods and approval certificates - Nondestructive weld inspecting - Corrosion protection - Bridge bearing - types, format, function, dimensioning, installation - Expansion Joints - Oscillation of bridge hangers and cables - oscillation damper - Opening bridges- Detailed reviews to different assembling procedures and - implements - Selective damage events Requirements: Basic knowledge in the calculation, dimensioning, and construction of structural elements and joints of constructional steelwork
Literature	• Herbert Schmidt, Ulrich Schulte, Rainer Zwätz, Lothar Bär: Ausführung von Stahlbauten • Petersen, Christian: Stahlbau, Abschnitt Brückenbau • Ahlgrimm, J., Lohrer, I.: Erneuerung der Eisenbahnüberführung in Fulda-Horas über die Fulda, Stahlbau 74 (2005), Heft 2, S. 114

Module M0964: Underground Constructions

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Applied Tunnel Constructions (L2407)	Lecture	2	3
Introduction to tunnel construction (L0707)	Lecture	1	2
Introduction to tunnel construction (L1811)	Recitation Section (large)	1	1

Module Responsible	Prof. Jürgen Grabe
Admission Requirements	None
Recommended Previous Knowledge	Modules from Bachelor studies Civil and environmental engineering: • Geotechnics I-II
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Knowledge of different tunnel construction types as well as special methods and techniques of subsoil construction.
Skills	Basic knowledge of tunnel design as well as practical skills in structural tunnel analysis.
Personal Competence	
Social Competence	Capacity for teamwork concerning project management and design of tunnels.
Autonomy	Promotion of independent and creative work flow in the framework of a design exercise.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** No, **Bonus** 5 %, **Form** Excercises, **Description**
Examination	Written exam
Examination duration and scale	120 minutes
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Compulsory Civil Engineering: Specialisation Coastal Engineering: Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Civil Engineering: Specialisation Computational Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory

Course L2407: Applied Tunnel Constructions

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Jürgen Grabe, Tim Babendererde
Language	DE
Cycle	WiSe
Content	
Literature	

Course L0707: Introduction to tunnel construction

Typ	Lecture
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Dr. Marius Milatz
Language	DE
Cycle	WiSe
Content	• Definitions • Historical development in tunneling • Geology for tunneling • Hard rock tunneling (construction composite and machines) • Tunnelung in temporarly stable soil with conventional construction methods • Tunneling in soft soils (form of supports, shield types, compressed air application) • Pipe jacking • Tunnel Lining, tunnel supporting structures • Calculation approaches for supporting structures in shield-driven tunnels • Surveying for tunneling • Safety requirements • Construction Contract • Literature and sources
Literature	• Vorlesung/Übung s. www.tu-harburg.de/gbt

Course L1811: Introduction to tunnel construction	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Marius Milatz
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0713: Concrete Structures

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Concrete Structures (L0579)	Seminar	1	1
Structural Concrete Members (L0577)	Lecture	2	3
Structural Concrete Members (L0578)	Recitation Section (large)	2	2

Module Responsible	Prof. Günter Rombach
Admission Requirements	None
Recommended Previous Knowledge	Basics of structural analysis, conception and dimensioning of structural concrete Modules: Reinforced Concrete Structures I+II, Structural Analysis I+II, Mechanics I+II
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students broaden their skills in structural engineering, especially in the field of buildings (houses, roofs, halls). They dispose of the knowledge for the conception and design of concrete buildings and structural members that are often used.
Skills	The students are able to apply procedures of the conception and dimensioning to to practical problems of structural engineering. They are capable to draft concrete buildings and to design them for general action effects and to plan their detailing and execution. Moreover, they can make design and construction sketches and draw up technical descriptions.
Personal Competence	
Social Competence	The students are able to obtain results of high quality in teamwork.
Autonomy	The students are able to carry out complex conception and dimensioning tasks of structures under the guidance of tutors.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / None / Presentation / Es werden 2 Referate ausgegeben
Examination	Written exam
Examination duration and scale	120 minutes
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Civil Engineering: Specialisation Computational Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory

Course L0579: Concrete Structures

Typ	Seminar
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Günter Rombach
Language	DE
Cycle	WiSe
Content	With help of a project teamwork the subjects of the course "Concrete Structures" is practiced, discussed and presented.
Literature	- Projektbezogene Unterlagen werden abgegeben.

Course L0577: Structural Concrete Members	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Günter Rombach
Language	DE
Cycle	WiSe
Content	• skyscrapers: structural elements • actions on structrues • bracing systems • design orf slabs (line and point supported plates and floor slabs) • membranes and deep beams • folded plates and shells • truss models • reinforced and prestressed members
Literature	Vorlesungsunterlagen können im STUDiP heruntergeladen werden • Zilch K., Zehetmaier G.: Bemessung im konstruktiven Ingenieurbau. Springer, Heidelberg 2010 • König, G., Liphardt S.: Hochhäuser aus Stahlbeton, Betonkalender 2003, Teil II, Seite 1-69, Verlag Ernst & Sohn, Berlin 2003 • Phocas, Marios C.: Hochhäuser : Tragwerk und Konstruktion, Stuttgart, Teubner, 2005 • Deutscher Ausschuss für Stahlbeton: Heft 600: Erläuterungen zu DIN EN 1992-1-1, Beuth Verlag, Berlin 2012 • Deutscher Ausschuss für Stahlbeton: Heft 240: Hilfsmittel zur Berechnung der Schnittgrößen und Formänderungen von Stahlbetontragwerken, Verlag Ernst & Sohn, Berlin 1978 • Stiglat, K., Wippel, H.: Massive Platten - Ausgewählte Kapitel der Schnittkraftermittlung und Bemessung, Betonkalender 1992, Teil I, 287-366, Verlag Ernst & Sohn, Berlin 1992 • Stiglat/Wippel: Platten. Verlag Ernst & Sohn, Berlin,1973 • Schlaich J.; Schäfer K.: Konstruieren im Stahlbetonbau. Betonkalender 1998, Teil II, S. 721ff, Verlag Ernst & Sohn, Berlin, 1998 • Dames K.-H.: Rohbauzeichnungen Bewehrungszeichnungen. Bauverlag, Wiesbaden 1997

Course L0578: Structural Concrete Members	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Günter Rombach
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Specialization II. Electrical Engineering

Module M0630: Robotics and Navigation in Medicine

Courses

Title	Typ	Hrs/wk	CP
Robotics and Navigation in Medicine (L0335)	Lecture	2	3
Robotics and Navigation in Medicine (L0338)	Project Seminar	2	2
Robotics and Navigation in Medicine (L0336)	Recitation Section (small)	1	1

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	• principles of math (algebra, analysis/calculus) • principles of programming, e.g., in Java or C++ • solid R or Matlab skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can explain kinematics and tracking systems in clinical contexts and illustrate systems and their components in detail. Systems can be evaluated with respect to collision detection and safety and regulations. Students can assess typical systems regarding design and limitations.
Skills	The students are able to design and evaluate navigation systems and robotic systems for medical applications.
Personal Competence	
Social Competence	The students are able to grasp practical tasks in groups, develop solution strategies independently, define work processes and work on them collaboratively. The students are able to collaboratively organize their work processes and software solutions using virtual communication and software management tools. The students can critically reflect on the results of other groups, make constructive suggestions for improvement, and also incorporate them into their own work.
Autonomy	The students can assess their level of knowledge and independently control their learning processes on this basis as well as document their work results. They can critically evaluate the results achieved and present them in an appropriate argumentative manner to the other groups.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 10 % / Presentation Yes / 10 % / Written elaboration
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Data Science: Specialisation III. Applications: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computer Science in Engineering: Specialisation II. Engineering Science: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0335: Robotics and Navigation in Medicine	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	- kinematics - calibration - tracking systems - navigation and image guidance - motion compensation The seminar extends and complements the contents of the lecture with respect to recent research results.
Literature	Spong et al.: Robot Modeling and Control, 2005 Troccaz: Medical Robotics, 2012 Further literature will be given in the lecture.

Course L0338: Robotics and Navigation in Medicine	
Typ	Project Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0336: Robotics and Navigation in Medicine	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0673: Information Theory and Coding

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Information Theory and Coding (L0436)	Lecture	3	4
Information Theory and Coding (L0438)	Recitation Section (large)	2	2

Module Responsible	Prof. Gerhard Bauch
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics 1-3 • Probability theory and random processes • Basic knowledge of communications engineering (e.g. from lecture "Fundamentals of Communications and Random Processes")
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know the basic definitions for quantification of information in the sense of information theory. They know Shannon's source coding theorem and channel coding theorem and are able to determine theoretical limits of data compression and error-free data transmission over noisy channels. They understand the principles of source coding as well as error-detecting and error-correcting channel coding. They are familiar with the principles of decoding, in particular with modern methods of iterative decoding. They know fundamental coding schemes, their properties and decoding algorithms. The students are familiar with the contents of lecture and tutorials. They can explain and apply them to new problems.
Skills	The students are able to determine the limits of data compression as well as of data transmission through noisy channels and based on those limits to design basic parameters of a transmission scheme. They can estimate the parameters of an error-detecting or error-correcting channel coding scheme for achieving certain performance targets. They are able to compare the properties of basic channel coding and decoding schemes regarding error correction capabilities, decoding delay, decoding complexity and to decide for a suitable method. They are capable of implementing basic coding and decoding schemes in software.
Personal Competence	
Social Competence	The students can jointly solve specific problems.
Autonomy	The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Data Science: Specialisation I. Mathematics: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Wireless and Sensor Technologies: Elective Compulsory Computer Science in Engineering: Specialisation II. Engineering Science: Elective Compulsory Information and Communication Systems: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory

Course L0436: Information Theory and Coding

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	SoSe

Content	• Introduction to information theory and coding
	• Definitions of information: Self information, entropy
	• Binary entropy function
	• Source coding theorem
	• Entropy of continuous random variables: Differential entropy, differential entropy of uniformly and Gaussian distributed random variables
	• Source coding
	    ◦ Principles of lossless source coding
	    ◦ Optimal source codes
	    ◦ Prefix codes, prefix-free codes, instantaneous codes
	    ◦ Morse code
	    ◦ Huffman code
	    ◦ Shannon code
	    ◦ Bounds on the average codeword length

    - Relative entropy, Kullback-Leibler distance, Kullback-Leibler divergence
    - Cross entropy
    - Lempel-Ziv algorithm
    - Lempel-Ziv-Welch (LZW) algorithm
    - Text compression and image compression using variants of the Lempel-Ziv algorithm
- Channel models
    - AWGN channel
    - Binary-input AWGN channel
    - Binary symmetric channel (BSC)
    - Relationship between AWGN channel and BSC
    - Binary error and erasure channel (BEEC)
    - Binary erasure channel (BEC)
    - Discrete memoryless channels (DMC)
- Definitions of information for multiple random variables
    - Mutual information and channel capacity
    - Entropy, conditional entropy
    - Chain rules for entropy and mutual information
- Channel coding theorem
- Channel capacity of fundamental channels: BSC, BEC, AWGN channel, binary-input AWGN channel etc.
- Power-limited vs. bandlimited transmission
- Capacity of parallel AWGN channels
    - Waterfilling
    - Examples: Multiple input multiple output (MIMO) channels, complex equivalent baseband channels, orthogonal frequency division multiplex (OFDM)
- Source-channel coding theorem, separation theorem
- Multiuser information theory
    - Multiple access channel (MAC)
    - Broadcast channel
    - Principles of multiple access, time division multiple access (TDMA), frequency division multiple access (FDMA), non-orthogonal multiple access (NOMA), hybrid multiple access
    - Achievable rate regions of TDMA and FDMA with power constraint, energy constraint, power spectral density constraint, respectively
    - Achievable rate region of the two-user and K-user multiple access channels
    - Achievable rate region of the two-user and K user broadcast channels
    - Multiuser diversity
- Channel coding
    - Principles and types of channel coding
    - Code rate, data rate, Hamming distance, minimum Hamming distance, Hamming weight, minimum Hamming weight
    - Error detecting and error correcting codes
    - Simple block codes: Repetition codes, single parity check codes, Hamming code, etc.
    - Syndrome decoding
    - Representations of binary data
    - Non-binary symbol alphabets and non-binary codes
    - Code and encoder, systematic and non-systematic encoders
    - Properties of Hamming distance and Hamming weight
    - Decoding spheres
    - Perfect codes
    - Linear codes
    - Decoding principles
        - Syndrome decoding
        - Maximum a posteriori probability (MAP) decoding and maximum likelihood (ML) decoding
        - Hard decision and soft decision decoding
        - Log-likelihood ratios (LLRs), boxplus operation
        - MAP and ML decoding using log-likelihood ratios
        - Soft-in soft-out decoders
    - Error rate performance comparison of codes in terms of SNR per info bit vs. SNR per code bit
    - Linear block codes
        - Generator matrix and parity check matrix, properties of generator matrix and parity check matrix
        - Dual codes
    - Low density parity check (LDPC) codes
        - Sparse parity check matrix
        - Tanner graphs, cycles and girth
        - Degree distributions
        - Code rate and degree distribution
        - Regular and irregular LDPC codes
        - Message passing decoding
            - Message passing decoding in binary erasure channels (BEC)
            - Systematic encoding using erasure message passing decoding
            - Message passing decoding in binary symmetric channels (BSC)
                - Extrinsic information
                - Bit-flipping decoding
                - Effects of short cycles in the Tanner graph
                - Alternative bit-flipping decoding
                - Soft decision message passing decoding: Sum product decoding
            - Bit error rate performance of LDPC codes

	- Repeat accumulate codes and variants of repeat accumulate codes - Message passing decoding and turbo decoding of repeat accumulate codes ◦ Convolutional codes - Encoding using shift registers - Trellis representation - Hard decision and soft decision Viterbi decoding - Bit error rate performance of convolutional codes - Asymptotic coding gain - Viterbi decoding complexity - Free distance and optimum convolutional codes - Generator polynomial description and octal description - Catastrophic convolutional codes - Non-systematic and recursive systematic convolutional (RSC) encoders - Rate compatible punctured convolutional (RCPC) codes - Hybrid automatic repeat request (HARQ) with incremental redundancy - Unequal error protection with punctured convolutional codes - Error patterns of convolutional codes ◦ Concatenated codes - Serial concatenated codes - Parallel concatenated codes, Turbo codes - Iterative decoding, turbo decoding - Bit error rate performance of turbo codes - Interleaver design for turbo codes ◦ Coded modulation - Principle of coded modulation - Achievable rates with PSK/QAM modulation - Trellis coded modulation (TCM) - Set partitioning - Ungerböck codes - Multilevel coding - Bit-interleaved coded modulation
Literature	Bossert, M.: Kanalcodierung. Oldenbourg. Friedrichs, B.: Kanalcodierung. Springer. Lin, S., Costello, D.: Error Control Coding. Prentice Hall. Roth, R.: Introduction to Coding Theory. Johnson, S.: Iterative Error Correction. Cambridge. Richardson, T., Urbanke, R.: Modern Coding Theory. Cambridge University Press. Gallager, R. G.: Information theory and reliable communication. Whiley-VCH Cover, T., Thomas, J.: Elements of information theory. Wiley.

Course L0438: Information Theory and Coding	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0712: Microwave Semiconductor Devices and Circuits I

Courses

Title	Typ	Hrs/wk	CP
Microwave Semiconductor Devices and Circuits I (L0580)	Lecture	3	4
Microwave Semiconductor Devices and Circuits I (L0581)	Recitation Section (large)	2	2

Module Responsible	Prof. Alexander Kölpin
Admission Requirements	None
Recommended Previous Knowledge	Electrical Engineering IV, Microwave Engineering, Fundamentals of Semiconductor Technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are capable of explaining the functionality of amplifier, mixer, and oscillator in detail. They can present theories, concepts, and reasonable assumptions for description and synthesis of these devices. They are able to apply thorough knowledge of semiconductor physics of selected microwave devices to amplifier, mixer, and oscillator. They can compare different devices with respect to various parameters (such as frequency range, power und efficiency).
Skills	The students can assess occurring linear and nonlinear effects in active microwave circuits and are capable of analyzing and evaluating them. They are able to develop passive and active linear microwave circuits with the help of modern software-tools, taking application requirements into account.
Personal Competence	
Social Competence	The students are able to carry out subject-specific tasks in small groups, and to adequately present solutions (e.g. in CAD-Exercises).
Autonomy	The students are able to obtain additional information from given literature sources and set the content in context with the lecture. They can link and deepen their knowledge of other courses, e.g., Electrical Engineering IV, Theoretical Engineering, Microwave Engineering, Semiconductor Devices. The students acquire the ability to communicate problems and solutions in the field of microwave semiconductor devices and circuits in English.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Electrical Engineering: Specialisation Wireless and Sensor Technologies: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory

Course L0580: Microwave Semiconductor Devices and Circuits I	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Alexander Kölpin
Language	DE/EN
Cycle	SoSe
Content	- Amplifier: S-Parameters, stability, gain definitions; Bipolar Junction Transistor and HBT, MESFET and HEMT; Circuit applications, nonlinear distortions, low noise and power amplifier - Mixer: Conversion matrix analysis; pn- and Schottky-diode, FET; Circuit applications, conversion gain and noise figure - Oszillator: Oscillation start-up, steady state operation, stability; IMPATT-diode, Gunn-element, FET; oscillator stabilization - Linear passive circuits: Planar microwave circuits, quarterwave matching circuits and discontinuities, lowpass-filter and bandpass-filter synthesis - Design of active circuits
Literature	- E. Voges, „Hochfrequenztechnik“, Hüthig (2004) - H.-G. Unger, W. Harth, „Hochfrequenz-Halbleiterelektronik“, S. Hirzel Verlag (1972) - S.M. Sze, „Physics of Semiconductor Devices”, John Wiley & Sons (1981) - A. Jacob, „Lecture Notes Microwave Semiconductor Devices and Circuits Part I“

Course L0581: Microwave Semiconductor Devices and Circuits I	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Alexander Kölpin
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0746: Microsystem Engineering

Courses

Title	Typ	Hrs/wk	CP
Microsystem Engineering (L0680)	Lecture	2	4
Microsystem Engineering (L0682)	Project-/problem-based Learning	2	2

Module Responsible	Dr. Timo Lipka
Admission Requirements	None
Recommended Previous Knowledge	Basic courses in physics, mathematics and electric engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know about the most important technologies and materials of MEMS as well as their applications in sensors and actuators.
Skills	Students are able to analyze and describe the functional behaviour of MEMS components and to evaluate the potential of microsystems.
Personal Competence	
Social Competence	Students are able to solve specific problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire particular knowledge using specialized literature and to integrate and associate this knowledge with other fields.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** No; **Bonus** 10 %; **Form** Presentation; **Description**
Examination	Written exam
Examination duration and scale	2h
Assignment for the Following Curricula	Electrical Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0680: Microsystem Engineering	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Dr. Timo Lipka
Language	EN
Cycle	WiSe
Content	Object and goal of MEMS Scaling Rules Lithography Film deposition Structuring and etching Energy conversion and force generation Electromagnetic Actuators Reluctance motors Piezoelectric actuators, bi-metal-actuator Transducer principles Signal detection and signal processing Mechanical and physical sensors Acceleration sensor, pressure sensor Sensor arrays System integration Yield, test and reliability
Literature	M. Kasper: Mikrosystementwurf, Springer (2000) M. Madou: Fundamentals of Microfabrication, CRC Press (1997)

Course L0682: Microsystem Engineering	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Timo Lipka
Language	EN
Cycle	WiSe
Content	Examples of MEMS components Layout consideration Electric, thermal and mechanical behaviour Design aspects
Literature	Wird in der Veranstaltung bekannt gegeben

Module M0676: Digital Communications

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Digital Communications (L0444)	Lecture	2	3
Digital Communications (L0445)	Recitation Section (large)	2	2
Laboratory Digital Communications (L0646)	Practical Course	1	1

Module Responsible	Prof. Gerhard Bauch
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics 1-3 • Signals and Systems • Fundamentals of Communications and Random Processes
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to understand, compare and design modern digital information transmission schemes. They are familiar with the properties of linear and non-linear digital modulation methods. They can describe distortions caused by transmission channels and design and evaluate detectors including channel estimation and equalization. They know the principles of single carrier transmission and multi-carrier transmission as well as the fundamentals of basic multiple access schemes. The students are familiar with the contents of lecture and tutorials. They can explain and apply them to new problems.
Skills	The students are able to design and analyse a digital information transmission scheme including multiple access. They are able to choose a digital modulation scheme taking into account transmission rate, required bandwidth, error probability, and further signal properties. They can design an appropriate detector including channel estimation and equalization taking into account performance and complexity properties of suboptimum solutions. They are able to set parameters of a single carrier or multi carrier transmission scheme and trade the properties of both approaches against each other.
Personal Competence	
Social Competence	The students can jointly solve specific problems.
Autonomy	The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes / **Bonus** None / **Form** Written elaboration / **Description**
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Data Science: Specialisation II. Computer Science: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Electrical Engineering: Core Qualification: Compulsory Computer Science in Engineering: Specialisation II. Engineering Science: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0444: Digital Communications

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	WiSe
Content	• Repetition: Baseband Transmission ◦ Pulse shaping: Non-return to zero (NRZ) rectangular pulses, raised-cosine pulses, square-root raised-cosine pulses ◦ Power spectral density (psd) of baseband signals ◦ Intersymbol interference (ISI) ◦ First and second Nyquist criterion ◦ AWGN channel ◦ Matched filter ◦ Matched-filter receiver and correlation receiver ◦ Noise whitening matched filter ◦ Discrete-time AWGN channel model • Representation of bandpass signals and systems in the equivalent baseband ◦ Quadrature amplitude modulation (QAM) ◦ Equivalent baseband signal and system ◦ Analytical signal ◦ Equivalent baseband random process, equivalent baseband white Gaussian noise process

  - Equivalent baseband AWGN channel
  - Equivalent baseband channel model with frequency-offset and phase noise
  - Equivalent baseband Rayleigh fading and Rice fading channel models
  - Equivalent baseband frequency-selective channel model
  - Discrete memoryless channels (DMC)
- Bandpass transmission via carrier modulation
  - Amplitude modulation, frequency modulation, phase modulation
  - Linear digital modulation methods
    - On-off keying, M-ary amplitude shift keying (M-ASK), M-ary phase shift keying (M-PSK), M-ary quadrature amplitude modulation (M-QAM), offset-QPSK
    - Signal space representation of transmit signal constellations and signals
    - Energy of linear digital modulated signals, average energy per symbol
    - Power spectral density of linear digital modulated signals
    - Bandwidth efficiency
    - Correlation coefficient of elementary signals
    - Error probabilities of linear digital modulation methods
      - Error functions
      - Gray mapping and natural mapping
      - Bit error probabilities, symbol error probabilities, pairwise symbol error probabilities
      - Euclidean distance and Hamming distance
      - Exact and approximate computation of error probabilities
      - Performance comparison of modulation schemes in terms of per bit SNR vs. per symbol SNR
    - Hierarchical modulation, multilevel modulation
    - Effects of carrier phase offset and carrier frequency offset
    - Differential modulation
      - M-ary differential phase shift keying (M-PSK)
      - Coherent and non-coherent detection of DPSK
      - p/M-differential phase shift keying (p/M-DPSK)
      - Differential amplitude and phase shift keying (DAPSK)
  - Non-linear digital modulation methods
    - Frequency shift keying (FSK)
    - Modulation index
    - Minimum shift keying (MSK)
      - Offset-QPSK representation of MSK
      - MSK with differential precoding and rotation
      - Bit error probabilities of MSK
      - Gaussian minimum shift keying (GMSK)
      - Power spectral density of MSK and GMSK
    - Continuous phase modulation (CPM)
      - General description of CPM signals
      - Frequency pulses and phase pulses
    - Coherent and non-coherent detection of FSK
  - Performance comparison of linear and non-linear digital modulation methods
- Frequency-selective channels, ISI channels
  - Intersymbol interference and frequency-selectivity
  - RMS delay spread
  - Narrowband and broadband channels
  - Equivalent baseband transmission model for frequency-selective channels
  - Receive filter design
- Equalization
  - Symbol-spaced and fractionally-spaced equalizers
  - Inverse system
  - Non-recursive linear equalizers
    - Linear zero-forcing (ZF) equalizer
    - Linear minimum mean squared error (MMSE) equalizer
  - Non-linear equalization:
    - Decision feedback equalizer (DFE)
    - Tomlinson-Harashima precoding
  - Maximum a posteriori probability (MAP) and maximum likelihood equalizer, Viterbi algorithm
- Single-carrier vs. multi-carrier transmission
- Multi-carrier transmission
  - General multicarrier transmission
  - Orthogonal frequency division multiplex (OFDM)
    - OFDM implementation using the Fast Fourier Transform (FFT)
    - Cyclic guard interval
    - Power spectral density of OFDM
    - Peak-to-average power ratio (PAPR)
- Multiple access
  - Principles of time division multiple access (TDMA), frequency division multiple access (FDMA), code division multiple access (CDMA), non-orthogonal multiple access (NOMA), hybrid multiple access
- Spread spectrum communications
  - Direct sequence spread spectrum communications
  - Frequency hopping
  - Protection against eavesdropping
  - Protection against narrowband jammers

	◦ Short vs. long spreading codes
	◦ Direct sequence spread spectrum communications in frequency-selective channels
	    ▪ Rake receiver
	◦ Code division multiple access (CDMA)
	    ▪ Design criteria of spreading sequences, autocorrelation function and crosscorrelation function of spreading sequences
	    ▪ Intersymbol interference (ISI) and multiple access interference (MAI)
	    ▪ Pseudo noise (PN) sequences, maximum length sequences (m-sequences), Gold codes, Walsh-Hadamard codes, orthogonal variable spreading factor (OVSF) codes
	    ▪ Multicode transmission
	    ▪ CDMA in uplink and downlink of a wireless communications system
	    ▪ Single-user detection vs. multi-user detection

Literature	K. Kammeyer: Nachrichtenübertragung, Teubner P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner. J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill. S. Haykin: Communication Systems. Wiley R.G. Gallager: Principles of Digital Communication. Cambridge A. Goldsmith: Wireless Communication. Cambridge. D. Tse, P. Viswanath: Fundamentals of Wireless Communication. Cambridge.

Course L0445: Digital Communications	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0646: Laboratory Digital Communications	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe
Content	- DSL transmission - Random processes - Digital data transmission
Literature	K. Kammeyer: Nachrichtenübertragung, Teubner P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner. J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill. S. Haykin: Communication Systems. Wiley R.G. Gallager: Principles of Digital Communication. Cambridge A. Goldsmith: Wireless Communication. Cambridge. D. Tse, P. Viswanath: Fundamentals of Wireless Communication. Cambridge.

Module M0925: Digital Circuit Design

Courses

Title	Typ	Hrs/wk	CP
Digital Circuit Design (L0698)	Lecture	2	3
Advanced Digital Circuit Design (L0699)	Lecture	2	3

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	40 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Microelectronics and Microsystems: Specialisation Microelectronics Complements: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory

Course L0698: Digital Circuit Design

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Volkhard Klinger
Language	EN
Cycle	WiSe
Content	
Literature	

Course L0699: Advanced Digital Circuit Design

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Volkhard Klinger
Language	EN
Cycle	SoSe
Content	
Literature	

Module M1048: Integrated Circuit Design

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Integrated Circuit Design (L0691)	Lecture	3	4
Integrated Circuit Design (L0998)	Recitation Section (small)	1	2

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of (solid-state) physics and mathematics. Knowledge in fundamentals of electrical engineering and electrical networks.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain basic concepts of electron transport in semiconductor devices (energy bands, generation/recombination, carrier concentrations, drift and diffusion current densities, semiconductor device equations). • Students are able to explain functional principles of pn-diodes, MOS capacitors, and MOSFETs using energy band diagrams. • Students can present and discuss current-voltage relationships and small-signal equivalent circuits of these devices. • Students can explain the physics and current-voltage behavior transistors based on charged carrier flow. • Students are able to explain the basic concepts for static and dynamic logic gates for integrated circuits • Students can exemplify approaches for low power consumption on the device and circuit level • Students can describe the potential and limitations of analytical expression for device and circuit analysis. • Students can explain characterization techniques for MOS devices.
Skills	• Students can qualitatively construct energy band diagrams of the devices for varying applied voltages. • Students are able to qualitatively determine electric field, carrier concentrations, and charge flow from energy band diagrams. • Students can understand scientific publications from the field of semiconductor devices. • Students can calculate the dimensions of MOS devices in dependence of the circuits properties • Students can design complex electronic circuits and anticipate possible problems. • Students know procedure for optimization regarding high performance and low power consumption
Personal Competence	
Social Competence	• Students can team up with other experts in the field to work out innovative solutions. • Students are able to work by their own or in small groups for solving problems and answer scientific questions. • Students have the ability to critically question the value of their contributions to working groups.
Autonomy	• Students are able to assess their knowledge in a realistic manner. • Students are able to define their personal approaches to solve challenging problems
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0691: Integrated Circuit Design	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Matthias Kuhl
Language	EN
Cycle	WiSe
Content	• Electron transport in semiconductors • Electronic operating principles of diodes, MOS capacitors, and MOS field-effect transistors • MOS transistor as four terminal device • Performace degradation due to short channel effects • Scaling-down of MOS technology • Digital logic circuits • Basic analog circuits • Operational amplifiers • Bipolar and BiCMOS circuits
Literature	• Yuan Taur, Tak H. Ning: Fundamentals of Modern VLSI Devices, Cambridge University Press 1998 • R. Jacob Baker: CMOS, Circuit Design, Layout and Simulation, IEEE Press, Wiley Interscience, 3rd Edition, 2010 • Neil H.E. Weste and David Money Harris, Integrated Circuit Design, Pearson, 4th International Edition, 2013 • John E. Ayers, Digital Integrated Circuits: Analysis and Design, CRC Press, 2009 • Richard C. Jaeger and Travis N. Blalock: Microelectronic Circuit Design, Mc Graw-Hill, 4rd. Edition, 2010

Course L0998: Integrated Circuit Design	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Matthias Kuhl
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0548: Bioelectromagnetics: Principles and Applications

Courses

Title	Typ	Hrs/wk	CP
Bioelectromagnetics: Principles and Applications (L0371)	Lecture	3	5
Bioelectromagnetics: Principles and Applications (L0373)	Recitation Section (small)	2	1

Module Responsible	Prof. Christian Schuster
Admission Requirements	None
Recommended Previous Knowledge	Basic principles of physics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the basic principles, relationships, and methods of bioelectromagnetics, i.e. the quantification and application of electromagnetic fields in biological tissue. They can define and exemplify the most important physical phenomena and order them corresponding to wavelength and frequency of the fields. They can give an overview over measurement and numerical techniques for characterization of electromagnetic fields in practical applications . They can give examples for therapeutic and diagnostic utilization of electromagnetic fields in medical technology.
Skills	Students know how to apply various methods to characterize the behavior of electromagnetic fields in biological tissue. In order to do this they can relate to and make use of the elementary solutions of Maxwell’s Equations. They are able to assess the most important effects that these models predict for biological tissue, they can order the effects corresponding to wavelength and frequency, respectively, and they can analyze them in a quantitative way. They are able to develop validation strategies for their predictions. They are able to evaluate the effects of electromagnetic fields for therapeutic and diagnostic applications and make an appropriate choice.
Personal Competence	
Social Competence	Students are able to work together on subject related tasks in small groups. They are able to present their results effectively in English (e.g. during small group exercises).
Autonomy	Students are capable to gather information from subject related, professional publications and relate that information to the context of the lecture. They are able to make a connection between their knowledge obtained in this lecture with the content of other lectures (e.g. theory of electromagnetic fields, fundamentals of electrical engineering / physics). They can communicate problems and effects in the field of bioelectromagnetics in English.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** None; **Form** Presentation; **Description**
Examination	Oral exam
Examination duration and scale	45 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Microwave Engineering, Optics, and Electromagnetic Compatibility: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Electrical Engineering: Specialisation Wireless and Sensor Technologies: Elective Compulsory Computer Science in Engineering: Specialisation II. Engineering Science: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0371: Bioelectromagnetics: Principles and Applications	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	WiSe
Content	- Fundamental properties of electromagnetic fields (phenomena) - Mathematical description of electromagnetic fields (Maxwell’s Equations) - Electromagnetic properties of biological tissue - Principles of energy absorption in biological tissue, dosimetry - Numerical methods for the computation of electromagnetic fields (especially FDTD) - Measurement techniques for characterization of electromagnetic fields - Behavior of electromagnetic fields of low frequency in biological tissue - Behavior of electromagnetic fields of medium frequency in biological tissue - Behavior of electromagnetic fields of high frequency in biological tissue - Behavior of electromagnetic fields of very high frequency in biological tissue - Diagnostic applications of electromagnetic fields in medical technology - Therapeutic applications of electromagnetic fields in medical technology - The human body as a generator of electromagnetic fields
Literature	- C. Furse, D. Christensen, C. Durney, "Basic Introduction to Bioelectromagnetics", CRC (2009) - A. Vorst, A. Rosen, Y. Kotsuka, "RF/Microwave Interaction with Biological Tissues", Wiley (2006) - S. Grimnes, O. Martinsen, "Bioelectricity and Bioimpedance Basics", Academic Press (2008) - F. Barnes, B. Greenebaum, "Bioengineering and Biophysical Aspects of Electromagnetic Fields", CRC (2006)

Course L0373: Bioelectromagnetics: Principles and Applications	
Typ	Recitation Section (small)
Hrs/wk	2
CP	1
Workload in Hours	Independent Study Time 2, Study Time in Lecture 28
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0710: Microwave Engineering

Courses

Title	Typ	Hrs/wk	CP
Microwave Engineering (L0573)	Lecture	2	3
Microwave Engineering (L0574)	Recitation Section (large)	2	2
Microwave Engineering (L0575)	Practical Course	1	1

Module Responsible	Prof. Alexander Kölpin
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of communication engineering, semiconductor devices and circuits. Basics of Wave propagation from transmission line theory and theoretical electrical engineering.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the propagation of electromagnetic waves and related phenomena. They can describe transmission systems and components. They can name different types of antennas and describe the main characteristics of antennas. They can explain noise in linear circuits, compare different circuits using characteristic numbers and select the best one for specific scenarios.
Skills	Students are able to calculate the propagation of electromagnetic waves. They can analyze complete transmission systems und configure simple receiver circuits. They can calculate the characteristic of simple antennas and arrays based on the geometry. They can calculate the noise of receivers and the signal-to-noise-ratio of transmission systems. They can apply their theoretical knowledge to the practical courses.
Personal Competence	
Social Competence	Students work together in small groups during the practical courses. Together they document, evaluate and discuss their results.
Autonomy	Students are able to relate the knowledge gained in the course to contents of previous lectures. With given instructions they can extract data needed to solve specific problems from external sources. They are able to apply their knowledge to the laboratory courses using the given instructions.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory**: Yes; **Bonus**: None; **Form**: Subject theoretical and practical work; **Description**:
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Electrical Engineering: Core Qualification: Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory

Course L0573: Microwave Engineering	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Kölpin
Language	DE/EN
Cycle	WiSe
Content	- Antennas: Analysis - Characteristics - Realizations - Radio Wave Propagation - Transmitter: Power Generation with Vacuum Tubes and Transistors - Receiver: Preamplifier - Heterodyning - Noise - Selected System Applications
Literature	H.-G. Unger, „Elektromagnetische Theorie für die Hochfrequenztechnik, Teil I“, Hüthig, Heidelberg, 1988 H.-G. Unger, „Hochfrequenztechnik in Funk und Radar“, Teubner, Stuttgart, 1994 E. Voges, „Hochfrequenztechnik - Teil II: Leistungsröhren, Antennen und Funkübertragung, Funk- und Radartechnik“, Hüthig, Heidelberg, 1991 E. Voges, „Hochfrequenztechnik“, Hüthig, Bonn, 2004 C.A. Balanis, “Antenna Theory”, John Wiley and Sons, 1982 R. E. Collin, “Foundations for Microwave Engineering”, McGraw-Hill, 1992 D. M. Pozar, “Microwave and RF Design of Wireless Systems”, John Wiley and Sons, 2001 D. M. Pozar, “Microwave Engineerin”, John Wiley and Sons, 2005

Course L0574: Microwave Engineering	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Alexander Kölpin
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0575: Microwave Engineering	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Alexander Kölpin
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Specialization II. Energy and Environmental Engineering

Module M0512: Use of Solar Energy

Courses

Title	Typ	Hrs/wk	CP
Energy Meteorology (L0016)	Lecture	1	1
Energy Meteorology (L0017)	Recitation Section (small)	1	1
Collector Technology (L0018)	Lecture	2	2
Solar Power Generation (L0015)	Lecture	2	2

Module Responsible	Prof. Martin Kaltschmitt
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	With the completion of this module, students will be able to deal with technical foundations and current issues and problems in the field of solar energy and explain and evaulate these critically in consideration of the prior curriculum and current subject specific issues. In particular they can professionally describe the processes within a solar cell and explain the specific features of application of solar modules. Furthermore, they can provide an overview of the collector technology in solar thermal systems.
Skills	Students can apply the acquired theoretical foundations of exemplary energy systems using solar radiation. In this context, for example they can assess and evaluate potential and constraints of solar energy systems with respect to different geographical assumptions. They are able to dimension solar energy systems in consideration of technical aspects and given assumptions. Using module-comprehensive knowledge students can evalute the economic and ecologic conditions of these systems. They can select calculation methods within the radiation theory for these topics.
Personal Competence	
Social Competence	Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module.
Autonomy	Students can independently exploit sources and acquire the particular knowledge about the subject area with respect to emphasis fo the lectures. Furthermore, with the assistance of lecturers, they can discrete use calculation methods for analysing and dimensioning solar energy systems. Based on this procedure they can concrete assess their specific learning level and can consequently define the further workflow.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 20 % / Written elaboration / Ausarbeitung Kollektortechnik
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Energy Systems: Specialisation Energy Systems: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory

Course L0016: Energy Meteorology	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Volker Matthias, Dr. Beate Geyer
Language	DE
Cycle	SoSe

Content	• Introduction: radiation source Sun, Astronomical Foundations, Fundamentals of radiation
	• Structure of the atmosphere
	• Properties and laws of radiation
	    ◦ Polarization
	    ◦ Radiation quantities
	    ◦ Planck's radiation law
	    ◦ Wien's displacement law
	    ◦ Stefan-Boltzmann law
	    ◦ Kirchhoff's law
	    ◦ Brightness temperature
	    ◦ Absorption, reflection, transmission
	• Radiation balance, global radiation, energy balance
	• Atmospheric extinction
	• Mie and Rayleigh scattering
	• Radiative transfer
	• Optical effects in the atmosphere
	• Calculation of the sun and calculate radiation on inclined surfaces

Literature	• Helmut Kraus: Die Atmosphäre der Erde • Hans Häckel: Meteorologie • Grant W. Petty: A First Course in Atmosheric Radiation • Martin Kaltschmitt, Wolfgang Streicher, Andreas Wiese: Renewable Energy • Alexander Löw, Volker Matthias: Skript Optik Strahlung Fernerkundung

Course L0017: Energy Meteorology	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Beate Geyer
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0018: Collector Technology	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Agis Papadopoulos
Language	DE
Cycle	SoSe
Content	• Introduction: Energy demand and application of solar energy. • Heat transfer in the solar thermal energy: conduction, convection, radiation. • Collectors: Types, structure, efficiency, dimensioning, concentrated systems. • Energy storage: Requirements, types. • Passive solar energy: components and systems. • Solar thermal low temperature systems: collector variants, construction, calculation. • Solar thermal high temperature systems: Classification of solar power plants construction. • Solar air conditioning.
Literature	• Vorlesungsskript. • Kaltschmitt, Streicher und Wiese (Hrsg.). Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte, 5. Auflage, Springer, 2013. • Stieglitz und Heinzel .Thermische Solarenergie: Grundlagen, Technologie, Anwendungen. Springer, 2012. • Von Böckh und Wetzel. Wärmeübertragung: Grundlagen und Praxis, Springer, 2011. • Baehr und Stephan. Wärme- und Stoffübertragung. Springer, 2009. • de Vos. Thermodynamics of solar energy conversion. Wiley-VCH, 2008. • Mohr, Svoboda und Unger. Praxis solarthermischer Kraftwerke. Springer, 1999.

Course L0015: Solar Power Generation	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Martin Schlecht, Prof. Alf Mews, Roman Fritsches-Baguhl
Language	DE
Cycle	SoSe
Content	Photovoltaics: 1. Introduction 2. Primary energies and consumption, available solar energy 3. Physics of the ideal solar cell 4. Light absorption, PN transition, characteristic sizes of the solar cell, efficiency 5. Physics of the real solar cell 6. Charge carrier recombination, characteristic curves, barrier layer recombination, equivalent circuit diagram 7. Increasing efficiency 8. Methods for increasing the quantum yield and reducing recombination 9. Hetero- and tandem structures 10. Heterojunction, Schottky, electrochemical, MIS and SIS cell, tandem cell 11. Concentrator cells 12. Concentrator optics and tracking systems, concentrator cells 13. Technology and properties: solar cell types, manufacturing, monocrystalline silicon and gallium arsenide, polycrystalline silicon and silicon thin film cells, thin film cells on carriers (amorphous silicon, CIS, electrochemical cells) 14. Modules 15. Switches Concentrating solar power plants: 1. Introduction 2. Point focused technologies 3. Line focused technologies 4. Design of CSP projects
Literature	• A. Götzberger, B. Voß, J. Knobloch: Sonnenenergie: Photovoltaik, Teubner Studienskripten, Stuttgart, 1995 • A. Götzberger: Sonnenenergie: Photovoltaik : Physik und Technologie der Solarzelle, Teubner Stuttgart, 1994 • H.-J. Lewerenz, H. Jungblut: Photovoltaik, Springer, Berlin, Heidelberg, New York, 1995 • A. Götzberger: Photovoltaic solar energy generation, Springer, Berlin, 2005 • C. Hu, R. M. White: Solar Cells, Mc Graw Hill, New York, 1983 • H.-G. Wagemann: Grundlagen der photovoltaischen Energiewandlung: Solarstrahlung, Halbleitereigenschaften und Solarzellenkonzepte, Teubner, Stuttgart, 1994 • R. J. van Overstraeten, R.P. Mertens: Physics, technology and use of photovoltaics, Adam Hilger Ltd, Bristol and Boston, 1986 • B. O. Seraphin: Solar energy conversion Topics of applied physics V 01 31, Springer, Berlin, Heidelberg, New York, 1995 • P. Würfel: Physics of Solar cells, Principles and new concepts, Wiley-VCH, Weinheim 2005 • U. Rindelhardt: Photovoltaische Stromversorgung, Teubner-Reihe Umwelt, Stuttgart 2001 • V. Quaschning: Regenerative Energiesysteme, Hanser, München, 2003 • G. Schmitz: Regenerative Energien, Ringvorlesung TU Hamburg-Harburg 1994/95, Institut für Energietechnik

Module M0513: System Aspects of Renewable Energies

Courses

Title	Typ	Hrs/wk	CP
Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage (L0021)	Lecture	2	2
Energy Trading (L0019)	Lecture	1	1
Energy Trading (L0020)	Recitation Section (small)	1	1
Deep Geothermal Energy (L0025)	Lecture	2	2

Module Responsible	Prof. Martin Kaltschmitt
Admission Requirements	None
Recommended Previous Knowledge	Module: Technical Thermodynamics I Module: Technical Thermodynamics II
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe the processes in energy trading and the design of energy markets and can critically evaluate them in relation to current subject specific problems. Furthermore, they are able to explain the basics of thermodynamics of electrochemical energy conversion in fuel cells and can establish and explain the relationship to different types of fuel cells and their respective structure. Students can compare this technology with other energy storage options. In addition, students can give an overview of the procedure and the energetic involvement of deep geothermal energy.
Skills	Students can apply the learned knowledge of storage systems for excessive energy to explain for various energy systems different approaches to ensure a secure energy supply. In particular, they can plan and calculate domestic, commercial and industrial heating equipment using energy storage systems in an energy-efficient way and can assess them in relation to complex power systems. In this context, students can assess the potential and limits of geothermal power plants and explain their operating mode. Furthermore, the students are able to explain the procedures and strategies for marketing of energy and apply it in the context of other modules on renewable energy projects. In this context they can unassistedly carry out analysis and evaluations of energie markets and energy trades.
Personal Competence	
Social Competence	Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module.
Autonomy	Students can independently exploit sources , acquire the particular knowledge about the subject area and transform it to new questions.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	3 hours written exam
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory

Course L0021: Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Fröba
Language	DE
Cycle	SoSe
Content	1. Introduction to electrochemical energy conversion 2. Function and structure of electrolyte 3. Low-temperature fuel cell ◦ Types ◦ Thermodynamics of the PEM fuel cell ◦ Cooling and humidification strategy 4. High-temperature fuel cell ◦ The MCFC ◦ The SOFC ◦ Integration Strategies and partial reforming 5. Fuels ◦ Supply of fuel ◦ Reforming of natural gas and biogas ◦ Reforming of liquid hydrocarbons 6. Energetic Integration and control of fuel cell systems
Literature	• Hamann, C.; Vielstich, W.: Elektrochemie 3. Aufl.; Weinheim: Wiley - VCH, 2003

Course L0019: Energy Trading	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Michael Sagorje, Dr. Sven Orlowski
Language	DE
Cycle	SoSe
Content	• Basic concepts and tradable products in energy markets • Primary energy markets • Electricity Markets • European Emissions Trading Scheme • Influence of renewable energy • Real options • Risk management Within the exercise the various tasks are actively discussed and applied to various cases of application.
Literature	

Course L0020: Energy Trading	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Michael Sagorje, Dr. Sven Orlowski
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0025: Deep Geothermal Energy	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Ben Norden
Language	DE
Cycle	SoSe
Content	1. Introduction to the deep geothermal use 2. Geological Basics I 3. Geological Basics II 4. Geology and thermal aspects 5. Rock Physical Aspects 6. Geochemical aspects 7. Exploration of deep geothermal reservoirs 8. Drilling technologies, piping and expansion 9. Borehole Geophysics 10. Underground system characterization and reservoir engineering 11. Microbiology and Upper-day system components 12. Adapted investment concepts, cost and environmental aspect
Literature	• Dipippo, R.: Geothermal Power Plants: Principles, Applications, Case Studies and Environmental Impact. Butterworth Heinemann; 3rd revised edition. (29. Mai 2012) • www.geo-energy.org • Edenhofer et al. (eds): Renewable Energy Sources and Climate Change Mitigation; Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2012. • Kaltschmitt et al. (eds): Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Springer, 5. Aufl. 2013. • Kaltschmitt et al. (eds): Energie aus Erdwärme. Spektrum Akademischer Verlag; Auflage: 1999 (3. September 2001) • Huenges, E. (ed.): Geothermal Energy Systems: Exploration, Development, and Utilization. Wiley-VCH Verlag GmbH & Co. KGaA; Auflage: 1. Auflage (19. April 2010)

Module M0874: Wastewater Systems

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Biological Wastewater Treatment (L0517)	Lecture	2	2
Biological Wastewater Treatment (L3122)	Recitation Section (large)	1	1
Advanced Wastewater Treatment (L0357)	Lecture	2	2
Advanced Wastewater Treatment (L0358)	Recitation Section (large)	1	1

Module Responsible	Prof. Ralf Otterpohl
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of wastewater management and the key processes involved in wastewater treatment.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to outline key areas of the full range of treatment systems in waste water management, as well as their mutual dependence for sustainable water protection. They can describe relevant economic, environmental and social factors.
Skills	Students are able to pre-design and explain the available wastewater treatment processes and the scope of their application in municipal and for some industrial treatment plants.
Personal Competence	
Social Competence	Social skills are not targeted in this module.
Autonomy	Students are in a position to work on a subject and to organize their work flow independently. They can also present on this subject.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Environmental Engineering: Specialisation Water Quality and Water Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Compulsory

Course L0517: Biological Wastewater Treatment

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Joachim Behrendt
Language	DE/EN
Cycle	SoSe
Content	Charaterisation of Wastewater Metobolism of Microorganisms Kinetic of mirobiotic processes Calculation of bioreactor for wastewater treatment Concepts of Wastewater treatment Design of WWTP Excursion to a WWTP Biofilms Biofim Reactors Anaerobic Wastewater and sldge treatment resources oriented sanitation technology Future challenges of wastewater treatment
Literature	**Gujer, Willi** Siedlungswasserwirtschaft : mit 84 Tabellen ISBN: 3540343296 (Gb.) URL: http://www.gbv.de/dms/bs/toc/516261924.pdf URL: http://deposit.d-nb.de/cgi-bin/dokserv?id=2842122&prov=M&dok_var=1&dok_ext=htm Berlin [u.a.] : Springer, 2007 TUB_HH_Katalog **Henze, Mogens**

Wastewater treatment : biological and chemical processes
ISBN: 3540422285 (Pp.)
Berlin [u.a.] : Springer, 2002
TUB_HH_Katalog
Imhoff, Karl (Imhoff, Klaus R.;)
Taschenbuch der Stadtentwässerung : mit 10 Tafeln
ISBN: 3486263331 ((Gb.))
München [u.a.] : Oldenbourg, 1999
TUB_HH_Katalog
Lange, Jörg (Otterpohl, Ralf; Steger-Hartmann, Thomas;)
Abwasser : Handbuch zu einer zukunftsfähigen Wasserwirtschaft
ISBN: 3980350215 (kart.) URL: http://www.gbv.de/du/services/agi/52567E5D44DA0809C12570220050BF25/000000700334
Donaueschingen-Pfohren : Mall-Beton-Verl., 2000
TUB_HH_Katalog
Mudrack, Klaus (Kunst, Sabine;)
Biologie der Abwasserreinigung : 18 Tabellen
ISBN: 382741427X URL: http://www.gbv.de/du/services/agi/94B581161B6EC747C1256E3F005A8143/420000114903
Heidelberg [u.a.] : Spektrum, Akad. Verl., 2003
TUB_HH_Katalog
Tchobanoglous, George (Metcalf & Eddy, Inc., ;)
Wastewater engineering : treatment and reuse
ISBN: 0070418780 (alk. paper) ISBN: 0071122508 (ISE (*pbk))
Boston [u.a.] : McGraw-Hill, 2003
TUB_HH_Katalog
Henze, Mogens
Activated sludge models ASM1, ASM2, ASM2d and ASM3
ISBN: 1900222248
London : IWA Publ., 2002
TUB_HH_Katalog
Kunz, Peter
Umwelt-Bioverfahrenstechnik
Vieweg, 1992
Bauhaus-Universität., Arbeitsgruppe Weiterbildendes Studium Wasser und Umwelt (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall, ;)
Abwasserbehandlung : Gewässerbelastung, Bemessungsgrundlagen, Mechanische Verfahren, Biologische Verfahren, Reststoffe aus der Abwasserbehandlung, Kleinkläranlagen
ISBN: 3860682725 URL: http://www.gbv.de/dms/weimar/toc/513989765_toc.pdf URL: http://www.gbv.de/dms/weimar/abs/513989765_abs.pdf
Weimar : Universitätsverl, 2006
TUB_HH_Katalog
Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall
DWA-Regelwerk
Hennef : DWA, 2004
TUB_HH_Katalog
Wiesmann, Udo (Choi, In Su; Dombrowski, Eva-Maria;)
Fundamentals of biological wastewater treatment
ISBN: 3527312196 (Gb.) URL: http://deposit.ddb.de/cgi-bin/dokserv?id=2774611&prov=M&dok_var=1&dok_ext=htm
Weinheim : WILEY-VCH, 2007
TUB_HH_Katalog

Course L3122: Biological Wastewater Treatment	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Joachim Behrendt
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0357: Advanced Wastewater Treatment	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Joachim Behrendt
Language	EN
Cycle	SoSe
Content	Survey on advanced wastewater treatment reuse of reclaimed municipal wastewater Precipitation Flocculation Depth filtration Membrane Processes Activated carbon adsorption Ozonation "Advanced Oxidation Processes" Disinfection
Literature	Metcalf & Eddy, Wastewater Engineering: Treatment and Reuse, McGraw-Hill, Boston 2003 Wassertechnologie, H.H. Hahn, Springer-Verlag, Berlin 1987 Membranverfahren: Grundlagen der Modul- und Anlagenauslegung, T. Melin und R. Rautenbach, Springer-Verlag, Berlin 2007 Trinkwasserdesinfektion: Grundlagen, Verfahren, Anlagen, Geräte, Mikrobiologie, Chlorung, Ozonung, UV-Bestrahlung, Membranfiltration, Qualitätssicherung, W. Roeske, Oldenbourg-Verlag, München 2006 Organische Problemstoffe in Abwässern, H. Gulyas, GFEU, Hamburg 2003

Course L0358: Advanced Wastewater Treatment	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Joachim Behrendt
Language	EN
Cycle	SoSe
Content	Aggregate organic compounds (sum parameters) Industrial wastewater Processes for industrial wastewater treatment Precipitation Flocculation Activated carbon adsorption Recalcitrant organic compounds
Literature	Metcalf & Eddy, Wastewater Engineering: Treatment and Reuse, McGraw-Hill, Boston 2003 Wassertechnologie, H.H. Hahn, Springer-Verlag, Berlin 1987 Membranverfahren: Grundlagen der Modul- und Anlagenauslegung, T. Melin und R. Rautenbach, Springer-Verlag, Berlin 2007 Trinkwasserdesinfektion: Grundlagen, Verfahren, Anlagen, Geräte, Mikrobiologie, Chlorung, Ozonung, UV-Bestrahlung, Membranfiltration, Qualitätssicherung, W. Roeske, Oldenbourg-Verlag, München 2006 Organische Problemstoffe in Abwässern, H. Gulyas, GFEU, Hamburg 2003

Module M0721: Air Conditioning

Courses

Title	Typ	Hrs/wk	CP
Air Conditioning (L0594)	Lecture	3	5
Air Conditioning (L0595)	Recitation Section (large)	1	1

Module Responsible	Prof. Arne Speerforck
Admission Requirements	None
Recommended Previous Knowledge	Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know the different kinds of air conditioning systems for buildings and mobile applications and how these systems are controlled. They are familiar with the change of state of humid air and are able to draw the state changes in a h1+x,x-diagram. They are able to calculate the minimum airflow needed for hygienic conditions in rooms and can choose suitable filters. They know the basic flow pattern in rooms and are able to calculate the air velocity in rooms with the help of simple methods. They know the principles to calculate an air duct network. They know the different possibilities to produce cold and are able to draw these processes into suitable thermodynamic diagrams. They know the criteria for the assessment of refrigerants.
Skills	Students are able to configure air condition systems for buildings and mobile applications. They are able to calculate an air duct network and have the ability to perform simple planning tasks, regarding natural heat sources and heat sinks. They can transfer research knowledge into practice. They are able to perform scientific work in the field of air conditioning.
Personal Competence	
Social Competence	In lectures and exercises, the students can use many examples and experiments to discuss in small groups in a goal-oriented manner, develop a solution and present it. Within the exercises, the students can independently develop further questions and work out targeted solutions.
Autonomy	Students are able to define tasks independently, to develop the necessary knowledge themselves based on the knowledge they have received, and to use suitable means for implementation. In the exercises, the students discuss the methods taught in the lectures using complex tasks and critically analyze the results.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min
Assignment for the Following Curricula	Energy Systems: Specialisation Energy Systems: Elective Compulsory Energy Systems: Specialisation Marine Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0594: Air Conditioning	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Arne Speerforck, Prof. Gerhard Schmitz
Language	DE
Cycle	SoSe
Content	1. Overview 1.1 Kinds of air conditioning systems 1.2 Ventilating 1.3 Function of an air condition system 2. Thermodynamic processes 2.1 Psychrometric chart 2.2 Mixer preheater, heater 2.3 Cooler 2.4 Humidifier 2.5 Air conditioning process in a Psychrometric chart 2.6 Desiccant assisted air conditioning 3. Calculation of heating and cooling loads 3.1 Heating loads 3.2 Cooling loads 3.3 Calculation of inner cooling load 3.4 Calculation of outer cooling load 4. Ventilating systems 4.1 Fresh air demand 4.2 Air flow in rooms 4.3 Calculation of duct systems 4.4 Fans 4.5 Filters 5. Refrigeration systems 5.1. compression chillers 5.2Absorption chillers
Literature	• Schmitz, G.: Klimaanlagen, Skript zur Vorlesung • VDI Wärmeatlas, 11. Auflage, Springer Verlag, Düsseldorf 2013 • Herwig, H.; Moschallski, A.: Wärmeübertragung, Vieweg+Teubner Verlag, Wiesbaden 2009 • Recknagel, H.; Sprenger, E.; Schrammek, E.-R.: Taschenbuch für Heizung- und Klimatechnik 2013/2014, 76. Auflage, Deutscher Industrieverlag, 2013

Course L0595: Air Conditioning	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Arne Speerforck, Prof. Gerhard Schmitz
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1000: Combined Heat and Power and Combustion Technology

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Combined Heat and Power and Combustion Technology (L0216)	Lecture	3	5
Combined Heat and Power and Combustion Technology (L0220)	Recitation Section (large)	1	1

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	• "Gas-Steam Power Plants" • "Technical Thermodynamics I and II" • "Heat Transfer" • "Fluid Mechanics"
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	**VBT/Combustion Engineering** The students outline the thermodynamic and chemical fundamentals of combustion processes and the main characteristics of various fuels. They gain basic knowledge in reaction kinetics and fundamentals of furnace design. The students are able to describe the formation of emissions and the primary reduction measures, and evaluate the impact of regulations and allowable limit levels. **KWK/Combined Heat and Power** The students present the layout, design and operation of Combined Heat and Power plants and are in a position to compare with each other district heating plants with back-pressure steam turbine or condensing turbine with pressure-controlled extraction tapping, CHP plants with gas turbine or with combined steam and gas turbine, or even district heating plants with an internal combustion engine. They can explain and analyse aspects of combined heat, power and cooling (CCHP) and describe the layout of the key components needed. Through this specialised knowledge they are able to evaluate the ecological significance of district CHP generation, as well as its economics. **Storage Technologies** The students present the layout, design and operation of electrical and heat storage technologies and are able to classify these in regards of their optimum operating range and conditions in power plants and complex energy systems. They evaluate the environmental effects of the storage technologies.
Skills	The students will be able to identify optimization possibilities due to combined power and heat production and the usage of short, medium and long-term storage technologies. The detailed understanding of the complete energy conversion chain, starting with the combustion of a fuel, the conversion of the primary energy into heat and power, storage and discharge of the storage enables the students to evaluate the efficiency and economies of the processes and to holistically consider energy utilisation. Examples from practical experience, such as the CHP energy supply facility of the TUHH and the district heating network of Hamburg will be used, to highlight the potential from electricity generation plants with simultaneous heat extraction and storage. Within the framework of the exercises the students deepen their knowledge based on examples from the industries.
Personal Competence	
Social Competence	Especially during the exercises the focus is placed on communication with the tutor. This animates the students to reflect on their existing knowledge and ask specific questions for improving further this knowledge level.
Autonomy	The students assisted by the tutors will be able to perform estimating calculations. In this manner the theoretical and practical knowledge from the lecture is consolidated and the potential impact of different process arrangements and boundary conditions highlighted.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6

Course achievement

Compulsory	Bonus	Form	Description
No	10 %	Written elaboration	Am Ende jeder Vorlesung wird schriftlich eine zu auswertende Kurzfrage (5-10 min) zu der Vorlesung der Vorwoche gestellt. In den Kurzfragen werden kleine Rechenaufgaben, Skizzen oder auch kleine Freitexte zur Beantwortung gestellt.
No	10 %	Written elaboration	Anhand der gelehrten Inhalte werden Kurzfragen gestellt und Projektaufgaben bearbeitet und präsentiert

Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Energy Systems: Specialisation Marine Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory

<table>
<tr><th colspan="2">Course L0216: Combined Heat and Power and Combustion Technology</th></tr>
<tr><td>Typ</td><td>Lecture</td></tr>
<tr><td>Hrs/wk</td><td>3</td></tr>
<tr><td>CP</td><td>5</td></tr>
<tr><td>Workload in Hours</td><td>Independent Study Time 108, Study Time in Lecture 42</td></tr>
<tr><td>Lecturer</td><td>NN</td></tr>
<tr><td>Language</td><td>DE</td></tr>
<tr><td>Cycle</td><td>SoSe</td></tr>
<tr><td>Content</td><td>Part 1: Combustion Engineering
• Thermodynamic and chemical fundamentals
• Fuels
• Reaction kinetics
• Premixed flames
• Systematik of flames and combustion chambers
• Combustion Chamber design
• Reduction of Emissions

Part 2: Energy Storage

1.Motivation: Why is Energy storage essential ?

2.Storage of electrical energy
• Condensers
• Akkumulators
• Hydro power stations
• Short term storage with fly wheels
• Compressed air energy storage CAES
• Economics

3.Heat Storage
• Sensible heat storage
• Latent heat storage
• Thermocheical heat storage
• Economics

4.Sector coupling and Power to X
• PtG
• PtL
• Research on PtX

Part 3: "Combined Heat and Power":
• Layout, design and operation of Combined Heat and Power plants
• District heating plants with back-pressure steam turbine and condensing turbine with pressure-controlled extraction tapping
• District heating plants with gas turbine
• District heating plants with combined steam and gas turbine
• District heating plants with motor engine
• Combined cooling heat and power (CCHP)
• Layout of the key components
• Regulatory framework and allowable limits
• Economic significance and calculation of the profitability of district CHP plant</td></tr>
<tr><td>Literature</td><td>Bezüglich des Themenbereichs "Kraft-Wärme-Kopplung":
• W. Piller, M. Rudolph: Kraft-Wärme-Kopplung, VWEW Verlag
• Kehlhofer, Kunze, Lehmann, Schüller: Handbuch Energie, Band 7, Technischer Verlag Resch
• W. Suttor: Praxis Kraft-Wärme-Kopplung, C.F. Müller Verlag
• K.W. Schmitz, G. Koch: Kraft-Wärme-Kopplung, VDI Verlag
• K.-H. Suttor, W. Suttor: Die KWK Fibel, Resch Verlag

und für die Grundlagen der "Verbrennungstechnik":
• J. Warnatz, U. Maas, R.W. Dibble; Technische Verbrennung: physikalisch-chemische Grundlagen, Modellbildung, Schadstoffentstehung. Springer, Berlin [u. a.], 2001</td></tr>
</table>

Course L0220: Combined Heat and Power and Combustion Technology	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	NN
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1878: Sustainable energy from wind and water

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Offshore Geotechnical Engineering (L0067)	Lecture	1	1
Hydro Power Use (L0013)	Lecture	1	1
Wind Turbine Plants (L0011)	Lecture	2	3
Wind Energy Use - Focus Offshore (L0012)	Lecture	1	1

Module Responsible	Dr. Marvin Scherzinger
Admission Requirements	None
Recommended Previous Knowledge	Module: Technical Thermodynamics I, Module: Technical Thermodynamics II, Module: Fundamentals of Fluid Mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	By ending this module students can explain in detail knowledge of wind turbines with a particular focus of wind energy use in offshore conditions and can critical comment these aspects in consideration of current developments. Furthermore, they are able to describe fundamentally the use of water power to generate electricity. The students reproduce and explain the basic procedure in the implementation of renewable energy projects in countries outside Europe. Through active discussions of various topics within the seminar of the module, students improve their understanding and the application of the theoretical background and are thus able to transfer what they have learned in practice.
Skills	Students are able to apply the acquired theoretical foundations on exemplary water or wind power systems and evaluate and assess technically the resulting relationships in the context of dimensioning and operation of these energy systems. They can in compare critically the special procedure for the implementation of renewable energy projects in countries outside Europe with the in principle applied approach in Europe and can apply this procedure on exemplary theoretical projects.
Personal Competence	
Social Competence	Students can discuss scientific tasks subjet-specificly and multidisciplinary within a seminar.
Autonomy	Students can independently exploit sources in the context of the emphasis of the lecture material to clear the contents of the lecture and to acquire the particular knowledge about the subject area.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Compulsory

Course L0067: Offshore Geotechnical Engineering	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Jan Dührkop
Language	DE
Cycle	SoSe
Content	• Overview and Introduction Offshore Geotechnics • Introduction to Soil Mechanics • Offshore soil investigation • Focus on cyclical effects • Geotechnical design of offshore foundations • Monopiles • Jackets • Heavyweight foundations • Geotechnical preliminary exploration for the use of lift boats and platforms
Literature	• Randolph, M. and Gourvenec, S (2011): Offshore Geotechnical Engineering. Spon Press. • Poulos H.G. (1988): Marine Geotechnics. Unwin Hyman, London • BSH-Standard Baugrunderkundung für Offshore-Windenergieparks • Lesny K. (2010): Foundations for Offshore Wind Turbines. VGE Verlag, Essen. • EA-Pfähle (2012): Empfehlungen des Arbeitskreises Pfähle der DGGT. Ernst & Sohn, Berlin.

Course L0013: Hydro Power Use	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Stefan Achleitner
Language	DE
Cycle	SoSe
Content	• Introduction, importance of water power in the national and global context • Physical basics: Bernoulli's equation, usable height of fall, hydrological measures, loss mechanisms, efficiencies • Classification of Hydropower: Flow and Storage hydropower, low and high pressure systems • Construction of hydroelectric power plants: description of the individual components and their technical system interaction • Structural engineering components; representation of dams, weirs, dams, power houses, computer systems, etc. • Energy Technical Components: Illustration of the different types of hydraulic machinery, generators and grid connection • Hydropower and the Environment • Examples from practice
Literature	• Schröder, W.; Euler, G.; Schneider, K.: Grundlagen des Wasserbaus; Werner, Düsseldorf, 1999, 4. Auflage • Quaschning, V.: Regenerative Energiesysteme: Technologie - Berechnung - Simulation; Carl Hanser, München, 2011, 7. Auflage • Giesecke, J.; Heimerl, S.; Mosony, E.: Wasserkraftanlagen - Planung, Bau und Betrieb; Springer, Berlin, Heidelberg, 2009, 5. Auflage • von König, F.; Jehle, C.: Bau von Wasserkraftanlagen - Praxisbezogene Planungsunterlagen; C. F. Müller, Heidelberg, 2005, 4. Auflage • Strobl, T.; Zunic, F.: Wasserbau: Aktuelle Grundlagen - Neue Entwicklungen; Springer, Berlin, Heidelberg, 2006

Course L0011: Wind Turbine Plants	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Rudolf Zellermann
Language	DE
Cycle	SoSe
Content	• Historical development • Wind: origins, geographic and temporal distribution, locations • Power coefficient, rotor thrust • Aerodynamics of the rotor • Operating performance • Power limitation, partial load, pitch and stall control • Plant selection, yield prediction, economy • Excursion
Literature	Gasch, R., Windkraftanlagen, 4. Auflage, Teubner-Verlag, 2005

Course L0012: Wind Energy Use - Focus Offshore	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Martin Skiba
Language	DE
Cycle	SoSe
Content	• Introduction, importance of offshore wind power generation, Specific requirements for offshore engineering • Physical fundamentals for utilization of wind energy • Design and operation of offshore wind turbines, presentation of different concepts of offshore wind turbines, representation of the individual system components and their system-technical relationships • Foundation engineering, offshore site investigation, presentation of different concepts of offshore foundation structures, planning and fabrication of foundation structures • Electrical infrastructure of an offshore wind farm, Inner Park cabling, offshore substation, grid connection • Installation of offshore wind farms, installation techniques and auxiliary devices, construction logistics • Development and planning of offshore wind farms • Operation and optimization of offshore wind farms • Day excursion
Literature	• Gasch, R.; Twele, J.: Windkraftanlagen - Grundlagen, Entwurf, Planung und Betrieb; Vieweg + Teubner, Stuttgart, 2007, 7. Auflage • Molly, J. P.: Windenergie - Theorie, Anwendung, Messung; C. F. Müller, Heidel-berg, 1997, 3. Auflage • Hau, E.: Windkraftanalagen; Springer, Berlin, Heidelberg, 2008, 4.Auflage • Heier, S.: Windkraftanlagen - Systemauslegung, Integration und Regelung; Vieweg + Teubner, Stuttgart, 2009, 5. Auflage • Jarass, L.; Obermair, G.M.; Voigt, W.: Windenergie: Zuverlässige Integration in die Energieversorgung; Springer, Berlin, Heidelberg, 2009, 2. Auflage

Module M0801: Water Resources and -Supply

Courses

Title	Typ	Hrs/wk	CP
Chemistry of Drinking Water Treatment (L0311)	Lecture	2	1
Chemistry of Drinking Water Treatment (L0312)	Recitation Section (large)	1	2
Water Resource Management (L0402)	Lecture	2	2
Water Resource Management (L0403)	Recitation Section (small)	1	1

Module Responsible	Prof. Mathias Ernst
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of water management and the key processes involved in water treatment.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students will be able to outline key areas of conflict in water management, as well as their mutual dependence for sustainable water supply. They will understand relevant economic, environmental and social factors. Students will be able to explain and outline the organisational structures of water companies. They will be able to explain the available water treatment processes and the scope of their application.
Skills	Students will be able to assess complex problems in drinking water production and establish solutions involving water management and technical measures. They will be able to assess the evaluation methods that can be used for this. Students will be able to carry out chemical calculations for selected treatment processes and apply generally accepted technical rules and standards to these processes.
Personal Competence	
Social Competence	Working in a diverse group of specialists, students will be able to develop and document complex solutions for the management and treatment of drinking water. They will be able to take an appropriate professional position, for example representing user interests. They will be able to develop joint solutions in teams of diverse experts and present these solutions to others.
Autonomy	Students will be in a position to work on a subject independently and present on this subject.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min (chemistry) + presentation
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory

Course L0311: Chemistry of Drinking Water Treatment	
Typ	Lecture
Hrs/wk	2
CP	1
Workload in Hours	Independent Study Time 2, Study Time in Lecture 28
Lecturer	Dr. Klaus Johannsen
Language	DE
Cycle	WiSe
Content	The topic of this course is water chemistry with respect to drinking water treatment and water distribution Major topics are solubility of gases, carbonic acid system and calcium carbonate, blending, softening, redox processes, materials and legal requirements on drinking water treatment. Focus is put on generally accepted rules of technology (DVGW- and DIN-standards). Special emphasis is put on calculations using realistic analysis data (e.g. calculation of pH or calcium carbonate dissolution potential) in exercises. Students can get a feedback and gain extra points for exam by solving problems for homework. Knowledge of drinking water treatment processes is vital for this lecture. Therefore the most important processes are explained coordinated with the course “ Water resources management“ in the beginning of the semester.
Literature	**MHW (rev. by Crittenden, J. et al.):** Water treatment principles and design. John Wiley & Sons, Hoboken, 2005. **Stumm, W., Morgan, J.J.**: Aquatic chemistry. John Wiley & Sons, New York, 1996. **DVGW (Hrsg.):** Wasseraufbereitung - Grundlagen und Verfahren. Oldenbourg Industrie Verlag, München, 2004. **Jensen, J. N.**: A Problem Solving Approach to Aquatic Chemistry. John Wiley & Sons, Inc., New York, 2003.

Course L0312: Chemistry of Drinking Water Treatment	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Dr. Klaus Johannsen
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0402: Water Resource Management	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Mathias Ernst
Language	DE
Cycle	WiSe
Content	The lecture provides comprehensive knowledge on interaction of water ressource management and drinking water supply. Content overview: • Current situation of global water resources - User and Stakeholder conflicts - Wasserressourcenmanagement in urbane Gebieten - Rechtliche Aspekte, Organisationsformen Trinkwasserversorgungsunternehmen. - Ökobilanzierung, Benchmarking in der Wasserversorgung
Literature	• Aktuelle UN World Water Development Reports • Branchenbild der deutschen Wasserwirtschaft, VKU (2011) • Aktuelle Artikel wissenschaftlicher Zeitschriften • Ppt der Vorlesung

Course L0403: Water Resource Management	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Mathias Ernst
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1888: Environmental protection management

Courses

Title	Typ	Hrs/wk	CP
Health, Safety and Environmental Management (L0387)	Integrated Lecture	3	3
Air Pollution Abatement (L0203)	Lecture	2	3

Module Responsible	Dr. Swantje Pietsch-Braune
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Management and Controlling: Elective Compulsory Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Compulsory Water and Environmental Engineering: Specialisation Cities: Compulsory

Course L0387: Health, Safety and Environmental Management

Typ	Integrated Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Hans-Joachim Nau
Language	EN
Cycle	WiSe
Content	• Objectives of and benefit from HSE management • From dilution and end-of-pipe technology to eco-efficiency and eco-effectiveness Behaviour control: regulations, economic instruments and voluntary initiatives • Fundamentals of HSE legislation ISO 14001, EMAS and Responsible Care ISO 14001 requirements Environmental performance evaluation Risk management: hazard, risk and safety Health and safety at the workplace • Crisis management
Literature	C. Stephan: Industrial Health, Safety and Environmental Management, MV-Verlag, Münster, 2007/2012 (can be found in the library under GTG 315) Exercises can be downloaded from StudIP

Course L0203: Air Pollution Abatement	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Swantje Pietsch-Braune, Christian Eichler
Language	EN
Cycle	WiSe
Content	In the lecture methods for the reduction of emissions from industrial plants are treated. At the beginning a short survey of the different forms of air pollutants is given. In the second part physical principals for the removal of particulate and gaseous pollutants form flue gases are treated. Industrial applications of these principles are demonstrated with examples showing the removal of specific compounds, e.g. sulfur or mercury from flue gases of incinerators.
Literature	Handbook of air pollution prevention and control, Nicholas P. Cheremisinoff. - Amsterdam [u.a.] : Butterworth-Heinemann, 2002 Atmospheric pollution : history, science, and regulation, Mark Zachary Jacobson. - Cambridge [u.a.] : Cambridge Univ. Press, 2002 Air pollution control technology handbook, Karl B. Schnelle. - Boca Raton [u.a.] : CRC Press, c 2002 Air pollution, Jeremy Colls. - 2. ed. - London [u.a.] : Spon, 2002

Module M0949: Rural Development and Resources Oriented Sanitation for different Climate Zones

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Rural Development and Resources Oriented Sanitation for different Climate Zones (L0942)	Seminar	2	3
Rural Development and Resources Oriented Sanitation for different Climate Zones (L0941)	Lecture	2	3

Module Responsible	Prof. Ralf Otterpohl
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of the global situation with rising poverty, soil degradation, lack of water resources and sanitation
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can describe resources oriented wastewater systems mainly based on source control in detail. They can comment on techniques designed for reuse of water, nutrients and soil conditioners. Students are able to discuss a wide range of proven approaches in Rural Development from and for many regions of the world.
Skills	Students are able to design low-tech/low-cost sanitation, rural water supply, rainwater harvesting systems, measures for the rehabilitation of top soil quality combined with food and water security. Students can consult on the basics of soil building through “Holisitc Planned Grazing” as developed by Allan Savory.
Personal Competence	
Social Competence	The students are able to develop a specific topic in a team and to work out milestones according to a given plan.
Autonomy	Students are in a position to work on a subject and to organize their work flow independently. They can also present on this subject.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	During the course of the semester, the students work towards mile stones. The work includes presentations and papers. Detailed information will be provided at the beginning of the smester.
Assignment for the Following Curricula	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Environmental Engineering: Specialisation Water: Elective Compulsory Environmental Engineering: Specialisation Environment and Climate: Elective Compulsory Environmental Engineering: Specialisation Water Quality and Water Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory

Course L0942: Rural Development and Resources Oriented Sanitation for different Climate Zones

Typ	Seminar
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Ralf Otterpohl
Language	EN
Cycle	WiSe
Content	• Central part of this module is a group work on a subtopic of the lectures. The focus of these projects will be based on an interview with a target audience, practitioners or scientists. • The group work is divided into several Milestones and Assignments. The outcome will be presented in a final presentation at the end of the semester.
Literature	• J. Lange, R. Otterpohl 2000: Abwasser - Handbuch zu einer zukunftsfähigen Abwasserwirtschaft. Mallbeton Verlag (TUHH Bibliothek) • Winblad, Uno and Simpson-Hébert, Mayling 2004: Ecological Sanitation, EcoSanRes, Sweden (free download) • Schober, Sabine: WTO/TUHH Award winning Terra Preta Toilet Design: http://youtu.be/w_R09cYq6ys

Course L0941: Rural Development and Resources Oriented Sanitation for different Climate Zones	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Ralf Otterpohl
Language	EN
Cycle	WiSe
Content	• Living Soil - THE key element of Rural Development • Participatory Approaches • Rainwater Harvesting • Ecological Sanitation Principles and practical examples • Permaculture Principles of Rural Development • Performance and Resilience of Organic Small Farms • Going Further: The TUHH Toolbox for Rural Development • EMAS Technologies, Low cost drinking water supply
Literature	• Miracle Water Village, India, Integrated Rainwater Harvesting, Water Efficiency, Reforestation and Sanitation: http://youtu.be/9hmkgn0nBgk • Montgomery, David R. 2007: Dirt: The Erosion of Civilizations, University of California Press

Module M0540: Transport Processes

Courses

Title	Typ	Hrs/wk	CP
Multiphase Flows (L0104)	Lecture	2	2
Reactor Design Using Local Transport Processes (L0105)	Project-/problem-based Learning	2	2
Heat & Mass Transfer in Process Engineering (L0103)	Lecture	2	2

Module Responsible	Prof. Michael Schlüter
Admission Requirements	None
Recommended Previous Knowledge	All lectures from the undergraduate studies, especially mathematics, chemistry, thermodynamics, fluid mechanics, heat- and mass transfer.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • describe transport processes in single- and multiphase flows and they know the analogy between heat- and mass transfer as well as the limits of this analogy. • explain the main transport laws and their application as well as the limits of application. • describe how transport coefficients for heat- and mass transfer can be derived experimentally. • compare different multiphase reactors like trickle bed reactors, pipe reactors, stirring tanks and bubble column reactors. • are known. The Students are able to perform mass and energy balances for different kind of reactors. Further more the industrial application of multiphase reactors for heat- and mass transfer are known.
Skills	The students are able to: • optimize multiphase reactors by using mass- and energy balances, • use transport processes for the design of technical processes, • to choose a multiphase reactor for a specific application.
Personal Competence	
Social Competence	The students are able to discuss in international teams in english and develop an approach under pressure of time.
Autonomy	Students are able to define independently tasks, to solve the problem "design of a multiphase reactor". The knowledge that s necessary is worked out by the students themselves on the basis of the existing knowledge from the lecture. The students are able to decide by themselves what kind of equation and model is applicable to their certain problem. They are able to organize their own team and to define priorities for different tasks.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	15 min Presentation + 90 min multiple choice written examen
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Process Engineering: Core Qualification: Compulsory

Course L0104: Multiphase Flows	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	• Interfaces in MPF (boundary layers, surfactants) • Hydrodynamics & pressure drop in Film Flows • Hydrodynamics & pressure drop in Gas-Liquid Pipe Flows • Hydrodynamics & pressure drop in Bubbly Flows • Mass Transfer in Film Flows • Mass Transfer in Gas-Liquid Pipe Flows • Mass Transfer in Bubbly Flows • Reactive mass Transfer in Multiphase Flows • Film Flow: Application Trickle Bed Reactors • Pipe Flow: Application Turbular Reactors • Bubbly Flow: Application Bubble Column Reactors
Literature	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 L0105: Reactor Design Using Local Transport Processes	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	In this Problem-Based Learning unit the students have to design a multiphase reactor for a fast chemical reaction concerning optimal hydrodynamic conditions of the multiphase flow. The four students in each team have to: • collect and discuss material properties and equations for design from the literature, • calculate the optimal hydrodynamic design, • check the plausibility of the results critically, • write an exposé with the results. This exposé will be used as basis for the discussion within the oral group examen of each team.
Literature	see actual literature list in StudIP with recent published papers

Course L0103: Heat & Mass Transfer in Process Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	• Introduction - Transport Processes in Chemical Engineering • Molecular Heat- and Mass Transfer: Applications of Fourier's and Fick's Law • Convective Heat and Mass Transfer: Applications in Process Engineering • Unsteady State Transport Processes: Cooling & Drying • Transport at fluidic Interfaces: Two Film, Penetration, Surface Renewal • Transport Laws & Balance Equations with turbulence, sinks and sources • Experimental Determination of Transport Coefficients • Design and Scale Up of Reactors for Heat- and Mass Transfer • Reactive Mass Transfer • Processes with Phase Changes – Evaporization and Condensation • Radiative Heat Transfer - Fundamentals • Radiative Heat Transfer - Solar Energy
Literature	1. Baehr, Stephan: Heat and Mass Transfer, Wiley 2002. 2. Bird, Stewart, Lightfood: Transport Phenomena, Springer, 2000. 3. John H. Lienhard: A Heat Transfer Textbook, Phlogiston Press, Cambridge Massachusetts, 2008. 4. Myers: Analytical Methods in Conduction Heat Transfer, McGraw-Hill, 1971. 5. Incropera, De Witt: Fundamentals of Heat and Mass Transfer, Wiley, 2002. 6. Beek, Muttzall: Transport Phenomena, Wiley, 1983. 7. Crank: The Mathematics of Diffusion, Oxford, 1995. 8. Madhusudana: Thermal Contact Conductance, Springer, 1996. 9. Treybal: Mass-Transfer-Operation, McGraw-Hill, 1987.

Module M1125: Bioresources and Biorefineries

Courses

Title	Typ	Hrs/wk	CP
Biorefinery Technology (L0895)	Lecture	2	2
Biorefinery Technologie (L0974)	Recitation Section (small)	1	1
Bioresource Management (L0892)	Lecture	2	2
Bioresource Management (L0893)	Recitation Section (small)	1	1

Module Responsible	Dr. Ina Körner
Admission Requirements	None
Recommended Previous Knowledge	Basics on engineering; Basics of waste and energy management
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can give on overview on principles and theories in the field’s bioresource management and biorefinery technology and can explain specialized terms and technologies.
Skills	Students are capable of applying knowledge and know-how in the field’s bioresource management and biorefinery technology in order to perform technical and regional-planning tasks. They are also able to discuss the links to waste management, energy management and biotechnology.
Personal Competence	
Social Competence	Students can work goal-oriented with others and communicate and document their interests and knowledge in acceptable way.
Autonomy	Students are able to solve independently, with the aid of pointers, practice-related tasks bearing in mind possible societal consequences.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Environmental Engineering: Specialisation Waste and Energy: Elective Compulsory Environmental Engineering: Specialisation Biotechnology: Elective Compulsory Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory

Course L0895: Biorefinery Technology	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Ina Körner
Language	EN
Cycle	WiSe
Content	The Europe 2020 strategy calls for bioeconomy as the key for smart and green growth of today. Biorefineries are the fundamental part on the way to convert the use of fossil-based society to bio-based society. For this reason, agriculture and forestry sectors are increasingly deliver bioresources. It is not only for their traditional applications in the food and feed sectors such as pulp or paper and construction material productions, but also to produce bioenergy and bio-based products such as bio-plastics. However although bioresources are renewable, they are considered as limited resources as well. The bioeconomy’s limitation factor is the availability land on our world. In the context of the development of the bioeconomy, the sustainable and reliable supply of noon-food biomass feedstock is a critical success factor for the long-term perspective of bioenergy and other bio-based products production. Biorefineries are complex of technologies and process cascades using the available primary, secondary and tertiary bioresources to produce a multitude of products - a product mix from material and energy products. The lecture gives an overview on biorefinery technology and shall contribute to promotion of international biorefinery developments. Lectures: • What is a biorefinery: Overview on basic organic substrates and processes which lead to material and energy products • The way from a fossil based to a biobased economy in the 21st century • The worlds most advanced biorefinery • Presentation of various biorefinery systems and their products (e.g. lignocellulose biorefinery, green biorefinery, whole plant biorefinery, civilization biorefinery) • Example projects (e.g. combination of anaerobic digestion and composting in practice; demonstration project in Hamburgs city quarter Jenfelder Au) The lectures will be accompanied by technical tours. Optional it is also possible to visit more biorefinery lectures in the University of Hamburg (lectures in German only). In the exercise students have the possibility to work in groups on a biorefinery project or to work on a student-specific task.
Literature	Biorefineries - Industrial Process and Products - Status Qua and Future directions by Kamm, Gruber and Kamm (2010); Wiley VCH, available on-line in TUHH-library Powerpoint-Präsentations / selected Publications / further recommendations depending on the actual developments Industrial Biorefineries and White Biorefinery, by Pandey, Höfer, Larroche, Taherzadeh, Nampoothiri (Eds.); (2014 book development in progress)

Course L0974: Biorefinery Technologie	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Ina Körner
Language	EN
Cycle	WiSe
Content	1.) Selection of a topic within the thematic area "Biorefinery Technologie" from a given list or self-selected. 2.) Self-dependent recherches to the topic. 3.) Preparation of a written elaboration. 4.) Presentation of the results in the group.
Literature	Vom Thema abhängig. Eigene Recherchen nötig. Depending on the topic. Own recheches necassary.

Course L0892: Bioresource Management	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Ina Körner
Language	EN
Cycle	WiSe
Content	In the context of limited fossil resources, climate change mitigation and increasing population growth, Bioresources has a special role. They have to feed the population and in the same time they are important for material production such as pulp and paper or construction materials. Moreover they become more and more important in chemical industry and in energy provision as fossil substitution. Although Bioresources are renewable, they are also considered as limited resources. The availability of land on our planet is the main limitation factor. The sustainable and reliable supply of non-food biomass feedstock is a critical for successful and long term perspective on production of bioenergy and other bio-based products. As the consequence, the increasing competition and shortages continue to happen at the traditional sectors. On the other side, huge unused but potentials residue on waste and wastewater sector exist. Nowadays, a lot of activities to develop better processes, to create new bio-based products in order to become more efficient, the inclusion of secondary and tertiary bio-resources in the valorisation chain are going on. The lecture deals with the current state-of-the-art of bioresource management. It shows deficits and potentials for improvement especially in the sector of utilization of organic residues for material and energy generation: *Lectures on:* • Bioresource generation and utilization including lost potentials today • Basic biological, mechanical, physico-chemical and logistical processes • The conflict of material vs. energy generation from wood / waste wood • The basics of pulp & paper production including waste paper recycling • The Pros and Cons from biogas and compost production *Special lectures by invited guests from research and practice:* • Pathways of waste organics on the example of Hamburg`s City Cleaning Company • Utilization options of landscaping materials on the example of grass • Increase of process efficiency of anaerobic digestions • Decision support tools on the example of an municipality in Indonesia *Optional: Technical visits*
Literature	Power-Point presentations in STUD-IP

Course L0893: Bioresource Management	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Ina Körner
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0542: Fluid Mechanics in Process Engineering

Courses

Title	Typ	Hrs/wk	CP
Applications of Fluid Mechanics in Process Engineering (L0106)	Recitation Section (large)	2	2
Fluid Mechanics II (L0001)	Lecture	2	4

Module Responsible	Prof. Michael Schlüter
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I-III • Fundamentals in Fluid Mechanics • Technical Thermodynamics I-II • Heat- and Mass Transfer
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to describe different applications of fluid mechanics in Process Engineering, Bioprocess Engineering, Energy- and Environmental Process Engineering and Renewable Energies. They are able to use the fundamentals of fluid mechanics for calculations of certain engineering problems. The students are able to estimate if a problem can be solved with an analytical solution and what kind of alternative possibilities are available (e.g. self-similarity in an example of free jets, empirical solutions in an example with the Forchheimer equation, numerical methods in an example of Large Eddy Simulation.
Skills	Students are able to use the governing equations of Fluid Dynamics for the design of technical processes. Especially they are able to formulate momentum and mass balances to optimize the hydrodynamics of technical processes. They are able to transform a verbal formulated message into an abstract formal procedure.
Personal Competence	
Social Competence	The students are able to discuss a given problem in small groups and to develop an approach.
Autonomy	Students are able to define independently tasks for problems related to fluid mechanics. They are able to work out the knowledge that is necessary to solve the problem by themselves on the basis of the existing knowledge from the lecture.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Core Qualification: Compulsory

Course L0106: Applications of Fluid Mechanics in Process Engineering

Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	DE
Cycle	WiSe
Content	The Exercise-Lecture will bridge the gap between the theoretical content from the lecture and practical calculations. For this aim a special exercise is calculated at the blackboard that shows how the theoretical knowledge from the lecture can be used to solve real problems in Process Engineering.
Literature	1. Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971. 2. Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion. Frankfurt: Sauerländer 1972. 3. Crowe, C. T.: Engineering fluid mechanics. Wiley, New York, 2009. 4. Durst, F.: Strömungsmechanik: Einführung in die Theorie der Strömungen von Fluiden. Springer-Verlag, Berlin, Heidelberg, 2006. 5. Fox, R.W.; et al.: Introduction to Fluid Mechanics. J. Wiley & Sons, 1994. 6. Herwig, H.: Strömungsmechanik: Eine Einführung in die Physik und die mathematische Modellierung von Strömungen. Springer Verlag, Berlin, Heidelberg, New York, 2006. 7. Herwig, H.: Strömungsmechanik: Einführung in die Physik von technischen Strömungen: Vieweg+Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2008. 8. Kuhlmann, H.C.: Strömungsmechanik. München, Pearson Studium, 2007 9. Oertl, H.: Strömungsmechanik: Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele. Vieweg+ Teubner / GWV Fachverlage GmbH, Wiesbaden, 2009. 10. Schade, H.; Kunz, E.: Strömungslehre. Verlag de Gruyter, Berlin, New York, 2007. 11. Truckenbrodt, E.: Fluidmechanik 1: Grundlagen und elementare Strömungsvorgänge dichtebeständiger Fluide. Springer-Verlag, Berlin, Heidelberg, 2008. 12. Schlichting, H. : Grenzschicht-Theorie. Springer-Verlag, Berlin, 2006. 13. van Dyke, M.: An Album of Fluid Motion. The Parabolic Press, Stanford California, 1882. 14. White, F.: Fluid Mechanics, Mcgraw-Hill, ISBN-10: 0071311211, ISBN-13: 978-0071311212, 2011.

Course L0001: Fluid Mechanics II	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	DE
Cycle	WiSe
Content	• Differential equations for momentum-, heat and mass transfer • Examples for simplifications of the Navier-Stokes Equations • Unsteady momentum transfer • Free shear layer, turbulence and free jets • Flow around particles - Solids Process Engineering • Coupling of momentum and heat transfer - Thermal Process Engineering • Rheology – Bioprocess Engineering • Coupling of momentum- and mass transfer – Reactive mixing, Chemical Process Engineering • Flow threw porous structures - heterogeneous catalysis • Pumps and turbines - Energy- and Environmental Process Engineering • Wind- and Wave-Turbines - Renewable Energy • Introduction into Computational Fluid Dynamics
Literature	1. Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971. 2. Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion. Frankfurt: Sauerländer 1972. 3. Crowe, C. T.: Engineering fluid mechanics. Wiley, New York, 2009. 4. Durst, F.: Strömungsmechanik: Einführung in die Theorie der Strömungen von Fluiden. Springer-Verlag, Berlin, Heidelberg, 2006. 5. Fox, R.W.; et al.: Introduction to Fluid Mechanics. J. Wiley & Sons, 1994. 6. Herwig, H.: Strömungsmechanik: Eine Einführung in die Physik und die mathematische Modellierung von Strömungen. Springer Verlag, Berlin, Heidelberg, New York, 2006. 7. Herwig, H.: Strömungsmechanik: Einführung in die Physik von technischen Strömungen: Vieweg+Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2008. 8. Kuhlmann, H.C.: Strömungsmechanik. München, Pearson Studium, 2007 9. Oertl, H.: Strömungsmechanik: Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele. Vieweg+ Teubner / GWV Fachverlage GmbH, Wiesbaden, 2009. 10. Schade, H.; Kunz, E.: Strömungslehre. Verlag de Gruyter, Berlin, New York, 2007. 11. Truckenbrodt, E.: Fluidmechanik 1: Grundlagen und elementare Strömungsvorgänge dichtebeständiger Fluide. Springer-Verlag, Berlin, Heidelberg, 2008. 12. Schlichting, H. : Grenzschicht-Theorie. Springer-Verlag, Berlin, 2006. 13. van Dyke, M.: An Album of Fluid Motion. The Parabolic Press, Stanford California, 1882.

Module M0619: Waste Treatment Technologies

Courses

Title	Typ	Hrs/wk	CP
Waste and Environmental Chemistry (L0328)	Practical Course	2	2
Biological Waste Treatment (L0318)	Project-/problem-based Learning	3	4

Module Responsible	Prof. Kerstin Kuchta
Admission Requirements	None
Recommended Previous Knowledge	chemical and biological basics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The module aims possess knowledge concerning the planning of biological waste treatment plants. Students are able to explain the design and layout of anaerobic and aerobic waste treatment plants in detail, describe different techniques for waste gas treatment plants for biological waste treatment plants and explain different methods for waste analytics.
Skills	The students are able to discuss the compilation of design and layout of plants. They can critically evaluate techniques and quality control measurements. The students can recherché and evaluate literature and date connected to the tasks given in der module and plan additional tests. They are capable of reflecting and evaluating findings in the group.
Personal Competence	
Social Competence	Students can participate in subject-specific and interdisciplinary discussions, develop cooperated solutions and defend their own work results in front of others and promote the scientific development in front of colleagues. Furthermore, they can give and accept professional constructive criticism.
Autonomy	Students can independently tap knowledge from literature, business or test reports and transform it to the course projects. They are capable, in consultation with supervisors as well as in the interim presentation, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes · **Bonus** None · **Form** Subject theoretical and practical work · **Description**
Examination	Presentation
Examination duration and scale	Elaboration and Presentation (15-25 minutes in groups)
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Environmental Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory

Course L0328: Waste and Environmental Chemistry	
Typ	Practical Course
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kerstin Kuchta
Language	DE/EN
Cycle	WiSe
Content	The participants are divided into groups. Each group prepares a transcript on the experiment performed, which is then used as basis for discussing the results and to evaluate the performance of the group and the individual student. In some experiments the test procedure and the results are presented in seminar form, accompanied by discussion and results evaluation. Experiments ar e.g. Screening and particle size determination Fos/Tac AAS Chalorific value
Literature	Scripte

Course L0318: Biological Waste Treatment	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	WiSe
Content	1. Introduction 2. biological basics 3. determination process specific material characterization 4. aerobic degradation (Composting, stabilization) 5. anaerobic degradation (Biogas production, fermentation) 6. Technical layout and process design 7. Flue gas treatment 8. Plant design practical phase
Literature	

Module M0742: Thermal Energy Systems

Courses

Title	Typ	Hrs/wk	CP
Thermal Engergy Systems (L0023)	Lecture	3	5
Thermal Engergy Systems (L0024)	Recitation Section (large)	1	1

Module Responsible	Prof. Arne Speerforck
Admission Requirements	None
Recommended Previous Knowledge	Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know the different energy conversion stages and the difference between efficiency and annual efficiency. They have increased knowledge in heat and mass transfer, especially in regard to buildings and mobile applications. They are familiar with German energy saving code and other technical relevant rules. They know to differ different heating systems in the domestic and industrial area and how to control such heating systems. They are able to model a furnace and to calculate the transient temperatures in a furnace. They have the basic knowledge of emission formations in the flames of small burners and how to conduct the flue gases into the atmosphere. They are able to model thermodynamic systems with object oriented languages.
Skills	Students are able to calculate the heating demand for different heating systems and to choose the suitable components. They are able to calculate a pipeline network and have the ability to perform simple planning tasks, regarding solar energy. They can write Modelica programs and can transfer research knowledge into practice. They are able to perform scientific work in the field of thermal engineering.
Personal Competence	
Social Competence	In lectures and exercises, the students can use many examples and experiments to discuss in small groups in a goal-oriented manner, develop a solution and present it. Within the exercises, the students can independently develop further questions and work out targeted solutions.
Autonomy	Students are able to define tasks independently, to develop the necessary knowledge themselves based on the knowledge they have received, and to use suitable means for implementation. In the exercises, the students discuss the methods taught in the lectures using complex tasks and critically analyze the results.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: Compulsory Energy Systems: Specialisation Marine Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0023: Thermal Engergy Systems	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Gerhard Schmitz
Language	DE
Cycle	WiSe
Content	1. Introduction 2. Fundamentals of Thermal Engineering 2.1 Heat Conduction 2.2 Convection 2.3 Radiation 2.4 Heat transition 2.5 Combustion parameters 2.6 Electrical heating 2.7 Water vapor transport 3. Heating Systems 3.1 Warm water heating systems 3.2 Warm water supply 3.3 piping calculation 3.4 boilers, heat pumps, solar collectors 3.5 Air heating systems 3.6 radiative heating systems 4. Thermal traetment systems 4.1 Industrial furnaces 4.2 Melting furnaces 4.3 Drying plants 4.4 Emission control 4.5 Chimney calculation 4.6 Energy measuring 5. Laws and standards 5.1 Buildings 5.2 Industrial plants
Literature	• Schmitz, G.: Klimaanlagen, Skript zur Vorlesung • VDI Wärmeatlas, 11. Auflage, Springer Verlag, Düsseldorf 2013 • Herwig, H.; Moschallski, A.: Wärmeübertragung, Vieweg+Teubner Verlag, Wiesbaden 2009 • Recknagel, H.; Sprenger, E.; Schrammek, E.-R.: Taschenbuch für Heizung- und Klimatechnik 2013/2014, 76. Auflage, Deutscher Industrieverlag, 2013

Course L0024: Thermal Engergy Systems	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Arne Speerforck
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Specialization II. Information Technology

Module M0837: Simulation of Communication Networks

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Simulation of Communication Networks (L0887)	Project-/problem-based Learning	5	6

Module Responsible	Prof. Andreas Timm-Giel
Admission Requirements	None
Recommended Previous Knowledge	• Knowledge of computer and communication networks • Basic programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain the necessary stochastics, the discrete event simulation technology and modelling of networks for performance evaluation.
Skills	Students are able to apply the method of simulation for performance evaluation to different, also not practiced, problems of communication networks. The students can analyse the obtained results and explain the effects observed in the network. They are able to question their own results.
Personal Competence	
Social Competence	Students are able to acquire expert knowledge in groups, present the results, and discuss solution approaches and results. They are able to work out solutions for new problems in small teams.
Autonomy	Students are able to transfer independently and in discussion with others the acquired method and expert knowledge to new problems. They can identify missing knowledge and acquire this knowledge independently.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0887: Simulation of Communication Networks	
Typ	Project-/problem-based Learning
Hrs/wk	5
CP	6
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Lecturer	Dr.-Ing. Koojana Kuladinithi
Language	EN
Cycle	SoSe
Content	In the course necessary basic stochastics and the discrete event simulation are introduced. Also simulation models for communication networks, for example, traffic models, mobility models and radio channel models are presented in the lecture. Students work with a simulation tool, where they can directly try out the acquired skills, algorithms and models. At the end of the course increasingly complex networks and protocols are considered and their performance is determined by simulation.
Literature	• Skript des Instituts für Kommunikationsnetze Further literature is announced at the beginning of the lecture.

Module M1884: Data-Driven Innovation

Courses

Title	Typ	Hrs/wk	CP
Data-Driven Innovation (L3114)	Lecture	3	3
Data-Driven Innovation Seminar (L3115)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Moritz Göldner
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results

Professional Competence

Knowledge

By the end of this course, students will be able to:

- Understand the principles of Design Thinking and recognize their significance in conjunction with data-driven decision-making within the innovation process.
- Apply new methods for data analysis to identify user needs and insights.
- Demonstrate competence in using tools, including generative AI, through practical experience with real case studies and/or publicly accessible data repositories.
- Utilize methods that support strategic decision-making in the context of data-driven innovation.
- Evaluate ethical aspects and privacy regulations related to data-driven innovation.

Skills

- The students develop a profound understanding of the principles of Design Thinking and recognize their significance in the innovation process, taking into account data-driven decision-making.
- The students learn advanced methods for data analysis that enable them to effectively identify and understand user needs and insights.
- Through practical exercises involving real case studies and/or publicly accessible data repositories, the students gain competencies in using various tools, including generative artificial intelligence.
- The students acquire methods that assist them in making and implementing strategic decisions in the context of data-driven innovation.
- The students are sensitized to the ethical aspects and privacy regulations that need to be considered in the context of data-driven innovation and learn to critically evaluate them.

The students acquire these skills through active engagement in paper presentations, group work, case studies, and other practical exercises. They are guided to deliver multiple presentations and work in small groups on real-world problems. Through these diverse methodological approaches, the students are empowered to apply their skills in practice and continuously develop their competencies.

Personal Competence

Social Competence

- Teamwork and collaboration: Students are encouraged to collaborate closely with their peers in group work and case studies. They learn to effectively work in interdisciplinary teams to solve complex problems and develop innovative approaches. In the process, they further develop their communication and cooperation skills.
- Presentation and communication skills: Through paper presentations and other formats, students are guided to present their findings and research results to their peers. This enhances their ability to present content clearly and convincingly and effectively communicate their ideas.
- Discussion and negotiation skills: The lecture promotes active discussions and the exchange of different viewpoints. Students learn to express their opinions and arguments, consider other perspectives, and engage in constructive discussions. This develops their ability for critical reflection and collaboration in an academic environment.
- Empathy and collaboration: Dealing with data-driven innovation requires an understanding of the needs and perspectives of various stakeholders. Students learn to be empathetic and prioritize collaboration and common goals. This helps them develop solutions that take into account the needs and concerns of all parties involved.
- Intercultural competence: Through collaboration in interdisciplinary teams, students have the opportunity to work with peers from different cultural backgrounds and disciplines. They develop intercultural competencies by expanding their perspectives and learning to communicate and collaborate successfully in a global environment.

By practically applying these social skills in various exercises, group work, and discussions, students are prepared to work successfully in team-based projects and further develop their abilities to collaborate with other professionals.

Autonomy

- Self-Management: Students learn to effectively organize their time, set priorities, and independently plan and manage their tasks. They develop strategies for self-motivation and overcoming challenges to successfully complete their studies.
- Self-Directed Learning: Students are encouraged to independently research knowledge, study additional literature, and engage with current developments in their field of study. They develop the ability for self-directed learning and continuous education to keep their knowledge up to date with the latest trends and innovations in their field.
- Problem-Solving Skills: Students learn to identify, analyze, and develop solutions for complex problems. They are encouraged to employ critical thinking and analytical skills to find effective solutions to real-world challenges. The lecture exposes them to various case studies and practical exercises to enhance their problem-solving abilities.
- Taking Initiative: Students are encouraged to be proactive and take initiative in pursuing their own learning and career goals. They develop the ability to recognize opportunities, address challenges, and develop innovative solutions. They are supported in taking risks and taking responsibility for their own learning and personal development.

Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes, **Bonus** 20 %, **Form** Excercises, **Description** Erfolgreiche Teilnahme PBL-Übung
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Data Science: Specialisation III. Applications: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Global Technology and Innovation Management & Entrepreneurship: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory

Course L3114: Data-Driven Innovation	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Moritz Göldner
Language	EN
Cycle	SoSe
Content	This course aims to combine the principles of design thinking with data science, focusing on all steps of the design thinking process from understanding the problem, investigating user’s needs and integrating these needs into the development and testing in a data-driven manner. Students will learn several methods to accelerate the innovation process (such as generative AI and modern market research platforms) as well as more general data science methodologies to streamline the innovation process. Established and modern, data-driven methods will be compared and critically evaluated, including ethical and privacy-related considerations. Through a series of lectures, hands-on exercises, and project presentations, students will not only develop a robust theoretical understanding of these topics, but will also gain practical experience applying these concepts in realistic innovation scenarios.
Literature	Luo, J. (2023). Data-driven innovation: What is it?. IEEE Transactions on Engineering Management, 70(2), 784-790. https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9707478

Course L3115: Data-Driven Innovation Seminar	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Moritz Göldner
Language	EN
Cycle	SoSe
Content	This course aims to combine the principles of design thinking with data science, focusing on all steps of the design thinking process from understanding the problem, investigating user’s needs and integrating these needs into the development and testing in a data-driven manner. Students will learn several methods to accelerate the innovation process (such as generative AI and modern market research platforms) as well as more general data science methodologies to streamline the innovation process. Established and modern, data-driven methods will be compared and critically evaluated, including ethical and privacy-related considerations. Through a series of lectures, hands-on exercises, and project presentations, students will not only develop a robust theoretical understanding of these topics, but will also gain practical experience applying these concepts in realistic innovation scenarios.
Literature	• Luo, J. (2023). Data-driven innovation: What is it?. IEEE Transactions on Engineering Management, 70(2), 784-790. https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9707478

Module M0627: Machine Learning and Data Mining

Courses

Title	Typ	Hrs/wk	CP
Machine Learning and Data Mining (L0340)	Lecture	2	4
Machine Learning and Data Mining (L0510)	Recitation Section (small)	2	2

Module Responsible	NN
Admission Requirements	None
Recommended Previous Knowledge	• Calculus • Stochastics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the difference between instance-based and model-based learning approaches, and they can enumerate basic machine learning technique for each of the two basic approaches, either on the basis of static data, or on the basis of incrementally incoming data . For dealing with uncertainty, students can describe suitable representation formalisms, and they explain how axioms, features, parameters, or structures used in these formalisms can be learned automatically with different algorithms. Students are also able to sketch different clustering techniques. They depict how the performance of learned classifiers can be improved by ensemble learning, and they can summarize how this influences computational learning theory. Algorithms for reinforcement learning can also be explained by students.
Skills	Student derive decision trees and, in turn, propositional rule sets from simple and static data tables and are able to name and explain basic optimization techniques. They present and apply the basic idea of first-order inductive leaning. Students apply the BME, MAP, ML, and EM algorithms for learning parameters of Bayesian networks and compare the different algorithms. They also know how to carry out Gaussian mixture learning. They can contrast kNN classifiers, neural networks, and support vector machines, and name their basic application areas and algorithmic properties. Students can describe basic clustering techniques and explain the basic components of those techniques. Students compare related machine learning techniques, e.g., k-means clustering and nearest neighbor classification. They can distinguish various ensemble learning techniques and compare the different goals of those techniques.
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L0340: Machine Learning and Data Mining	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Rainer Marrone
Language	EN
Cycle	SoSe
Content	• Decision trees • First-order inductive learning • Incremental learning: Version spaces • Uncertainty • Bayesian networks • Learning parameters of Bayesian networks BME, MAP, ML, EM algorithm • Learning structures of Bayesian networks • Gaussian Mixture Models • kNN classifier, neural network classifier, support vector machine (SVM) classifier • Clustering Distance measures, k-means clustering, nearest neighbor clustering • Kernel Density Estimation • Ensemble Learning • Reinforcement Learning • Computational Learning Theory
Literature	1. Artificial Intelligence: A Modern Approach (Third Edition), Stuart Russel, Peter Norvig, Prentice Hall, 2010, Chapters 13, 14, 18-21 2. Machine Learning: A Probabilistic Perspective, Kevin Murphy, MIT Press 2012

Course L0510: Machine Learning and Data Mining	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Rainer Marrone
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1879: Causal Data Science for Business Analytics

Courses

Title	Typ	Hrs/wk	CP
Business Analytics with Causal Data Science (L3096)	Project-/problem-based Learning	2	3
Causal Data Science (L3095)	Lecture	2	3

Module Responsible	Prof. Christoph Ihl
Admission Requirements	None
Recommended Previous Knowledge	- Linear Algebra - Basics of programming - School knowledge in economics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After completing the module, students will be able to: - understand the difference between “correlation” and “causation”. - understand the shortcomings of current correlation-based approaches. - discuss the conceptual ideas behind various causal data science tools and algorithms. - critical examination of (study) results and spurious correlations. - understanding of application of methods in business and practice.
Skills	- develop causal knowledge relevant for specific data-driven decisions. - carry out state-of the art causal data analyses. - isolating causal effects despite the existence of confounding factors. - programming in relevant programming languages. - selection of the appropriate method depending on the problem.
Personal Competence	
Social Competence	Students can work on the problems both individually and in groups during the exercise times and also ask questions and contribute to the solution of other people's problems outside the exercise times in a dedicated forum for the course (Mattermost). In addition, students learn to prepare and present their results during the course.
Autonomy	Students learn to transfer the knowledge and skills they have learned to other subject areas and to link them to new learning content. To obtain information and solve problems, especially those related to programming errors, they learn to use appropriate resources to help themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Solutions to coding problem sets after each class session
Assignment for the Following Curricula	Data Science: Specialisation III. Applications: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory

Course L3096: Business Analytics with Causal Data Science	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christoph Ihl
Language	EN
Cycle	SoSe
Content	Most managerial decision problems require answers to questions such as “what happens to Y if we do X?”, or “was it X that caused Y to change?” In other words, practical business decision-making requires knowledge about cause-and-effect. While most data science and machine learning approaches are designed to efficiently detect patterns in high-dimensional data, they are not able to distinguish causal relationships from simple correlations. That means, commonly used approaches to business analytics often fall short to provide decision makers with important causal knowledge. Therefore, many leading companies currently try to develop specific causal data science capabilities. This module will provide an introduction into the topic of causal inference with the help of modern data science and machine learning approaches and with a focus on applications to practical business problems from various management areas. Based on an overarching framework for causal data science, the course will guide students to detect sources of confounding influence factors, understand the problem of selective measurement in data collection, and extrapolate causal knowledge across different business contexts. We also cover several tools for causal inference, such as A/B testing and experiments, difference-in-differences, instrumental variables, matching, regression discontinuity designs, etc. A variety of hands-on examples will be discussed that allow students to apply their newly obtained knowledge and carry out state-of-the-art causal analyses by themselves. Topics covered: 1. Introduction and Overview 2. Probability and Regression Review 3. Potential Outcomes Causal Model 4. Directed Acyclic Graphs 5. Experiments and A/B-Testing 6. Matching and Subclassification 7. Regression Discontinuity 8. Instrumental Variables 9. Panel Data 10. Difference-in-Differences 11. Synthetic Control 12. Heterogeneous Treatment Effects 13. Mediation Analysis
Literature	• Angrist, J. D., & Pischke, J. S. (2014). Mastering metrics: The path from cause to effect. Princeton university press. • Cunningham, Scott (2021). Causal Inference: The Mixtape, New Haven: Yale University Press. • Hernán Miguel A., and Robins James M. (2020). Causal Inference: What If. Boca Raton: Chapman & Hall/CRC. • Huntington-Klein, Nick. The effect (2021). An introduction to research design and causality. Chapman and Hall/CRC. • Imbens, G. W., & Rubin, D. B. (2015). Causal inference in statistics, social, and biomedical sciences. Cambridge University Press. • Mullainathan, Sendhil, and Jann Spiess. (2017). Machine Learning: An Applied Econometric Approach. Journal of Economic Perspectives, 31(2): 87-106. • Pearl, Judea, and Dana Mackenzie (2018). The Book of Why. Basic Books, New York, NY. • Pearl, Judea, Madelyn Glymour, and Nicholas P. Jewell (2016). Causal Inference in Statistics: A Primer. John Wiley & Sons, Inc., New York, NY.

Course L3095: Causal Data Science	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christoph Ihl
Language	EN
Cycle	SoSe
Content	Most managerial decision problems require answers to questions such as “what happens to Y if we do X?”, or “was it X that caused Y to change?” In other words, practical business decision-making requires knowledge about cause-and-effect. While most data science and machine learning approaches are designed to efficiently detect patterns in high-dimensional data, they are not able to distinguish causal relationships from simple correlations. That means, commonly used approaches to business analytics often fall short to provide decision makers with important causal knowledge. Therefore, many leading companies currently try to develop specific causal data science capabilities. This module will provide an introduction into the topic of causal inference with the help of modern data science and machine learning approaches and with a focus on applications to practical business problems from various management areas. Based on an overarching framework for causal data science, the course will guide students to detect sources of confounding influence factors, understand the problem of selective measurement in data collection, and extrapolate causal knowledge across different business contexts. We also cover several tools for causal inference, such as A/B testing and experiments, difference-in-differences, instrumental variables, matching, regression discontinuity designs, etc. A variety of hands-on examples will be discussed that allow students to apply their newly obtained knowledge and carry out state-of-the-art causal analyses by themselves. Topics covered: 1. Introduction and Overview 2. Probability and Regression Review 3. Potential Outcomes Causal Model 4. Directed Acyclic Graphs 5. Experiments and A/B-Testing 6. Matching and Subclassification 7. Regression Discontinuity 8. Instrumental Variables 9. Panel Data 10. Difference-in-Differences 11. Synthetic Control 12. Heterogeneous Treatment Effects 13. Mediation Analysis
Literature	• Angrist, J. D., & Pischke, J. S. (2014). Mastering metrics: The path from cause to effect. Princeton university press. • Cunningham, Scott (2021). Causal Inference: The Mixtape, New Haven: Yale University Press. • Hernán Miguel A., and Robins James M. (2020). Causal Inference: What If. Boca Raton: Chapman & Hall/CRC. • Huntington-Klein, Nick. The effect (2021). An introduction to research design and causality. Chapman and Hall/CRC. • Imbens, G. W., & Rubin, D. B. (2015). Causal inference in statistics, social, and biomedical sciences. Cambridge University Press. • Mullainathan, Sendhil, and Jann Spiess. (2017). Machine Learning: An Applied Econometric Approach. Journal of Economic Perspectives, 31(2): 87-106. • Pearl, Judea, and Dana Mackenzie (2018). The Book of Why. Basic Books, New York, NY. • Pearl, Judea, Madelyn Glymour, and Nicholas P. Jewell (2016). Causal Inference in Statistics: A Primer. John Wiley & Sons, Inc., New York, NY.

Module M0676: Digital Communications

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Digital Communications (L0444)	Lecture	2	3
Digital Communications (L0445)	Recitation Section (large)	2	2
Laboratory Digital Communications (L0646)	Practical Course	1	1

Module Responsible	Prof. Gerhard Bauch
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics 1-3 • Signals and Systems • Fundamentals of Communications and Random Processes
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to understand, compare and design modern digital information transmission schemes. They are familiar with the properties of linear and non-linear digital modulation methods. They can describe distortions caused by transmission channels and design and evaluate detectors including channel estimation and equalization. They know the principles of single carrier transmission and multi-carrier transmission as well as the fundamentals of basic multiple access schemes. The students are familiar with the contents of lecture and tutorials. They can explain and apply them to new problems.
Skills	The students are able to design and analyse a digital information transmission scheme including multiple access. They are able to choose a digital modulation scheme taking into account transmission rate, required bandwidth, error probability, and further signal properties. They can design an appropriate detector including channel estimation and equalization taking into account performance and complexity properties of suboptimum solutions. They are able to set parameters of a single carrier or multi carrier transmission scheme and trade the properties of both approaches against each other.
Personal Competence	
Social Competence	The students can jointly solve specific problems.
Autonomy	The students are able to acquire relevant information from appropriate literature sources. They can control their level of knowledge during the lecture period by solving tutorial problems, software tools, clicker system.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes / **Bonus** None / **Form** Written elaboration / **Description**
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Data Science: Specialisation II. Computer Science: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Electrical Engineering: Core Qualification: Compulsory Computer Science in Engineering: Specialisation II. Engineering Science: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0444: Digital Communications

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	WiSe

Content

- Repetition: Baseband Transmission
  - Pulse shaping: Non-return to zero (NRZ) rectangular pulses, raised-cosine pulses, square-root raised-cosine pulses
  - Power spectral density (psd) of baseband signals
  - Intersymbol interference (ISI)
  - First and second Nyquist criterion
  - AWGN channel
  - Matched filter
  - Matched-filter receiver and correlation receiver
  - Noise whitening matched filter
  - Discrete-time AWGN channel model
- Representation of bandpass signals and systems in the equivalent baseband
  - Quadrature amplitude modulation (QAM)
  - Equivalent baseband signal and system
  - Analytical signal
  - Equivalent baseband random process, equivalent baseband white Gaussian noise process

- Equivalent baseband AWGN channel
- Equivalent baseband channel model with frequency-offset and phase noise
- Equivalent baseband Rayleigh fading and Rice fading channel models
- Equivalent baseband frequency-selective channel model
- Discrete memoryless channels (DMC)

- Bandpass transmission via carrier modulation
  - Amplitude modulation, frequency modulation, phase modulation
  - Linear digital modulation methods
    - On-off keying, M-ary amplitude shift keying (M-ASK), M-ary phase shift keying (M-PSK), M-ary quadrature amplitude modulation (M-QAM), offset-QPSK
    - Signal space representation of transmit signal constellations and signals
    - Energy of linear digital modulated signals, average energy per symbol
    - Power spectral density of linear digital modulated signals
    - Bandwidth efficiency
    - Correlation coefficient of elementary signals
    - Error probabilities of linear digital modulation methods
      - Error functions
      - Gray mapping and natural mapping
      - Bit error probabilities, symbol error probabilities, pairwise symbol error probabilities
      - Euclidean distance and Hamming distance
      - Exact and approximate computation of error probabilities
      - Performance comparison of modulation schemes in terms of per bit SNR vs. per symbol SNR
    - Hierarchical modulation, multilevel modulation
    - Effects of carrier phase offset and carrier frequency offset
    - Differential modulation
      - M-ary differential phase shift keying (M-PSK)
      - Coherent and non-coherent detection of DPSK
      - p/M-differential phase shift keying (p/M-DPSK)
      - Differential amplitude and phase shift keying (DAPSK)
  - Non-linear digital modulation methods
    - Frequency shift keying (FSK)
    - Modulation index
    - Minimum shift keying (MSK)
      - Offset-QPSK representation of MSK
      - MSK with differential precoding and rotation
      - Bit error probabilities of MSK
      - Gaussian minimum shift keying (GMSK)
      - Power spectral density of MSK and GMSK
    - Continuous phase modulation (CPM)
      - General description of CPM signals
      - Frequency pulses and phase pulses
    - Coherent and non-coherent detection of FSK
  - Performance comparison of linear and non-linear digital modulation methods
- Frequency-selective channels, ISI channels
  - Intersymbol interference and frequency-selectivity
  - RMS delay spread
  - Narrowband and broadband channels
  - Equivalent baseband transmission model for frequency-selective channels
  - Receive filter design
- Equalization
  - Symbol-spaced and fractionally-spaced equalizers
  - Inverse system
  - Non-recursive linear equalizers
    - Linear zero-forcing (ZF) equalizer
    - Linear minimum mean squared error (MMSE) equalizer
  - Non-linear equalization:
    - Decision feedback equalizer (DFE)
    - Tomlinson-Harashima precoding
  - Maximum a posteriori probability (MAP) and maximum likelihood equalizer, Viterbi algorithm
- Single-carrier vs. multi-carrier transmission
- Multi-carrier transmission
  - General multicarrier transmission
  - Orthogonal frequency division multiplex (OFDM)
    - OFDM implementation using the Fast Fourier Transform (FFT)
    - Cyclic guard interval
    - Power spectral density of OFDM
    - Peak-to-average power ratio (PAPR)
- Multiple access
  - Principles of time division multiple access (TDMA), frequency division multiple access (FDMA), code division multiple access (CDMA), non-orthogonal multiple access (NOMA), hybrid multiple access
- Spread spectrum communications
  - Direct sequence spread spectrum communications
  - Frequency hopping
  - Protection against eavesdropping
  - Protection against narrowband jammers

	- Short vs. long spreading codes - Direct sequence spread spectrum communications in frequency-selective channels - Rake receiver - Code division multiple access (CDMA) - Design criteria of spreading sequences, autocorrelation function and crosscorrelation function of spreading sequences - Intersymbol interference (ISI) and multiple access interference (MAI) - Pseudo noise (PN) sequences, maximum length sequences (m-sequences), Gold codes, Walsh-Hadamard codes, orthogonal variable spreading factor (OVSF) codes - Multicode transmission - CDMA in uplink and downlink of a wireless communications system - Single-user detection vs. multi-user detection
Literature	K. Kammeyer: Nachrichtenübertragung, Teubner P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner. J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill. S. Haykin: Communication Systems. Wiley R.G. Gallager: Principles of Digital Communication. Cambridge A. Goldsmith: Wireless Communication. Cambridge. D. Tse, P. Viswanath: Fundamentals of Wireless Communication. Cambridge.

Course L0445: Digital Communications	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Gerhard Bauch
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0646: Laboratory Digital Communications	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Gerhard Bauch
Language	DE/EN
Cycle	WiSe
Content	- DSL transmission - Random processes - Digital data transmission
Literature	K. Kammeyer: Nachrichtenübertragung, Teubner P.A. Höher: Grundlagen der digitalen Informationsübertragung, Teubner. J.G. Proakis, M. Salehi: Digital Communications. McGraw-Hill. S. Haykin: Communication Systems. Wiley R.G. Gallager: Principles of Digital Communication. Cambridge A. Goldsmith: Wireless Communication. Cambridge. D. Tse, P. Viswanath: Fundamentals of Wireless Communication. Cambridge.

Module M0753: Software Verification

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Software Verification (L0629)	Lecture	2	3
Software Verification (L0630)	Recitation Section (small)	2	3

Module Responsible	Prof. Sibylle Schupp
Admission Requirements	None
Recommended Previous Knowledge	• Automata theory and formal languages • Computational logic • Object-oriented programming, algorithms, and data structures • Functional programming or procedural programming • Concurrency
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students apply the major verification techniques in model checking and deductive verification. They explain in formal terms syntax and semantics of the underlying logics, and assess the expressivity of different logics as well as their limitations. They classify formal properties of software systems. They find flaws in formal arguments, arising from modeling artifacts or underspecification.
Skills	Students formulate provable properties of a software system in a formal language. They develop logic-based models that properly abstract from the software under verification and, where necessary, adapt model or property. They construct proofs and property checks by hand or using tools for model checking or deductive verification, and reflect on the scope of the results. Presented with a verification problem in natural language, they select the appropriate verification technique and justify their choice.
Personal Competence	
Social Competence	Students discuss relevant topics in class. They defend their solutions orally. They communicate in English.
Autonomy	Using accompanying on-line material for self study, students can assess their level of knowledge continuously and adjust it appropriately. Working on exercise problems, they receive additional feedback. Within limits, they can set their own learning goals. Upon successful completion, students can identify and precisely formulate new problems in academic or applied research in the field of software verification. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports. They can devise plans to arrive at new solutions or assess existing ones.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** Yes · **Bonus** 15 % · **Form** Excercises · **Description**
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Data Science: Specialisation II. Computer Science: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems: Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Software: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory

Course L0629: Software Verification

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	WiSe
Content	◦ Model checking (bounded model checking, CTL, LTL) ◦ Real-time model checking (TCTL, timed automata) ◦ Deductive verification (Hoare logic) ◦ Tool support ◦ Recent developments of verification techniques and applications
Literature	• C. Baier and J-P. Katoen, Principles of Model Checking, MIT Press 2007. • M. Huth and M. Bryan, Logic in Computer Science. Modelling and Reasoning about Systems, 2nd Edition, 2004. • Selected Research Papers

Course L0630: Software Verification	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0836: Communication Networks

Courses

Title	Typ	Hrs/wk	CP
Selected Topics of Communication Networks (L0899)	Project-/problem-based Learning	2	2
Communication Networks (L0897)	Lecture	2	2
Communication Networks Excercise (L0898)	Project-/problem-based Learning	1	2

Module Responsible	Prof. Andreas Timm-Giel
Admission Requirements	None
Recommended Previous Knowledge	• Fundamental stochastics • Basic understanding of computer networks and/or communication technologies is beneficial
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe the principles and structures of communication networks in detail. They can explain the formal description methods of communication networks and their protocols. They are able to explain how current and complex communication networks work and describe the current research in these examples.
Skills	Students are able to evaluate the performance of communication networks using the learned methods. They are able to work out problems themselves and apply the learned methods. They can apply what they have learned autonomously on further and new communication networks.
Personal Competence	
Social Competence	Students are able to define tasks themselves in small teams and solve these problems together using the learned methods. They can present the obtained results. They are able to discuss and critically analyse the solutions.
Autonomy	Students are able to obtain the necessary expert knowledge for understanding the functionality and performance capabilities of new communication networks independently.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Presentation
Examination duration and scale	1.5 hours colloquium with three students, therefore about 30 min per student. Topics of the colloquium are the posters from the previous poster session and the topics of the module.
Assignment for the Following Curricula	Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L0899: Selected Topics of Communication Networks

Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr.-Ing. Koojana Kuladinithi
Language	EN
Cycle	WiSe
Content	Example networks selected by the students will be researched on in a PBL course by the students in groups and will be presented in a poster session at the end of the term.
Literature	• see lecture

Course L0897: Communication Networks	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr.-Ing. Koojana Kuladinithi
Language	EN
Cycle	WiSe
Content	
Literature	• Skript des Instituts für Kommunikationsnetze • Tannenbaum, Computernetzwerke, Pearson-Studium Further literature is announced at the beginning of the lecture.

Course L0898: Communication Networks Excercise	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Dr.-Ing. Koojana Kuladinithi
Language	EN
Cycle	WiSe
Content	Part of the content of the lecture Communication Networks are reflected in computing tasks in groups, others are motivated and addressed in the form of a PBL exercise.
Literature	• announced during lecture

Module M0733: Software Analysis

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Software Analysis (L0631)	Lecture	2	3
Software Analysis (L0632)	Recitation Section (small)	2	3

Module Responsible	Prof. Sibylle Schupp
Admission Requirements	None
Recommended Previous Knowledge	• Basic knowledge of software-engineering activities • Discrete algebraic structures • Object-oriented programming, algorithms, and data structures • Functional programming or Procedural programming
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students apply the major approaches to data-flow analysis, control-flow analysis, and type-based analysis, along with their classification schemes, and employ abstract interpretation. They explain the standard forms of internal representations and models, including their mathematical structure and properties, and evaluate their suitability for a particular analysis. They explain and categorize the major analysis algorithms. They distinguish precise solutions from approximative approaches, and show termination and soundness properties.
Skills	Presented with an analytical task for a software artifact, students select appropriate approaches from software analysis, and justify their choice. They design suitable representations by modifying standard representations. They develop customized analyses and devise them as safe overapproximations. They formulate analyses in a formal way and construct arguments for their correctness, behavior, and precision.
Personal Competence	
Social Competence	Students discuss relevant topics in class. They defend their solutions orally. They communicate in English.
Autonomy	Using accompanying on-line material for self study, students can assess their level of knowledge continuously and adjust it appropriately. Working on exercise problems, they receive additional feedback. Within limits, they can set their own learning goals. Upon successful completion, students can identify and precisely formulate new problems in academic or applied research in the field of software analysis. Within this field, they can conduct independent studies to acquire the necessary competencies and compile their findings in academic reports. They can devise plans to arrive at new solutions or assess existing ones.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	software artifacts/mathematical write-ups; short presentation
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory

Course L0631: Software Analysis

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	WiSe
Content	• Modeling: Control-Flow Modeling, Data Dependences, Intermediate Languages) • Classical Bit-Vector Analyses (Reaching Definition, Very Busy Expressions, Liveness, Available Expressions, May/Must, Forward/Backward) • Monotone Frameworks (Lattices, Transfer Functions, Ascending Chain Condition, Distributivity, Constant Propagation) • Theory of Data-Flow Analysis (Tarski's Fixed Point Theorem, Data-Flow Equations, MFP Solution, MOP Solution, Worklist Algorithm) • Non-Classical Data-Flow Analyses • Abstract Interpretation (Galois Connections, Approximating Fixed Points, Construction Techniques) • Type Systems (Type Derivation, Inference Trees, Algorithm W, Unification) • Recent Developments of Analysis Techniques and Applications
Literature	• Flemming Nielsen, Hanne Nielsen, and Chris Hankin. Principles of Program Analysis. Springer, 2nd. ed. 2005. • Uday Khedker, Amitabha Sanyal, and Bageshri Karkara. Data Flow Analysis: Theory and Practice. CRC Press, 2009. • Benjamin Pierce, Types and Programming Languages, MIT Press. • Selected research papers

Course L0632: Software Analysis	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Sibylle Schupp
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1598: Image Processing

Courses

Title	Typ	Hrs/wk	CP
Image Processing (L2443)	Lecture	2	4
Image Processing (L2444)	Recitation Section (small)	2	2

Module Responsible	Prof. Tobias Knopp
Admission Requirements	None
Recommended Previous Knowledge	Signal and Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know about • visual perception • multidimensional signal processing • sampling and sampling theorem • filtering • image enhancement • edge detection • multi-resolution procedures: Gauss and Laplace pyramid, wavelets • image compression • image segmentation • morphological image processing
Skills	The students can • analyze, process, and improve multidimensional image data • implement simple compression algorithms • design custom filters for specific applications
Personal Competence	
Social Competence	Students can work on complex problems both independently and in teams. They can exchange ideas with each other and use their individual strengths to solve the problem.
Autonomy	Students are able to independently investigate a complex problem and assess which competencies are required to solve it.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Data Science: Core Qualification: Elective Compulsory Data Science: Specialisation I. Mathematics/Computer Science: Elective Compulsory Data Science: Specialisation II. Computer Science: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Software and Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L2443: Image Processing	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	DE/EN
Cycle	WiSe
Content	• Visual perception • Multidimensional signal processing • Sampling and sampling theorem • Filtering • Image enhancement • Edge detection • Multi-resolution procedures: Gauss and Laplace pyramid, wavelets • Image Compression • Segmentation • Morphological image processing
Literature	Bredies/Lorenz, Mathematische Bildverarbeitung, Vieweg, 2011 Pratt, Digital Image Processing, Wiley, 2001 Bernd Jähne: Digitale Bildverarbeitung - Springer, Berlin 2005

Course L2444: Image Processing	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Tobias Knopp
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1880: Deep Learning for Social Analytics

Courses

Title	Typ	Hrs/wk	CP
Deep Learning for Text and Graphs (L3097)	Lecture	2	3
Social Analytics with Deep Learning (L3098)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Christoph Ihl
Admission Requirements	None
Recommended Previous Knowledge	• Basic knowledge of Python • Familiarity with probability theory, linear algebra and statistics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Understand how text and graphs can be transformed into data • Identify underlying relational structures of data that can be represented as graphs • Discuss the conceptual ideas behind various deep learning architectures • Decide about suitable deep learning architectures for a given task
Skills	• Proficiency in Python for deep learning applications • Apply basic natural language processing methods such as embedding and dependency parsing • Model complex data using graph representations • Set up deep learning architectures for different tasks • Make predictions employing deep learning models
Personal Competence	
Social Competence	• Collaboration on projects and assignments • Communication regarding computational, algorithmic and modeling challenges
Autonomy	• Maneuver in the field of deep learning including scientific literature and models • Solve computational, algorithmic, and modeling challenges related to deep learning models • Critical thinking skills • Self-sufficient problem-solving regarding coding issues
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	Solutions to coding problem sets after each class session
Assignment for the Following Curricula	Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Data Science: Specialisation III. Applications: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory

Course L3097: Deep Learning for Text and Graphs	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christoph Ihl
Language	EN
Cycle	WiSe
Content	Today, massive amounts of valuable data come in digital, yet often unstructured forms such as text or graphs. People communicate almost everything in language: e.g., social media, web search, product reviews, advertising, emails, customer service, language translation, chatbots, medical reports, etc. At the same time, they choose to interact with other people, products or websites. These networked interaction patterns can be represented as graphs of relationships between people and objects. Analyzing these new data sources and forms can help decision makers to significantly improve the effectiveness and efficiency of products, services and processes. This course introduces the fundamentals and current state of machine learning for natural language processing (NLP) and graphs in terms of content, users, and social relations. The course has a particular emphasis on key advancements in deep learning (or neural network) architectures, which in recent years have obtained very high performance across many different tasks, using single end-to-end models that do not require traditional, task-specific feature engineering. The course focuses on the computational, algorithmic, and modeling challenges specific to learning architecture for text and graphs. Students will gain a thorough introduction to modern deep learning algorithms. Through lectures and coding labs, students will learn the necessary skills to design, implement, and understand their own deep learning models. We will use Python and the deep learning framework PyTorch (Geometric). Topics Covered: 1. Intro: Text and Graphs as Data 2. Word Embeddings 3. Fundamentals of Deep Learning 4. Dependency Parsing 5. Recurrent Neural Networks for Text 6. Contextual Word Embeddings with Transformers 7. Analyzing Graphs 8. Graph Embeddings 9. Graph Embeddings for Complex Graphs 10. Graph Neural Networks (GNNs) 11. GNNs for Complex Graphs 12. GNNs for Text 13. Deep Generative Models for Text and Graphs
Literature	• Chollet, F., & Allaire, J. J. (2018). Deep Learning mit R und Keras: Das Praxis-Handbuch von den Entwicklern von Keras und RStudio. MITP-Verlags GmbH & Co. KG. • Hamilton, William L. (2020). Graph Representation Learning. Synthesis Lectures on Artificial Intelligence and Machine Learning, Vol. 14, No. 3 , Pages 1-159. • Hapke, H., Howard, C., & Lane, H. (2019). Natural Language Processing in Action: Understanding, analyzing, and generating text with Python. Simon and Schuster. • Hvitfeldt, E., & Silge, J. (2021). Supervised machine learning for text analysis in R. • Ma, Y., & Tang, J. (2021). Deep learning on graphs. Cambridge University Press. • Rao, D., & McMahan, B. (2019). Natural language processing with PyTorch: build intelligent language applications using deep learning. O'Reilly Media, Inc.

Course L3098: Social Analytics with Deep Learning	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Christoph Ihl
Language	EN
Cycle	WiSe
Content	Today, massive amounts of valuable data come in digital, yet often unstructured forms such as text or graphs. People communicate almost everything in language: e.g., social media, web search, product reviews, advertising, emails, customer service, language translation, chatbots, medical reports, etc. At the same time, they choose to interact with other people, products or websites. These networked interaction patterns can be represented as graphs of relationships between people and objects. Analyzing these new data sources and forms can help decision makers to significantly improve the effectiveness and efficiency of products, services and processes. This course introduces the fundamentals and current state of machine learning for natural language processing (NLP) and graphs in terms of content, users, and social relations. The course has a particular emphasis on key advancements in deep learning (or neural network) architectures, which in recent years have obtained very high performance across many different tasks, using single end-to-end models that do not require traditional, task-specific feature engineering. The course focuses on the computational, algorithmic, and modeling challenges specific to learning architecture for text and graphs. Students will gain a thorough introduction to modern deep learning algorithms. Through lectures and coding labs, students will learn the necessary skills to design, implement, and understand their own deep learning models. We will use Python and the deep learning framework PyTorch (Geometric). Topics Covered: 1. Intro: Text and Graphs as Data 2. Word Embeddings 3. Fundamentals of Deep Learning 4. Dependency Parsing 5. Recurrent Neural Networks for Text 6. Contextual Word Embeddings with Transformers 7. Analyzing Graphs 8. Graph Embeddings 9. Graph Embeddings for Complex Graphs 10. Graph Neural Networks (GNNs) 11. GNNs for Complex Graphs 12. GNNs for Text 13. Deep Generative Models for Text and Graphs
Literature	• Chollet, F., & Allaire, J. J. (2018). Deep Learning mit R und Keras: Das Praxis-Handbuch von den Entwicklern von Keras und RStudio. MITP-Verlags GmbH & Co. KG. • Hamilton, William L. (2020). Graph Representation Learning. Synthesis Lectures on Artificial Intelligence and Machine Learning, Vol. 14, No. 3 , Pages 1-159. • Hapke, H., Howard, C., & Lane, H. (2019). Natural Language Processing in Action: Understanding, analyzing, and generating text with Python. Simon and Schuster. • Hvitfeldt, E., & Silge, J. (2021). Supervised machine learning for text analysis in R. • Ma, Y., & Tang, J. (2021). Deep learning on graphs. Cambridge University Press. • Rao, D., & McMahan, B. (2019). Natural language processing with PyTorch: build intelligent language applications using deep learning. O'Reilly Media, Inc. • Silge, J., & Robinson, D. (2017). Text mining with R: A tidy approach. O'Reilly Media, Inc.

Module M0629: Intelligent Autonomous Agents and Cognitive Robotics

Courses

Title	Typ	Hrs/wk	CP
Intelligent Autonomous Agents and Cognitive Robotics (L0341)	Lecture	2	4
Intelligent Autonomous Agents and Cognitive Robotics (L0512)	Recitation Section (small)	2	2

Module Responsible	Rainer Marrone
Admission Requirements	None
Recommended Previous Knowledge	Vectors, matrices, Calculus
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the agent abstraction, define intelligence in terms of rational behavior, and give details about agent design (goals, utilities, environments). They can describe the main features of environments. The notion of adversarial agent cooperation can be discussed in terms of decision problems and algorithms for solving these problems. For dealing with uncertainty in real-world scenarios, students can summarize how Bayesian networks can be employed as a knowledge representation and reasoning formalism in static and dynamic settings. In addition, students can define decision making procedures in simple and sequential settings, with and with complete access to the state of the environment. In this context, students can describe techniques for solving (partially observable) Markov decision problems, and they can recall techniques for measuring the value of information. Students can identify techniques for simultaneous localization and mapping, and can explain planning techniques for achieving desired states. Students can explain coordination problems and decision making in a multi-agent setting in term of different types of equilibria, social choice functions, voting protocol, and mechanism design techniques.
Skills	Students can select an appropriate agent architecture for concrete agent application scenarios. For simplified agent application students can derive decision trees and apply basic optimization techniques. For those applications they can also create Bayesian networks/dynamic Bayesian networks and apply bayesian reasoning for simple queries. Students can also name and apply different sampling techniques for simplified agent scenarios. For simple and complex decision making students can compute the best action or policies for concrete settings. In multi-agent situations students will apply techniques for finding different equilibria states,e.g., Nash equilibria. For multi-agent decision making students will apply different voting protocols and compare and explain the results.
Personal Competence	
Social Competence	Students are able to discuss their solutions to problems with others. They communicate in English
Autonomy	Students are able of checking their understanding of complex concepts by solving varaints of concrete problems
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L0341: Intelligent Autonomous Agents and Cognitive Robotics	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Rainer Marrone
Language	EN
Cycle	WiSe
Content	• Definition of agents, rational behavior, goals, utilities, environment types • Adversarial agent cooperation: Agents with complete access to the state(s) of the environment, games, Minimax algorithm, alpha-beta pruning, elements of chance • Uncertainty: Motivation: agents with no direct access to the state(s) of the environment, probabilities, conditional probabilities, product rule, Bayes rule, full joint probability distribution, marginalization, summing out, answering queries, complexity, independence assumptions, naive Bayes, conditional independence assumptions • Bayesian networks: Syntax and semantics of Bayesian networks, answering queries revised (inference by enumeration), typical-case complexity, pragmatics: reasoning from effect (that can be perceived by an agent) to cause (that cannot be directly perceived). • Probabilistic reasoning over time: Environmental state may change even without the agent performing actions, dynamic Bayesian networks, Markov assumption, transition model, sensor model, inference problems: filtering, prediction, smoothing, most-likely explanation, special cases: hidden Markov models, Kalman filters, Exact inferences and approximations • Decision making under uncertainty: Simple decisions: utility theory, multivariate utility functions, dominance, decision networks, value of informatio Complex decisions: sequential decision problems, value iteration, policy iteration, MDPs Decision-theoretic agents: POMDPs, reduction to multidimensional continuous MDPs, dynamic decision networks • Simultaneous Localization and Mapping • Planning • Game theory (Golden Balls: Split or Share) Decisions with multiple agents, Nash equilibrium, Bayes-Nash equilibrium • Social Choice Voting protocols, preferences, paradoxes, Arrow's Theorem, • Mechanism Design Fundamentals, dominant strategy implementation, Revelation Principle, Gibbard-Satterthwaite Impossibility Theorem, Direct mechanisms, incentive compatibility, strategy-proofness, Vickrey-Groves-Clarke mechanisms, expected externality mechanisms, participation constraints, individual rationality, budget balancedness, bilateral trade, Myerson-Satterthwaite Theorem
Literature	1. Artificial Intelligence: A Modern Approach (Third Edition), Stuart Russell, Peter Norvig, Prentice Hall, 2010, Chapters 2-5, 10-11, 13-17 2. Probabilistic Robotics, Thrun, S., Burgard, W., Fox, D. MIT Press 2005 3. Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations, Yoav Shoham, Kevin Leyton-Brown, Cambridge University Press, 2009

Course L0512: Intelligent Autonomous Agents and Cognitive Robotics	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Rainer Marrone
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Specialization II. Logistics

Module M0978: Sustainable Mobility of Goods and Logistics Systems

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
International Logistics and Transport Systems (L1168)	Project-/problem-based Learning	3	4
Sustainable Mobility of Goods, Logistics, Traffic (L1165)	Lecture	2	2

Module Responsible	Prof. Heike Flämig
Admission Requirements	None
Recommended Previous Knowledge	• Introduction to Logistics and Mobility • Foundations of Management • Legal Foundations of Transportation and Logistics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to... • give definitions of system theory, (international) transport chains and logistics in the context of supply chain management • explain trends and strategies for mobility of goods and logistics • describe elements of integrated and multi-modal transport chains and their advantages and disadvantages • deduce impacts of management decisions on logistics system and traffic system and explain how stakeholders influence them • explain the correlations between economy and logistics systems, mobility of goods, space-time-structures and the traffic system as well as ecology and politics
Skills	Students are able to... • Design intermodal transport chains and logistic concepts • apply the commodity chain theory and case study analysis • evaluate different international transport chains • cope with differences in cultures that influence international transport chains
Personal Competence	
Social Competence	Students are able to... • develop a feeling of social responsibility for their future jobs • give constructive feedback to others about their presentation skills • plan and execute teamwork tasks
Autonomy	Students are able to improve presentation skills by feedback of others
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Excercises Yes / None / Participation in excursions
Examination	Written exam
Examination duration and scale	written exam (60 minutes), exercises in groups (min. 80% attendance), one-day excursion with short presentations
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory Mechanical Engineering and Management: Specialisation Management: Elective Compulsory

Course L1168: International Logistics and Transport Systems	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Heike Flämig
Language	EN
Cycle	SoSe
Content	The problem-oriented-learning lecture consists of case studies and complex problems concerning the systemic characteristics of different modes of transport as well as the organization and realization of transport chains. Students get to know specific issues from practice of logistics and mobility of goods and work out recommondations for solutions.
Literature	David, Pierre A.; Stewart, Richard D.: International Logistics: The Management of International Trade Operations, 3rd Edition, Mason, 2010 Schieck, Arno: Internationale Logistik: Objekte, Prozesse und Infrastrukturen grenzüberschreitender Güterströme, München, 2009

Course L1165: Sustainable Mobility of Goods, Logistics, Traffic	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Heike Flämig
Language	EN
Cycle	SoSe
Content	The intention of this lecture is to provide a general system analysis-based overview of how transportation chains emerge and how they are developed. The respective advantages and disadvantages of different international transportation chains of goods are to be pointed out from a micro- and a macroeconomic point of view. The effects on the traffic system as well as the ecological and social consequences of a spatial devision of economical activities are to be discussed. The overview of current international transportation chains is carried out on the basis of concrete material- and appendant information flows. Established transportation chains and some of their individual elements are to become transparent to the students by a number of practical examples. 1. A conceptual systems model 2. Elements of integrated and multi-modal transportation chains 3. interaction of transport and traffic, demand and supply on different layers of the transport system 4. Global Issues in Supply Chain Management 5. Global Players and networks 6. Logistics and corporate social responsibility (CSR) 7. Methods and data for assessment of international transport chains 8. Influence of cultural aspects on international transport chains 9. New solutions using different focuses of the transport and logstics system
Literature	David, Pierre A.; Stewart, Richard D.: International Logistics: The Management of International Trade Operations, 3rd Edition, Mason, 2010 Schieck, Arno: Internationale Logistik: Objekte, Prozesse und Infrastrukturen grenzüberschreitender Güterströme, München, 2009 BLOECH, J., IHDE, G. B. (1997) Vahlens Großes Logistiklexikon, München, Verlag C.H. Beck IHDE, G. B. (1991) Transport, Verkehr, Logistik, München, Verlag Franz Vahlen, 2. völlig überarbeitete und erweiterte Auflage NUHN, H., HESSE, M. (2006) Verkehrsgeographie, Paderborn, München, Wien, Zürich, Verlage Ferdinand Schöningh PFOHL, H.-C. (2000) Logistiksysteme - Betriebswirtschaftliche Grundlagen, Berlin, Heidelberg, New York, Springer-Verlag, 6. Auflage

Module M1132: Maritime Transport

Courses

Title	Typ	Hrs/wk	CP
Maritime Transport (L0063)	Lecture	2	3
Maritime Transport (L0064)	Recitation Section (small)	2	3

Module Responsible	Prof. Carlos Jahn
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to... • present the actors involved in the maritime transport chain with regard to their typical tasks; • name common cargo types in shipping and classify cargo to the corresponding categories; • explain operating forms in maritime shipping, transport options and management in transport networks; • weigh the advantages and disadvantages of the various modes of hinterland transport and apply them in practice; • estimate the potential of digitisation in maritime shipping.
Skills	The students are able to... • determine the mode of transport, actors and functions of the actors in the maritime supply chain; • identify possible cost drivers in a transport chain and recommend appropriate proposals for cost reduction; • record, map and systematically analyse material and information flows of a maritime logistics chain, identify possible problems and recommend solutions; • perform risk assessments of human disruptions to the supply chain; • analyse accidents in the field of maritime logistics and evaluating their relevance in everyday life; • deal with current research topics in the field of maritime logistics in a differentiated way; • plan the deployment of a fleet based on scenarios; • apply different process modelling methods in a hitherto unknown field of activity and to work out the respective advantages.
Personal Competence	
Social Competence	The students are able to... • discuss and organise extensive work packages in groups; • document and present the elaborated results.
Autonomy	The students are capable to... • research and select technical literature, including standards and guidelines; • submit own shares in an extensive written elaboration in small groups in due time.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	Compulsory: No; Bonus: 15 %; Form: Subject theoretical and practical work; Description: Teilnahme an einem Planspiel und anschließende schriftliche Ausarbeitung
Examination	Written exam
Examination duration and scale	120 minutes
Assignment for the Following Curricula	Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Maritime Technology: Elective Compulsory

Course L0063: Maritime Transport	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Carlos Jahn
Language	DE
Cycle	SoSe
Content	The general tasks of maritime logistics include the planning, design, implementation and control of material and information flows in the logistics chain ship - port - hinterland. The aim of the course is to provide students with knowledge of maritime transport and the actors involved in the maritime transport chain. Typical problem areas and tasks will be dealt with, taking into account the economic development. Thus, classical problems as well as current developments and trends in the field of maritime logistics are considered. In the lecture, the components of the maritime logistics chain and the actors involved will be examined and risk assessments of human disturbances on the supply chain will be developed. In addition, students learn to estimate the potential of digitisation in maritime shipping, especially with regard to the monitoring of ships. In addition, students are able to design operational planning for fleets of container or tramp vessels. Further content of the lecture is the different modes of transport in the hinterland, which students can evaluate after completion of the course regarding their advantages and disadvantages.
Literature	• Clausen, Uwe and Geiger, Christiane. Verkehrs- und Transportlogistik. Berlin Heidelberg: Springer-Verlag, 2013. • Schönknecht, Axel. Maritime Containerlogistik: Leistungsvergleich von Containerschiffen in intermodalen Transportketten. Berlin Heidelberg: Springer-Verlag, 2009. • Rodrigue, Jean-Paul. Geography of Transport Systems. London New York: Routledge, 2020. • Stopford, Martin. Maritime Economics Routledge, 2009.

Course L0064: Maritime Transport	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Carlos Jahn
Language	DE
Cycle	SoSe
Content	The exercise lesson bases on the haptic management game MARITIME. MARITIME focuses on providing knowledge about structures and processes in a maritime transport network. Furthermore, the management game systematically provides process management methodology and also promotes personal skills of the participants.
Literature	• Brinkmann, Birgitt. Seehäfen: Planung und Entwurf. Berlin Heidelberg: Springer-Verlag, 2005. • Koch Susanne. Methoden des Prozessmanagements. In: Einführung in das Management von Geschäftsprozessen. Springer, Berlin, Heidelberg, 2011. • Liebetruth, Thomas. Prozessmanagement in Einkauf und Logistik, Springer Gabler: Wiesbaden, 2020. • Schönknecht, Axel. Maritime Containerlogistik: Leistungsvergleich von Containerschiffen in intermodalen Transportketten. Berlin Heidelberg: Springer-Verlag, 2009. • Stopford, Martin. Maritime Economics Routledge, 2009

Module M1089: Integrated Maintenance and Spare Part Logistics

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Spare Part Logistics (L1403)	Lecture	1	2
Maintenance Logistics (L1401)	Lecture	2	2
Exercises to Integrated Maintenance and Spare Part Logistics (L1405)	Recitation Section (small)	1	2

Module Responsible	Prof. Kathrin Fischer
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of logistical processes
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students can explain basic concepts of maintenance and spare parts logistics and distinguish between them. • Students can explain key approaches and concepts of maintenance and spare parts logistics, locate them in a theoretical context and present practical applications.
Skills	• Students can plan and evaluate processes, techniques and organizational forms in the field of maintenance and spare parts logistics. • Students can apply planning methods in maintenance and spare parts logistics to practical examples. • Students can develop and apply key performance indicator systems and carry out current status analyses.
Personal Competence	
Social Competence	• Students can present and argue their own expert opinions and work results in front of teachers and other students in an appropriate manner. • Students can achieve accurate work results as members of a team.
Autonomy	• Students can access specialist knowledge independently and transfer the knowledge acquired to new problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	2 hours
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory

Course L1403: Spare Part Logistics

Typ	Lecture
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Ingo Martens
Language	DE
Cycle	SoSe
Content	• Introduction: Logistical spare parts management, factors influencing need for spare parts, spare logistics requireents, integration of spare parts logistics and maintenance logistics. • Methoda: Analysis of spare parts stocks, diffentiation of spare parts strategy, forecasting need for spare parts, process chains • Planning: preliminary planning, concept planning and realisation, planning instruments and tools. • Practical examples for: optimization of spare parts centers, optimization of international spare parts distribution, performance-based logistics, new business models in spare parts logistics.
Literature	Scripts and text documents to be handed out during the course.

Course L1401: Maintenance Logistics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Ingo Martens
Language	DE
Cycle	SoSe
Content	• Introduction: developments and trends in integrated maintenance and spare parts logistics, components of integrated maintenance, the terms maintenance and maintenance logistics, need for action and the “maintenance dilemma,” maintenance planning measures. • Basics of integrated maintenance: maintenance technology, organisational structures and workflows, maintenance controlling, integration of employees and management. • Knowledge-based business management and maintenance: Production and maintenance, condition knowledge and diagnosis, business management strategy, management, motivation and success. • Target and key performance indicator systems: developing target systems, performance indicator requirements, performance indicator analysis, strengths and weaknesses analysis, potential analysis, performance indicator models, monitoring (IH Cockpit) • Maintenance methods: make or buy versus outsourcing, total productive maintenance, differentiating between logistics strategies. • Maintenance planning: concept planning and realization, concept planning tasks and steps, supplementing planning basics, technology and organisation sub-concepts, overall concept of integrated maintenance and spare parts logistics. • Practical examples, including for: energy-efficient asset management, maintenance strategies in highly automated goods distribution centers, remote diagnosis and service management in wind energy plants, value stream analysis in maintenance.
Literature	Skripte und Textdokumente, die während der Vorlesung herausgegeben werden. Scripts and text documents to be handed out during the course.

Course L1405: Exercises to Integrated Maintenance and Spare Part Logistics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Ingo Martens
Language	DE
Cycle	SoSe
Content	
Literature	Es wird die in den Vorlesungen "Instandhaltungdslogistik" und "Ersatzteillogistik" verwendete Literatur empfohlen.

Module M1133: Port Logistics

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Port Logistics (L0686)	Lecture	2	3
Port Logistics (L1473)	Recitation Section (small)	2	3

Module Responsible	Prof. Carlos Jahn
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Th After completing the module, students can... • reflect on the development of seaports (in terms of the functions of the ports and the corresponding terminals, as well as the relevant operator models) and place them in their historical context; • explain and evaluate different types of seaport terminals and their specific characteristics (cargo, transhipment technologies, logistic functional areas); • analyze common planning tasks (e.g. berth planning, stowage planning, yard planning) at seaport terminals and develop suitable approaches (in terms of methods and tools) to solve these planning tasks; • identify future developments and trends regarding the planning and control of innovative seaport terminals and discuss them in a problem-oriented manner.
Skills	After completing the module, students will be able to... • recognize functional areas in ports and seaport terminals; • define and evaluate suitable operating systems for container terminals; • perform static calculations with regard to given boundary conditions, e.g. required capacity (parking spaces, equipment requirements, quay wall length, port access) on selected terminal types; • reliably estimate which boundary conditions influence common logistics indicators in the static planning of selected terminal types and to what extent.
Personal Competence	
Social Competence	After completing the module, students can... • transfer the acquired knowledge to further questions of port logistics; • discuss and successfully organize extensive task packages in small groups; • in small groups, document work results in writing in an understandable form and present them to an appropriate extent.
Autonomy	After completing the module, the students are able to... • research and select specialist literature, including standards, guidelines and journal papers, and to develop the contents independently; • submit own parts in an extensive written elaboration in small groups in due time and to present them jointly within a fixed time frame.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** No / **Bonus** 15 % / **Form** Written elaboration / **Description**
Examination	Written exam
Examination duration and scale	120 minutes
Assignment for the Following Curricula	Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Maritime Technology: Elective Compulsory

Course L0686: Port Logistics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Carlos Jahn
Language	DE
Cycle	SoSe
Content	Port Logistics deals with the planning, control, execution and monitoring of material flows and the associated information flows in the port system and its interfaces to numerous actors inside and outside the port area. The extraordinary role of maritime transport in international trade requires very efficient ports. These must meet numerous requirements in terms of economy, speed, safety and the environment. Against this background, the lecture Port Logistics deals with the planning, control, execution and monitoring of material flows and the associated information flows in the port system and its interfaces to numerous actors inside and outside the port area. The aim of the lecture Port Logistics is to convey an understanding of structures and processes in ports. The focus will be on different types of terminals, their characteristical layouts and the technical equipment used as well as the ongoing digitization and interaction of the players involved. In addition, renowned guest speakers from science and practice will be regularly invited to discuss some lecture-relevant topics from alternative perspectives. The following contents will be conveyed in the lectures: • Instruction of structures and processes in the port • Planning, control, implementation and monitoring of material and information flows in the port • Fundamentals of different terminals, characteristical layouts and the technical equipment used • Handling of current issues in port logistics
Literature	• Alderton, Patrick (2013). Port Management and Operations. • Biebig, Peter and Althof, Wolfgang and Wagener, Norbert (2017). Seeverkehrswirtschaft: Kompendium. • Brinkmann, Birgitt. Seehäfen: Planung und Entwurf. Berlin Heidelberg: Springer-Verlag, 2005. • Büter, Clemens (2013). Außenhandel: Grundlagen internationaler Handelsbeziehungen. • Gleissner, Harald and Femerling, J. Christian (2012). Logistik: Grundlagen, Übungen, Fallbeispiele. • Jahn, Carlos; Saxe, Sebastian (Hg.). Digitalization of Seaports - Visions of the Future, Stuttgart: Fraunhofer Verlag, 2017. • Kummer, Sebastian (2019). Einführung in die Verkehrswirtschaft • Lun, Y.H.V. and Lai, K.-H. and Cheng, T.C.E. (2010). Shipping and Logistics Management. • Woitschützke, Claus-Peter (2013). Verkehrsgeografie.

Course L1473: Port Logistics	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Carlos Jahn
Language	DE
Cycle	SoSe
Content	The content of the exercise is the independent preparation of a scientific paper plus an accompanying presentation on a current topic of port logistics. The paper deals with current topics of port logistics. For example, the future challenges in sustainability and productivity of ports, the digital transformation of terminals and ports or the introduction of new regulations by the International Maritime Organization regarding the verified gross weight of containers. Due to the international orientation of the event, the paper is to be prepared in English.
Literature	• Alderton, Patrick (2013). Port Management and Operations. • Biebig, Peter and Althof, Wolfgang and Wagener, Norbert (2017). Seeverkehrswirtschaft: Kompendium. • Brinkmann, Birgitt. Seehäfen: Planung und Entwurf. (2005) Berlin Heidelberg: Springer-Verlag. • Büter, Clemens (2013). Außenhandel: Grundlagen internationaler Handelsbeziehungen. • Gleissner, Harald and Femerling, J. Christian (2012). Logistik: Grundlagen, Übungen, Fallbeispiele. • Jahn, Carlos; Saxe, Sebastian (Hg.) (2017) Digitalization of Seaports - Visions of the Future, Stuttgart: Fraunhofer Verlag. • Kummer, Sebastian (2019). Einführung in die Verkehrswirtschaft • Lun, Y.H.V. and Lai, K.-H. and Cheng, T.C.E. (2010). Shipping and Logistics Management. • Woitschützke, Claus-Peter (2013). Verkehrsgeografie.

Module M0977: Construction Logistics and Project Management

Courses

Title	Typ	Hrs/wk	CP
Construction Logistics (L1163)	Lecture	1	2
Construction Logistics (L1164)	Recitation Section (small)	1	2
Project Development and Management (L1161)	Lecture	1	1
Project Development and Management (L1162)	Project-/problem-based Learning	1	1

Module Responsible	Prof. Heike Flämig
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can... • give definitions of the main terms of construction logistics and project development and management • name advantages and disadvantages of internal or external construction logistics • explain characteristics of products, demand and production of construction objects and their consequences for construction specific supply chains • differentiate constructions logistics from other logistics systems
Skills	Students can... • carry out project life cycle assessments • apply methods and instruments of construction logistics • apply methods and instruments of project development and management • apply methods and instruments of conflict management • design supply and waste removal concepts for a construction project
Personal Competence	
Social Competence	Students can... • hold presentations in and for groups • apply methods of conflict solving skills in group work and case studies
Autonomy	Students can... • solve problems by holistic, systemic and flow oriented thinking • improve their creativity, negotiation skills, conflict and crises solution skills by applying methods of moderation in case studies
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Two written papers with presentations
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Elective Compulsory International Management and Engineering: Specialisation II. Civil Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L1163: Construction Logistics	
Typ	Lecture
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heike Flämig
Language	DE
Cycle	SoSe
Content	The lecture gives deeper insight how important logistics are as a competetive factor for construction projects and which issues are to be adressed. The following toppics are covered: • competetive factor logistics • the concept of systems, planning and coordination of logistics • material, equipment and reverse logistics • IT in construction logistics • elements of the planning model of construction logistics and their connections • flow oriented logistics systems for construction projects • logistics concepts for ready to use construction projects (especially procurement and waste removel logistics) • best practice examples (construction logistics Potsdamer Platz, recent case study of the region) Contents of the lecture are deepened in special exercises.
Literature	Flämig, Heike: Produktionslogistik in Stadtregionen. In: Forschungsverbund Ökologische Mobilität (Hrsg.) Forschungsbericht Bd. 15.2. Wuppertal 2000. Krauss, Siri: Die Baulogistik in der schlüsselfertigen Ausführung, Bauwerk Verlag GmbH Berlin 2005. Lipsmeier, Klaus: Abfallkennzahlen für Neubauleistungen im Hochbau : Verlag Forum für Abfallwirtschaft und Altlasten, 2004. Schmidt, Norbert: Wettbewerbsfaktor Baulogistik. Neue Wertschöpfungspotenziale in der Baustoffversorgung. In: Klaus, Peter: Edition Logistik. Band 6. Deutscher Verkehrs-Verlag. Hamburg 2003. Seemann, Y.F. (2007): Logistikkoordination als Organisationseinheit bei der Bauausführung Wissenschaftsverlag Mainz in Aachen, Aachen. (Mitteilungen aus dem Fachgebiet Baubetrieb und Bauwirtschaft (Hrsg. Kuhne, V.): Heft 20)

Course L1164: Construction Logistics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heike Flämig
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1161: Project Development and Management	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Heike Flämig, Dr. Anton Worobei
Language	DE
Cycle	SoSe
Content	Within the lecture, the main aspects of project development and management are tought: • Terms and definitions of project management • Advantages and disadvantages of different ways of project handling • organization, information, coordination and documentation • cost and fincance management in projects • time- and capacity management in projects • specific methods and instruments for successful team work Contents of the lecture are deepened in special exercises.
Literature	Projektmanagement-Fachmann. Band 1 und Band 2. RKW-Verlag, Eschborn, 2004.

Course L1162: Project Development and Management	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Heike Flämig, Dr. Anton Worobei
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1012: Laboratory of Logistics Engineering and Automatisation

Courses

Title	Typ	Hrs/wk	CP
Laboratory Technical Logistics and Automatisation (L1462)	Seminar	4	6

Module Responsible	Prof. Jochen Kreutzfeldt
Admission Requirements	None
Recommended Previous Knowledge	Bachelor degree in logistics Basics of object-oriented programming language, for example python or Java.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students will acquire the following knowledge: 1. The students know the basic concepts of machine learning (supervised learning, unsupervised learning, reinforcement learning). 2. The students know the necessary steps to implement machine learning models in python. 3. The students know the approaches and hurdles for implementing machine learning in logistics.
Skills	The students will acquire the following skills: 1. The students are able to select technical solutions of machine learning for logistical problems of warehousing, conveying, sorting, order picking and identifying and evaluate the implementability of the alternatives. 2. The students are able to implement selected solutions of machine learning on a model scale. 3. The students are able to estimate the implementation costs of selected solutions of machine learning.
Personal Competence	
Social Competence	The students will acquire the following social skills: 1. The students are able to develop technical solutions for logistical problems and implement them on a model scale within a group of students. 2. The technical solutions from the group can be jointly documented and presented to an audience. 3. The students are able to derive new ideas and improvements from the feedback received related to their developed solution proposals.
Autonomy	The students will acquire the following competencies: 1. Students are able, under the guidance of supervisors, to develop and implement independently solutions of machine learning for logistical problems of warehousing, conveying, sorting, order picking and identifying. 2. The students are able to evaluate their technical solutions and discuss the pros and cons.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Prototype construction in laboratory with documentation (group work)
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Logistics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory

Course L1462: Laboratory Technical Logistics and Automatisation	
Typ	Seminar
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Jochen Kreutzfeldt
Language	DE
Cycle	SoSe
Content	The aim of the seminar is the practical introduction of students in various technical solutions to logistical problems. Above all, the guided development of own solutions is the core task in the laboratory. The problems and solutions will be drawn from the following logistic topics: (1) warehousing (2) conveying (3) sorting (4) order picking (5) identifying The students develop technical solutions in small groups for selected problems and implement them on a lab scale. The solutions are presented to an audience and advantages and disadvantages are discussed. The recorded feedback is then added to the model solution.
Literature	Dembowski, Klaus (2015): Raspberry Pi - Das technische Handbuch. Konfiguration, Hardware, Applikationserstellung. 2., erw. und überarb. Aufl. 2015. Wiesbaden: Springer Vieweg. Follmann, Rüdiger (2014): Das Raspberry Pi Kompendium. 2014. Aufl. Berlin, Heidelberg: Springer Berlin Heidelberg (Xpert.press). Griemert, Rudolf (2015): Fördertechnik. Auswahl und Berechnung von Elementen und Baugruppen. [S.l.]: Morgan Kaufmann. Hompel, Michael ten; Büchter, Hubert; Franzke, Ulrich (2008): Identifikationssysteme und Automatisierung. [Intralogistik]. Berlin, Heidelberg: Springer. Hompel, Michael ten; Beck, Maria; Sadowsky, Volker (2011): Kommissionierung. Materialflusssysteme 2 - Planung und Berechnung der Kommissionierung in der Logistik. Berlin [u.a.]: Springer. Jodin, Dirk; Hompel, Michael ten (2012): Sortier- und Verteilsysteme. Grundlagen, Aufbau, Berechnung und Realisierung. 2. Aufl. Berlin: Springer Berlin. Martin, Heinrich (2014): Transport- und Lagerlogistik. Planung, Struktur, Steuerung und Kosten von Systemen der Intralogistik. 9., vollst. überarb. u. akt. Aufl. 2014. Wiesbaden: Imprint: Springer Vieweg. Purdum, Jack J. (2014): Beginning C for Arduino. Learn C programming for the Arduino. Second edition.: Springer Berlin. McRoberts, Michael (2014): Beginning Arduino. Second edition.: Springer Berlin.

Module M1100: Railways

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Railways (L1466)	Lecture	2	3
Railways (L1468)	Recitation Section (large)	2	3

Module Responsible	Prof. Carsten Gertz
Admission Requirements	None
Recommended Previous Knowledge	Introduction to railways
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can... • concieve the entrepreneurial perspective of transport and infrastructure companies • estimate intra- and intermodal competition • understand regulatory and transport policy determinants • reflect megatrends in the transport market • understand the key performance indicators for railway transport market
Skills	Students can... • apply traffic Intermodal perspective • understand strategic challenges, opportunities and issues of companies • recognize the relevance of sustainability and digitization for companies
Personal Competence	
Social Competence	Students can... • discuss and organize task packages in small groups • document and present work results in small groups
Autonomy	Students can... • research and select literature • submit their own shares of an extensive written work in small groups and present it collaborativly within a fixed time frame
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	written assignment as groupwork with presentation during the semester
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L1466: Railways

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Carsten Gertz, Maximilian Philip Freude
Language	DE
Cycle	WiSe
Content	
Literature	

Course L1468: Railways

Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Carsten Gertz, Maximilian Philip Freude
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1402: Machine Learning in Logistics

Courses

Title	Typ	Hrs/wk	CP
Digitalization in Traffic and Logistics (L2004)	Lecture	1	2
Basics of Machine Learning (L2003)	Lecture	1	2
Machine Learning in Logistics (L2005)	Recitation Section (small)	2	2

Module Responsible	Prof. Carlos Jahn
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students understand specific methods of machine learning. They are able to select appropriate procedures for given data. They can explain the principals of different learning methods. In addition, they can explain the major conceptual differences of learning methods.
Skills	Students can inspect, describe, and apply selected machine learning techniques to provided data sets. Additionally they can prepare raw data for machine learning algorithms. They are able to evaluate the usability in concrete company-relevant contexts and they know how to derive the requirements and potentials of an effective application, e.g. in relation to controlling or forecasting for the operational planning of companies or other organizations.
Personal Competence	
Social Competence	Students are capable of: • Discussing and organizing extensive research tasks in small groups • Jointly describing, differentiating between and evaluating problems
Autonomy	Students are able: • To research and select specialized literature • Read existing code, interpret it and modify it for new tasks
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 15 % / Presentation
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L2004: Digitalization in Traffic and Logistics	
Typ	Lecture
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Carlos Jahn
Language	DE
Cycle	WiSe
Content	When dealing with large amounts of data (big data), it is no longer possible for humans to spot all relevant data by simply looking at the raw data. In the co logistics, the handling of temporal data and movement data plays a particularly important role. In this course the visualization, the calculation of statistics, application of machine learning algorithms are covered. Students are given various tools for later practical application. The course utilizes the machine learning methods learned in "Basics of Machine Learning". These are used and evaluated in the context of practical application in of traffic and logistics. In addition, various pre-processing steps for raw data are presented and it is discussed, under which conditions these measurements are ap The lecture contents are: • The project structure for Machine Learning in science and industry • Use cases for machine learning in logistics • Image recognition in road traffic • Temporal data in traffic • Movement data • Automated anomaly detection
Literature	• Aggarwal, Charu C. (2017). Outlier Analysis. Springer International Publishing Switzerland. • Chapman, Peter and Clinton, Janet and Kerber, Randy and Khabaza, Tom and Reinartz, Thomas and Russel H. Shearer, C and Wirth, Robert (2000). DM 1.0 : Step-by-step data mining guide. • Géron, Aurélien (2018). Praxiseinstieg Machine Learning mit Scikit-Learn und TensorFlow: Konzepte, Tools und Techniken für intelligente Systeme. O'Reilly. • Haneke, Uwe and Trahasch, Stephan and Zimmer, Michael and Felden, Carsten (2019). Data Science - Grundlagen, Architekturen und Anwendungen. dpunk • Lenzen, Manuela (2020). Künstliche Intelligenz: Fakten, Chancen, Risiken. C.H. Beck. • VanderPlas, Jake (2017). Data Science mit Python : das Handbuch für den Einsatz von IPython, Jupyter, NumPy, Pandas, Matplotlib, Scikit-Learn. MITP.

Course L2003: Basics of Machine Learning	
Typ	Lecture
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Sibylle Schupp
Language	DE
Cycle	WiSe

Content	Students are able to understand specific procedures of machine learning and to use on real life examples. Students are able to use appropriate procedures for given data.
	
	Students are able to explain the differences between instance and model based learning approaches and are able to use specific approaches in machine learning on the base of static and incremental growing data.
	
	By the use of uncertainty the students can explain how axioms, parameter or structures can be learned. Additional the students learn to develop different cluster techniques.
	
	Planned content:
	• Supervised Learning:
	  ◦ Regressions
	  ◦ Decision trees
	  ◦ Bayesian networks
	  ◦ K-next neighbors
	  ◦ Logistical regressions
	  ◦ Neuronal Networks
	  ◦ Support Vector Machines
	  ◦ Ensemble Learning
	• Unsupervised Learning:
	  ◦ Hierarchical Clustering, K-Mean

Literature	John D. Kelleher, Fundamentals of Machine Learning for Predictive Data Analytics: Algorithms, Worked Examples, and Case Studies (MIT Press) Tom M. Mitchell, Machine Learning Kevin P. Murphy, Machine Learning: A Probabilistic Perspective

Course L2005: Machine Learning in Logistics	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Carlos Jahn
Language	DE
Cycle	WiSe
Content	In the exercise, the skills which the students acquired in the lectures will be applied to real life examples.
Literature	• Aggarwal, Charu C. (2017). Outlier Analysis. Springer International Publishing Switzerland. • Chapman, Peter and Clinton, Janet and Kerber, Randy and Khabaza, Tom and Reinartz, Thomas and Russel H. Shearer, C and Wirth, Robert (2000). DM 1.0 : Step-by-step data mining guide. • Géron, Aurélien (2018). Praxiseinstieg Machine Learning mit Scikit-Learn und TensorFlow: Konzepte, Tools und Techniken für intelligente Systeme. O'Reilly. • Haneke, Uwe and Trahasch, Stephan and Zimmer, Michael and Felden, Carsten (2019). Data Science - Grundlagen, Architekturen und Anwendungen. dpunk • Kelleher, John D. (2015) Fundamentals of Machine Learning for Predictive Data Analytics: Algorithms, Worked Examples, and Case Studies. MIT Press. • Mitchell, Tom M. (2005) Machine Learning. McGraw-Hill. • Murphy, Kevin P. (2012) Machine Learning: A Probabilistic Perspective. MIT Press. • VanderPlas, Jake (2017). Data Science mit Python : das Handbuch für den Einsatz von IPython, Jupyter, NumPy, Pandas, Matplotlib, Scikit-Learn. MIT Press.

Module M0739: Factory Planning & Production Logistics

Courses

Title	Typ	Hrs/wk	CP
Factory Planning (L1445)	Lecture	3	3
Production Logistics (L1446)	Lecture	2	3

Module Responsible	Prof. Jochen Kreutzfeldt
Admission Requirements	None
Recommended Previous Knowledge	Bachelor degree in logistics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students will acquire the following knowledge: 1. The students know the latest trends and developments in the planning of factories. 2. The students can explain basic procedures of factory planning and are able to deploy these procedures while considering different conditions. 3. The students know different methods of factory planning and are able to deal critically with these methods.
Skills	The students will acquire the following skills: 1. The students are able to analyze factories and other material flow systems with regard to new development and the need for change of these logistical systems. 2. The students are able to plan and redesign factories and other material handling systems. 3. The students are able to develop procedures for the implementation of new and revised material flow systems.
Personal Competence	
Social Competence	The students will acquire the following social skills: 1. The students are able to develop plans for the development of new and improvement of existing material flow systems within a group. 2. The developed planning proposal from the group work can be documented and presented together. 3. The students are able to derive suggestions for improvement from the feedback on the planning proposals and can even provide constructive criticism themselves.
Autonomy	The students will acquire the following independent competencies: 1. The students can plan and re-design material flow systems using existing planning procedures. 2. The students can evaluate independently the strengths and weaknesses of several techniques for factory planning and choose appropriate methods in a given context. 3. The students are able to carry out autonomously new plans and transformations of material flow systems.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L1445: Factory Planning	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Jochen Kreutzfeldt
Language	DE
Cycle	WiSe
Content	The lecture gives an introduction into the planning of factories and material flows. The students will learn process models and methods to plan new factories and improve existing material flow systems. The course includes three basic topics: (1) Analysis of factory and material flow systems (2) Development and re-planning of factory and material flow systems (3) Implementation and realization of factory planning The students are introduced into several different methods and models per topic. Practical examples and planning exercises deepen the methods and explain the application of factory planning. The special requirements of factory planning in an international context are discussed. Specific requirements of Current trends and issues in the factory planning round off the lecture.
Literature	Bracht, Uwe; Wenzel, Sigrid; Geckler, Dieter (2018): Digitale Fabrik: Methoden und Praxisbeispiele. 2. Aufl.: Springer, Berlin. Helbing, Kurt W. (2010): Handbuch Fabrikprojektierung. Berlin, Heidelberg: Springer Berlin Heidelberg. Lotter, Bruno; Wiendahl, Hans-Peter (2012): Montage in der industriellen Produktion: Optimierte Abläufe, rationelle Automatisierung. 2. Aufl.: Springer, Berlin. Müller, Egon; Engelmann, Jörg; Löffler, Thomas; Jörg, Strauch (2009): Energieeffiziente Fabriken planen und betreiben. Berlin, Heidelberg: Springer Berlin Heidelberg. Schenk, Michael; Müller, Egon; Wirth, Siegfried (2014): Fabrikplanung und Fabrikbetrieb. Methoden für die wandlungsfähige, vernetzte und ressourceneffiziente Fabrik. 2. Aufl. Berlin [u.a.]: Springer Vieweg. Wiendahl, Hans-Peter; Reichardt, Jürgen; Nyhuis, Peter (2014): Handbuch Fabrikplanung: Konzept, Gestaltung und Umsetzung wandlungsfähiger Produktionsstätten. 2. Aufl. Carl Hanser Verlag.

Course L1446: Production Logistics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dipl.-Ing. Arnd Schirrmann
Language	DE
Cycle	WiSe
Content	• Introduction: situation, significance and main innovation focuses of logistics in a production company, aspects of procurement, production, distribution and disposal logistics, production and transport networks • Logistics as a production strategy: logistics-oriented method of working in a factory, throughput time, corporate strategy, structured networking, reducing complexity, integrated organization, integrated product and production logistics (IPPL) • Logistics-compatible production and process structuring; logistics-compatible product, material flow, information and organizational structures • Logistics-oriented production control: situation and development tendencies, logistics and cybernetics, market-oriented production planning, control, monitoring, PPS systems and production control, cybernetic production organization and control, production logistics control systems. • Production logistics planning: key performance indicators, developing a production logistics concept, computerized aids to planning production logistics, IPPL functions, economic efficiency of logistics projects • Production logistics controlling: production logistics and controlling, material flow-oriented cost transparency, cost controlling (process cost accounting, costs model in IPPL), process controlling (integrated production system, methods and tools, MEPOT.net method portal)
Literature	Pawellek, G.: Produktionslogistik: Planung - Steuerung - Controlling. Carl Hanser Verlag 2007

Module M1739: Operational Aspekts in Aviation

Courses

Title	Typ	Hrs/wk	CP
Airline Operations (L1310)	Lecture	3	3
Flight Guidance I (Introduction) (L0848)	Lecture	2	2
Flight Guidance I (Introduction) (L0854)	Recitation Section (large)	1	1
Airport Operations (L1276)	Lecture	3	3
Airport Planning (L1275)	Lecture	2	2
Airport Planning (L1469)	Recitation Section (small)	1	1
Aviation and Environment (L2376)	Lecture	3	3

Module Responsible	Prof. Volker Gollnick
Admission Requirements	None
Recommended Previous Knowledge	Air Transportation Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Analysis and description of the interaction between people and aircraft in operation
Skills	Understanding and application of design and calculation methods Understanding of interdisciplinary and integrative interdependencies Evaluation of operational issues in aviation and development of operational solution options
Personal Competence	
Social Competence	Working in teams for focused solutions communication, assertiveness, technical persuasion
Autonomy	Organisation of worksflows and strategies for solutions structured task analysis and definition of solutions
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Data Science: Specialisation III. Applications: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L1310: Airline Operations

Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick, Dr. Karl Echtermeyer
Language	DE
Cycle	SoSe
Content	1. Introdution and overview 2. Airline business models 3. Interdependencies in flight planning (network management, slot management, netzwork structures, aircraft circulation) 4. Operative flight preparation (weight & balance, payload/range, etc.) 5. fleet policy 6. Aircraft assessment and fleet planning 7. Airline organisation 8. Aircraft maintenance, repair and overhaul
Literature	Volker Gollnick, Dieter Schmitt: The Air Transport System, Springer Berlin Heidelberg New York, 2014 Paul Clark: “Buying the Big Jets”, Ashgate 2008 Mike Hirst: The Air Transport System, AIAA, 2008

Course L0848: Flight Guidance I (Introduction)	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	Introduction and motivation Flight guidance principles (airspace structures, organization of air navigation services, etc.) Cockpit systems and Avionics (cockpit design, cockpit equipment, displays, computers and bus systems) Principles of flight measurement techniques (Measurement of position (geometric methods, distance measurement, direction measurement) Determination of the aircraft attitude (magnetic field- and inertial sensors) Measurement of speed Principles of Navigation Radio navigation Satellite navigation Airspace surveillance (radar systems) Commuication systems Integrated Navigation and Guidance Systems
Literature	Rudolf Brockhaus, Robert Luckner, Wolfgang Alles: "Flugregelung", Springer Berlin Heidelberg New York, 2011 Holger Flühr: "Avionik und Flugsicherungssysteme", Springer Berlin Heidelberg New York, 2013 Volker Gollnick, Dieter Schmitt "Air Transport Systems", Springer Berlin Heidelberg New York, 2016 R.P.G. Collinson „Introduction to Avionics", Springer Berlin Heidelberg New York 2003

Course L0854: Flight Guidance I (Introduction)	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1276: Airport Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick, Dr. Peter Willems
Language	DE
Cycle	WiSe
Content	FA-F Flight Operations Flight Operations - Production Infrastructures Operations Planning Master plan Airport capacity Ground handling Terminal operations
Literature	Richard de Neufville, Amedeo Odoni: Airport Systems, McGraw Hill, 2003

Course L1275: Airport Planning	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Häp
Language	DE
Cycle	WiSe
Content	1. Introduction, definitions, overviewg 2. Runway systems 3. Air space strucutres around airports 4. Airfield lightings, marking and information 5. Airfield and terminal configuration
Literature	N. Ashford, Martin Stanton, Clifton Moore: Airport Operations, John Wiley & Sons, 1991 Richard de Neufville, Amedeo Odoni: Airport Systems, Aviation Week Books, MacGraw Hill, 2003

Course L1469: Airport Planning	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Häp
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L2376: Aviation and Environment	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe

Content	The lecture provides the necessary basics and methods for understanding the interactions between air traffic and the environment, both in terms of the effects of weather / climate on flying and with regard to the effects of air traffic on pollutant emissions, noise and climate.
	
	The following topics are covered:
	
	• Atmospheric physics / chemistry
	    ◦ Structure and statics
	    ◦ Dynamics (water cycle, formation of weather events, high and low pressure areas, wind, gusts and turbulence)
	    ◦ Cloud physics (thermodynamics, contrails)
	    ◦ Radiation physics (energy balance, greenhouse effect)
	    ◦ Photochemistry (ozone chemistry)
	• Impact of weather on flying
	    ◦ Atmospheric influences on flight performance
	    ◦ Flight planning
	    ◦ Disturbances due to weather, e.g. thunderstorms, winter weather (icing), clear air turbulence, visibility
	    ◦ Effects of climate change and adaptation
	• Effects of air traffic on the environment and climate
	    ◦ Aviation pollutant emissions
	    ◦ Effect of emissions on concentrations in the atmosphere
	    ◦ Climate metrics / models and background scenarios
	    ◦ Emissions inventories
	• Mitigation measures
	    ◦ Technological measures, e.g. climate-optimized aircraft design
	    ◦ Alternative fuels
	    ◦ Operational measures, e.g. climate-optimized flight planning
	    ◦ Environmental policy measures, e.g. EU-ETS, CORSIA
	    ◦ Potentials and comparison, concept of eco-efficiency
	• Local environmental impacts
	    ◦ Local air quality (particulate matter, other emissions near the ground)
	    ◦ Noise (noise sources, noise metrics, noise impact, measurement, certification, psychoacoustics, noise mitigation)
	    ◦ Health effects
	• Aspects of sustainability
	    ◦ Other aspects, including life cycle emissions, disposal/recycling
	    ◦ Relation to global goals, e.g. United Nations goals for sustainable development, Paris climate agreement

Literature	• Ruijgrok, G.: Elements of Aircraft Pollution, Delft University Press, 2005 • Friedrich, R., Reis, S.: Emissions of Air Pollutants, Springer 2004 • Janic, M.: The Sustainability of Air Transportation, Ashgate, 2007 • Schumann, U. (ed.): Atmospheric Physics: Background - Methods - Trends, Springer, Berlin, Heidelberg, 2012 • Spiridonov, V., Curic, M.: Fundamentals of Meteorology, Springer, 2021 • Kaltschmitt, M., Neuling, U.: Biokerosene - Status and Prospects, Springer, 2018 • Roedel, W., Wagner, T.: Physik unserer Umwelt: Die Atmosphäre, Springer, 2017 • W. Bräunling: Flugzeugtriebwerke. Springer-Verlag Berlin, Deutschland, 2009 • G. Brüning, X. Hafer, G. Sachs: Flugleistungen, Springer, 1993

Specialization II. Aviation Systems

Module M0805: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)

Courses

Title	Typ	Hrs/wk	CP
Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) (L0516)	Lecture	2	3
Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) (L0518)	Recitation Section (large)	2	3

Module Responsible	Prof. Benedikt Kriegesmann
Admission Requirements	None
Recommended Previous Knowledge	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students possess an in-depth knowledge in acoustics regarding acoustic waves, noise protection, and psycho acoustics and are able to give an overview of the corresponding theoretical and methodical basis.
Skills	The students are capable to handle engineering problems in acoustics by theory-based application of the demanding methodologies and measurement procedures treated within the module.
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	The students are able to independently solve challenging acoustical problems in the areas treated within the module. Possible conflicting issues and limitations can be identified and the results are critically scrutinized.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0516: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)

Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr.-Ing. Sören Keuchel
Language	EN
Cycle	SoSe
Content	- Introduction and Motivation - Acoustic quantities - Acoustic waves - Sound sources, sound radiation - Sound engergy and intensity - Sound propagation - Signal processing - Psycho acoustics - Noise - Measurements in acoustics
Literature	Cremer, L.; Heckl, M. (1996): Körperschall. Springer Verlag, Berlin Veit, I. (1988): Technische Akustik. Vogel-Buchverlag, Würzburg Veit, I. (1988): Flüssigkeitsschall. Vogel-Buchverlag, Würzburg

Course L0518: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr.-Ing. Sören Keuchel
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1156: Systems Engineering

Courses

Title	Typ	Hrs/wk	CP
Systems Engineering (L1547)	Lecture	3	4
Systems Engineering (L1548)	Recitation Section (large)	1	2

Module Responsible	Prof. Ralf God
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Aircraft Cabin Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • understand systems engineering process models, methods and tools for the development of complex Systems • describe innovation processes and the need for technology Management • explain the aircraft development process and the process of type certification for aircraft • explain the system development process, including requirements for systems reliability • identify environmental conditions and test procedures for airborne Equipment • value the methodology of requirements-based engineering (RBE) and model-based requirements engineering (MBRE)
Skills	Students are able to: • plan the process for the development of complex Systems • organize the development phases and development Tasks • assign required business activities and technical Tasks • apply systems engineering methods and tools
Personal Competence	
Social Competence	Students are able to: • understand and accept their tasks within a development team • be comfortable with their role their tasks within the overall process • understand and serve their suppliers and customers in large projects • assume responsibility for people and technology in the development of safety-critical systems
Autonomy	Students are able to: • interact and communicate in a development team with division of tasks. • independently research and identify certification specifications • formulate requirements on their own • create test plans on their own and accompany certification processes
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 Minutes
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Compulsory Mechatronics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L1547: Systems Engineering	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	The objective of the lecture with the corresponding exercise is to accomplish the prerequisites for the development and integration of complex systems using the example of commercial aircraft and cabin systems. Competences in the systems engineering process, tools and methods is to be achieved. Regulations, guidelines and certification issues will be known. Key aspects of the course are processes for innovation and technology management, system design, system integration and certification as well as tools and methods for systems engineering: • Innovation processes • IP-protection • Technology management • Systems engineering • Aircraft program • Certification issues • Systems development • Safety objectives and fault tolerance • Environmental and operating conditions • Tools for systems engineering • Requirements-based engineering (RBE) • Model-based requirements engineering (MBRE)
Literature	- Skript zur Vorlesung - diverse Normen und Richtlinien (EASA, FAA, RTCA, SAE) - Hauschildt, J., Salomo, S.: Innovationsmanagement. Vahlen, 5. Auflage, 2010 - NASA Systems Engineering Handbook, National Aeronautics and Space Administration, 2007 - Hinsch, M.: Industrielles Luftfahrtmanagement: Technik und Organisation luftfahrttechnischer Betriebe. Springer, 2010 - De Florio, P.: Airworthiness: An Introduction to Aircraft Certification. Elsevier Ltd., 2010 - Pohl, K.: Requirements Engineering. Grundlagen, Prinzipien, Techniken. 2. korrigierte Auflage, dpunkt.Verlag, 2008

Course L1548: Systems Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0721: Air Conditioning

Courses

Title	Typ	Hrs/wk	CP
Air Conditioning (L0594)	Lecture	3	5
Air Conditioning (L0595)	Recitation Section (large)	1	1

Module Responsible	Prof. Arne Speerforck
Admission Requirements	None
Recommended Previous Knowledge	Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know the different kinds of air conditioning systems for buildings and mobile applications and how these systems are controlled. They are familiar with the change of state of humid air and are able to draw the state changes in a h1+x,x-diagram. They are able to calculate the minimum airflow needed for hygienic conditions in rooms and can choose suitable filters. They know the basic flow pattern in rooms and are able to calculate the air velocity in rooms with the help of simple methods. They know the principles to calculate an air duct network. They know the different possibilities to produce cold and are able to draw these processes into suitable thermodynamic diagrams. They know the criteria for the assessment of refrigerants.
Skills	Students are able to configure air condition systems for buildings and mobile applications. They are able to calculate an air duct network and have the ability to perform simple planning tasks, regarding natural heat sources and heat sinks. They can transfer research knowledge into practice. They are able to perform scientific work in the field of air conditioning.
Personal Competence	
Social Competence	In lectures and exercises, the students can use many examples and experiments to discuss in small groups in a goal-oriented manner, develop a solution and present it. Within the exercises, the students can independently develop further questions and work out targeted solutions.
Autonomy	Students are able to define tasks independently, to develop the necessary knowledge themselves based on the knowledge they have received, and to use suitable means for implementation. In the exercises, the students discuss the methods taught in the lectures using complex tasks and critically analyze the results.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min
Assignment for the Following Curricula	Energy Systems: Specialisation Energy Systems: Elective Compulsory Energy Systems: Specialisation Marine Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0594: Air Conditioning	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Arne Speerforck, Prof. Gerhard Schmitz
Language	DE
Cycle	SoSe
Content	1. Overview 1.1 Kinds of air conditioning systems 1.2 Ventilating 1.3 Function of an air condition system 2. Thermodynamic processes 2.1 Psychrometric chart 2.2 Mixer preheater, heater 2.3 Cooler 2.4 Humidifier 2.5 Air conditioning process in a Psychrometric chart 2.6 Desiccant assisted air conditioning 3. Calculation of heating and cooling loads 3.1 Heating loads 3.2 Cooling loads 3.3 Calculation of inner cooling load 3.4 Calculation of outer cooling load 4. Ventilating systems 4.1 Fresh air demand 4.2 Air flow in rooms 4.3 Calculation of duct systems 4.4 Fans 4.5 Filters 5. Refrigeration systems 5.1. compression chillers 5.2Absorption chillers
Literature	• Schmitz, G.: Klimaanlagen, Skript zur Vorlesung • VDI Wärmeatlas, 11. Auflage, Springer Verlag, Düsseldorf 2013 • Herwig, H.; Moschallski, A.: Wärmeübertragung, Vieweg+Teubner Verlag, Wiesbaden 2009 • Recknagel, H.; Sprenger, E.; Schrammek, E.-R.: Taschenbuch für Heizung- und Klimatechnik 2013/2014, 76. Auflage, Deutscher Industrieverlag, 2013

Course L0595: Air Conditioning	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Arne Speerforck, Prof. Gerhard Schmitz
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1690: Aircraft Design II (Special Air Vehicle Design)

Courses

Title	Typ	Hrs/wk	CP
Aircraft Design II (Conceptual Design of Rotorcraft, special operations aircraft, UAV) (L0844)	Lecture	3	3
Aircraft Design II (Conceptual Design of Rotorcraft, special operations aircraft, UAV) (L0847)	Recitation Section (large)	2	3

Module Responsible	Prof. Volker Gollnick
Admission Requirements	None
Recommended Previous Knowledge	Aircraft Design I (Design of Transport Aircraft) Air Transportation Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Understanding of various flight systems and its special characteristics (supersonic aircraft, rotorcraft, high performance aircraft, unmanned air systems) Understanding of pro´s and con´s and physical characteristics of different air systems Understanding of special mission requirements and its impact on systems definition and conceptual design Intensified knowledge of performance design on various air systems
Skills	Understanding and application of design and calculation methods Understanding of interdisciplinary and integrative interdependencies mission oriented technical definition of air systems special conceptual calculation methods for special equipment characteristics assessment of different design solutions
Personal Competence	
Social Competence	Working in teams for focused solutions communication, assertiveness, technical persuasion
Autonomy	Organisation of worksflows and strategies for solutions structured task analysis and definition of solutions
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L0844: Aircraft Design II (Conceptual Design of Rotorcraft, special operations aircraft, UAV)

Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick, Dr. Bernd Liebhardt, Jens Thöben
Language	DE/EN
Cycle	SoSe
Content	1. Design of supersonic civil aircraft 2. Principles of high performance and special operations aircraft design 3. Principles of Rotorcraft Design 4. Principles of Unmanned Air Systems design, air taxis, electric aircraft
Literature	Gareth Padfield: Helicopter Flight Dynamics, butterworth ltd. Raymond Prouty: Helicopter Performance Stability and Control, Krieger Publ. Klaus Hünecke: Das Kampfflugzeug von Heute, Motorbuch Verlag Jay Gundelach: Designing Unmanned Aircraft Systems - Configurative Approach, AIAA

Course L0847: Aircraft Design II (Conceptual Design of Rotorcraft, special operations aircraft, UAV)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Volker Gollnick, Dr. Bernd Liebhardt, Jens Thöben
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0764: Flight Control Systems

Courses

Title	Typ	Hrs/wk	CP
Flight Control Systems (L0736)	Lecture	3	4
Flight Control Systems (L0740)	Recitation Section (large)	2	2

Module Responsible	Prof. Frank Thielecke
Admission Requirements	None
Recommended Previous Knowledge	basic knowledge of: • mathematics • mechanics • thermo dynamics • electronics • fluid mechanics • control theory
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to... • describe the structure and the functioning of primary flight control systems as well as actuation-, avionic-, high lift systems of aircrafts in general along with corresponding properties and applications. • give an overview over the functioning and the structure of landing gears and landing gear systems • explain different configurations and designs and their origins
Skills	Students are able to... • size primary flight control actuation systems • perform a controller design process for the flight control actuators • design high-lift systems and high-lift kinematics • size landing gear components
Personal Competence	
Social Competence	Students are able to: • Develop joint solutions in mixed teams • Present and explain developed solutions in front of other students • Discuss developed solutions with experts
Autonomy	Students are able to: • derive requirements and perform appropriate yet simplified design processes for aircraft systems from complex issues and circumstances in a self-reliant manner • apply new skills and methods in the context of exercises in a self-reliant manner
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	165 Minutes
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Aeronautics: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L0736: Flight Control Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	SoSe
Content	• Actuation (Principles of actuators; electro-mechanical actuators; modeling, analysis and sizing of position control systems; hydro-mechanic actuation systems) • Flight Control Systems (control surfaces, hinge moments; requirements of stability and controllability, actuation power; principles of reversible and irreversible flight control systems; servo actuation systems) • Landing Gear Systems (Configurations and geometries; analysis of landing gear systems with respect to damper dynamics, dynamics of the breaking aircraft and power consumption; design and analysis of breaking systems with respect to energy and heat; anti-skit systems) • Fuel Systems (Architectures; aviation fuels; system components; fueling system; tank inerting system; fuel management; trim tank) • De- and Anti-Ice Systems: (Atmospheric icing conditions; principles of de- and anti-ice systems)
Literature	• Moir, Seabridge: Aircraft Systems • Torenbek: Synthesis of Subsonic Airplane Design • Curry: Aircraft Landing Gear Design: Principles and Practices

Course L0740: Flight Control Systems	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0763: Aircraft Energy Systems

Courses

Title	Typ	Hrs/wk	CP
Aircraft Energy Systems (L0735)	Lecture	3	4
Aircraft Energy Systems (L0739)	Recitation Section (large)	2	2

Module Responsible	Prof. Frank Thielecke
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Fluid mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • Assess challenges during the design of aircraft energy systems • Describe essential components and design points of hydraulic and electrical supply systems • Give an overview of the functionality of air conditioning systems • Describe different system concepts for de-icing • Identify constraints for the electrification of aircraft systems, and evaluate possible concepts and limitations • Describe architectures for fuel supply systems and illustrate design examples • Explain possible approaches for the integration of fuel cell systems and evaluate zero-emission concepts
Skills	Students are able to: • Design hydraulic and electric supply systems of aircrafts • Analyze the thermodynamic behavior of air conditioning systems • Design ice protection systems • Apply possible electrification concepts to existing aircraft systems • Design fuel supply systems • Perform the design of a fuel cell system
Personal Competence	
Social Competence	Students are able to: • Perform system design in groups and present and discuss results • Present systems engineering problems and discuss solutions with experts
Autonomy	Students are able to: • Reflect on the content of lectures autonomously • Apply methods learned in the course of exercises to more advanced problems • Identify complex system dependencies autonomously and abstract simplified models and design processes
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	165 Minutes
Assignment for the Following Curricula	Energy Systems: Specialisation Energy Systems: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Aeronautics: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L0735: Aircraft Energy Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	WiSe
Content	• Hydraulic Energy Systems (Fluids; pressure loss in valves and pipes; components of hydraulic systems like pumps, valves, etc.; pressure/flow characteristics; actuators; tanks; power and heat balances; emergency power) • Electric Energy Systems (Generators; constant-speed-drives; DC and AC converters; electrical power distribution; bus systems; monitoring; load analysis) • High Lift Systems (Principles; investigation of loads and system actuation power; principles and sizing of actuation and positioning systems; safety requirements and devices) • Environmental Control Systems (Thermodynamic analysis; expansion and compression cooling systems; control strategies; cabin pressure control systems)
Literature	• Moir, Seabridge: Aircraft Systems • Green: Aircraft Hydraulic Systems • Torenbek: Synthesis of Subsonic Airplane Design • SAE1991: ARP; Air Conditioning Systems for Subsonic Airplanes

Course L0739: Aircraft Energy Systems	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0771: Flight Physics

Courses

Title	Typ	Hrs/wk	CP
Aerodynamics and Flight Mechanics I (L0727)	Lecture	3	3
Flight Mechanics II (L0730)	Lecture	2	2
Flight Mechanics II (L0731)	Recitation Section (large)	1	1

Module Responsible	Prof. Frank Thielecke
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Aviation
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to... • Describe the fundamental equations of aerodynamics for compressible, incompressible and frictional flow • Explain the principles of wings and profiles • Explain the aircraft equations of motion • Evaluate aircraft performance and stability • Describe the dynamics of the longitudinal and lateral motion • Describe methods of flight simulation and airborne measurement technology
Skills	Students are able to... • Perform flight mechanic simulations • Derive flight mechanic relations from virtual and real flight test data
Personal Competence	
Social Competence	Students are able to: • Perform simulations in groups and discuss results • Evaluate flight test data in groups, discuss and present the results
Autonomy	Students are able to: • Process teaching content independently • Prepare, work out and process simulation models independently • Apply teaching content on virtual and real flight test data
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	160 Minutes
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Aeronautics: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L0727: Aerodynamics and Flight Mechanics I	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Frank Thielecke, Dr. Sven Geisbauer
Language	DE
Cycle	WiSe
Content	• Aerodynamics (fundamental equations of aerodynamics; compressible and incompressible flows; airfoils and wings; viscous flows) • Flight Mechanics (Equations of motion; flight performance; control surfaces; derivatives; lateral stability and control; trim conditions; flight maneuvers)
Literature	• Schlichting, H.; Truckenbrodt, E.: Aerodynamik des Flugzeuges I und II • Etkin, B.: Dynamics of Atmospheric Flight • Sachs/Hafer: Flugmechanik • Brockhaus: Flugregelung • J.D. Anderson: Introduction to flight

Course L0730: Flight Mechanics II	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	SoSe
Content	• stationary asymmetric flight • dynamics of lateral movement • methods of flight simulation • eyperimental methods of flight mechanics • model validation using system identification • wind tunnel techniques
Literature	• Schlichting, H.; Truckenbrodt, E.: Aerodynamik des Flugzeuges I und II • Etkin, B.: Dynamics of Atmospheric Flight • Sachs/Hafer: Flugmechanik • Brockhaus: Flugregelung • J.D. Anderson: Introduction to flight

Course L0731: Flight Mechanics II	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0812: Aircraft Design I (Civil Aircraft Design)

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Aircraft Design I (Design of Transport Aircraft) (L0820)	Lecture	3	3
Aircraft Design I (Design of Transport Aircraft) (L0834)	Recitation Section (large)	2	3

Module Responsible	Prof. Volker Gollnick
Admission Requirements	None
Recommended Previous Knowledge	• Bachelor Mech. Eng. • Bachelor Traffic Systems • Vordiplom Mech. Eng. • Module Air Transport Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	1. Principle understanding of integrated and civil aircraft design 2. Understanding of the interactions and contributions of the various disciplines 3. Impact of the relevant design parameter on the civil aircraft design 4. Introduction of the principle design methods
Skills	Understanding and application of design and calculation methods Understanding of interdisciplinary and integrative interdependencies
Personal Competence	
Social Competence	Working in interdisciplinary teams Communication
Autonomy	Organization of workflows and -strategies
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** No · **Bonus** 10 % · **Form** Attestation · **Description** Durchführung einer Konzeptauslegung für ein Verkehrsflugzeug
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Aeronautics: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L0820: Aircraft Design I (Design of Transport Aircraft)

Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick, Jens Thöben
Language	DE
Cycle	WiSe
Content	Introduction into the aircraft design process 1. Introduction/process of aircraft design/various aircraft configurations 2. Requirements and design objectives, main design parameter (u.a. payload-range-diagramme) 3. Statistical methods in overall aircraft design/data base methods 4. Cabin design (fuselage sizing, cabin interior, loading systems) 5. Principles of aerodynamic aircraft design (polar, geometry, 2D/3D aerodynamics) 6. Wing Design 7. Tail wings and landing gear 8. Principles of engine design and integration 9. Flight performance in cruise 10. Take off and landing field length 11. Loads and V-n-diagramme 12. Operating cost calculation
Literature	J. Roskam: "Airplane Design" D.P. Raymer: "Aircraft Design - A Conceptual Approach" J.P. Fielding: "Introduction to Aircraft Design" Jenkinson, Simpkon, Rhods: "Civil Jet Aircraft Design"

Course L0834: Aircraft Design I (Design of Transport Aircraft)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Volker Gollnick, Jens Thöben
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1155: Aircraft Cabin Systems

Courses

Title	Typ	Hrs/wk	CP
Aircraft Cabin Systems (L1545)	Lecture	3	4
Aircraft Cabin Systems (L1546)	Recitation Section (large)	1	2

Module Responsible	Prof. Ralf God
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • describe cabin operations, equipment in the cabin and cabin Systems • explain the functional and non-functional requirements for cabin Systems • elucidate the necessity of cabin operating systems and emergency Systems • assess the challenges human factors integration in a cabin environment
Skills	Students are able to: • design a cabin layout for a given business model of an Airline • design cabin systems for safe operations • design emergency systems for safe man-machine interaction • solve comfort needs and entertainment requirements in the cabin
Personal Competence	
Social Competence	Students are able to: • comprehend existing system solutions and explain them on the basis of existing requirements • discuss with experts in technical language • explain system functions • classify the criticality of functions • describe systems as is
Autonomy	Students are able to: • independently reflect on lecture content and expert presentations • independently develop more in-depth content • recognize further areas of knowledge
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 Minutes
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Aeronautics: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L1545: Aircraft Cabin Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	The objective of the lecture with the corresponding exercise is the acquisition of knowledge about aircraft cabin systems and cabin operations. A basic understanding of technological and systems engineering effort to maintain an artificial but comfortable and safe travel and working environment at cruising altitude is to be achieved. The course provides a comprehensive overview of current technology and cabin systems in modern passenger aircraft. The Fulfillment of requirements for the cabin as the central system of work are covered on the basis of the topics comfort, ergonomics, human factors, operational processes, maintenance and energy supply: • Materials used in the cabin • Ergonomics and human factors • Cabin interior and non-electrical systems • Cabin electrical systems and lights • Cabin electronics, communication-, information- and IFE-systems • Cabin and passenger process chains • RFID Aircraft Parts Marking • Energy sources and energy conversion
Literature	- Skript zur Vorlesung - Jenkinson, L.R., Simpkin, P., Rhodes, D.: Civil Jet Aircraft Design. London: Arnold, 1999 - Rossow, C.-C., Wolf, K., Horst, P. (Hrsg.): Handbuch der Luftfahrzeugtechnik. Carl Hanser Verlag, 2014 - Moir, I., Seabridge, A.: Aircraft Systems: Mechanical, Electrical and Avionics Subsystems Integration, Wiley 2008 - Davies, M.: The standard handbook for aeronautical and astronautical engineers. McGraw-Hill, 2003 - Kompendium der Flugmedizin. Verbesserte und ergänzte Neuauflage, Nachdruck April 2006. Fürstenfeldbruck, 2006 - Campbell, F.C.: Manufacturing Technology for Aerospace Structural Materials. Elsevier Ltd., 2006

Course L1546: Aircraft Cabin Systems	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1691: Operational Aspekts in Aviation

Courses

Title	Typ	Hrs/wk	CP
Airline Operations (L1310)	Lecture	3	3
Flight Guidance I (Introduction) (L0848)	Lecture	2	2
Flight Guidance I (Introduction) (L0854)	Recitation Section (large)	1	1
Airport Operations (L1276)	Lecture	3	3
Airport Planning (L1275)	Lecture	2	2
Airport Planning (L1469)	Recitation Section (small)	1	1
Aviation and Environment (L2376)	Lecture	3	3

Module Responsible	Prof. Volker Gollnick
Admission Requirements	None
Recommended Previous Knowledge	Air Transportation Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Analysis and description of the interaction between people and aircraft in operation
Skills	Understanding and application of design and calculation methods Understanding of interdisciplinary and integrative interdependencies Evaluation of operational issues in aviation and development of operational solution options
Personal Competence	
Social Competence	Working in teams for focused solutions communication, assertiveness, technical persuasion
Autonomy	Organisation of worksflows and strategies for solutions structured task analysis and definition of solutions
Workload in Hours	Depends on choice of courses
Credit points	12
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L1310: Airline Operations

Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick, Dr. Karl Echtermeyer
Language	DE
Cycle	SoSe
Content	1. Introdution and overview 2. Airline business models 3. Interdependencies in flight planning (network management, slot management, netzwork structures, aircraft circulation) 4. Operative flight preparation (weight & balance, payload/range, etc.) 5. fleet policy 6. Aircraft assessment and fleet planning 7. Airline organisation 8. Aircraft maintenance, repair and overhaul
Literature	Volker Gollnick, Dieter Schmitt: The Air Transport System, Springer Berlin Heidelberg New York, 2014 Paul Clark: “Buying the Big Jets”, Ashgate 2008 Mike Hirst: The Air Transport System, AIAA, 2008

Course L0848: Flight Guidance I (Introduction)	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	Introduction and motivation Flight guidance principles (airspace structures, organization of air navigation services, etc.) Cockpit systems and Avionics (cockpit design, cockpit equipment, displays, computers and bus systems) Principles of flight measurement techniques (Measurement of position (geometric methods, distance measurement, direction measurement) Determination of the aircraft attitude (magnetic field- and inertial sensors) Measurement of speed Principles of Navigation Radio navigation Satellite navigation Airspace surveillance (radar systems) Commuication systems Integrated Navigation and Guidance Systems
Literature	Rudolf Brockhaus, Robert Luckner, Wolfgang Alles: "Flugregelung", Springer Berlin Heidelberg New York, 2011 Holger Flühr: "Avionik und Flugsicherungssysteme", Springer Berlin Heidelberg New York, 2013 Volker Gollnick, Dieter Schmitt "Air Transport Systems", Springer Berlin Heidelberg New York, 2016 R.P.G. Collinson „Introduction to Avionics", Springer Berlin Heidelberg New York 2003

Course L0854: Flight Guidance I (Introduction)	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1276: Airport Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick, Dr. Peter Willems
Language	DE
Cycle	WiSe
Content	FA-F Flight Operations Flight Operations - Production Infrastructures Operations Planning Master plan Airport capacity Ground handling Terminal operations
Literature	Richard de Neufville, Amedeo Odoni: Airport Systems, McGraw Hill, 2003

Course L1275: Airport Planning	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Häp
Language	DE
Cycle	WiSe
Content	1. Introduction, definitions, overviewg 2. Runway systems 3. Air space strucutres around airports 4. Airfield lightings, marking and information 5. Airfield and terminal configuration
Literature	N. Ashford, Martin Stanton, Clifton Moore: Airport Operations, John Wiley & Sons, 1991 Richard de Neufville, Amedeo Odoni: Airport Systems, Aviation Week Books, MacGraw Hill, 2003

Course L1469: Airport Planning	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Häp
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L2376: Aviation and Environment	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe

Content	The lecture provides the necessary basics and methods for understanding the interactions between air traffic and the environment, both in terms of the effects of weather / climate on flying and with regard to the effects of air traffic on pollutant emissions, noise and climate.
	
	The following topics are covered:
	
	• Atmospheric physics / chemistry
	  ◦ Structure and statics
	  ◦ Dynamics (water cycle, formation of weather events, high and low pressure areas, wind, gusts and turbulence)
	  ◦ Cloud physics (thermodynamics, contrails)
	  ◦ Radiation physics (energy balance, greenhouse effect)
	  ◦ Photochemistry (ozone chemistry)
	• Impact of weather on flying
	  ◦ Atmospheric influences on flight performance
	  ◦ Flight planning
	  ◦ Disturbances due to weather, e.g. thunderstorms, winter weather (icing), clear air turbulence, visibility
	  ◦ Effects of climate change and adaptation
	• Effects of air traffic on the environment and climate
	  ◦ Aviation pollutant emissions
	  ◦ Effect of emissions on concentrations in the atmosphere
	  ◦ Climate metrics / models and background scenarios
	  ◦ Emissions inventories
	• Mitigation measures
	  ◦ Technological measures, e.g. climate-optimized aircraft design
	  ◦ Alternative fuels
	  ◦ Operational measures, e.g. climate-optimized flight planning
	  ◦ Environmental policy measures, e.g. EU-ETS, CORSIA
	  ◦ Potentials and comparison, concept of eco-efficiency
	• Local environmental impacts
	  ◦ Local air quality (particulate matter, other emissions near the ground)
	  ◦ Noise (noise sources, noise metrics, noise impact, measurement, certification, psychoacoustics, noise mitigation)
	  ◦ Health effects
	• Aspects of sustainability
	  ◦ Other aspects, including life cycle emissions, disposal/recycling
	  ◦ Relation to global goals, e.g. United Nations goals for sustainable development, Paris climate agreement

Literature	• Ruijgrok, G.: Elements of Aircraft Pollution, Delft University Press, 2005 • Friedrich, R., Reis, S.: Emissions of Air Pollutants, Springer 2004 • Janic, M.: The Sustainability of Air Transportation, Ashgate, 2007 • Schumann, U. (ed.): Atmospheric Physics: Background - Methods - Trends, Springer, Berlin, Heidelberg, 2012 • Spiridonov, V., Curic, M.: Fundamentals of Meteorology, Springer, 2021 • Kaltschmitt, M., Neuling, U.: Biokerosene - Status and Prospects, Springer, 2018 • Roedel, W., Wagner, T.: Physik unserer Umwelt: Die Atmosphäre, Springer, 2017 • W. Bräunling: Flugzeugtriebwerke. Springer-Verlag Berlin, Deutschland, 2009 • G. Brüning, X. Hafer, G. Sachs: Flugleistungen, Springer, 1993

Module M1193: Cabin Systems Engineering

Courses

Title	Typ	Hrs/wk	CP
Computer and communication technology in cabin electronics and avionics (L1557)	Lecture	2	2
Computer and communication technology in cabin electronics and avionics (L1558)	Recitation Section (small)	1	1
Model-Based Systems Engineering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3

Module Responsible	Prof. Ralf God
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Systems Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • describe the structure and operation of computer architectures • explain the structure and operation of digital communication Networks • explain architectures of cabin electronics, integrated modular avionics (IMA) and Aircraft Data Communication Network (ADCN) • understand the approach of Model-Based Systems Engineering (MBSE) in the design of hardware and software-based cabin systems
Skills	Students are able to: • understand, operate and maintain a Minicomputer • build up a network communication and communicate with other network participants • connect a minicomputer with a cabin management system (A380 CIDS) and communicate over a AFDX®-Network • model system functions by means of formal languages SysML/UML and generate software code from the models • execute software code on a minicomputer
Personal Competence	
Social Competence	Students are able to: • form teams of two or small groups for the practical work • work out partial results themselves and combine them with others to form an overall solution • represent and contribute their own solution • take over the guidance of the team • contribute in the team
Autonomy	Students are able to: • organize and plan their practical tasks • further develop their own skills • take their own initiative • explore their own new ways of solving problems
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 minutes
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L1557: Computer and communication technology in cabin electronics and avionics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	The objective of the lecture with the corresponding exercise is the acquisition of knowledge of computer and communication technology in electronic systems in the cabin and in aircraft. For the system engineer the strong interaction of software, mechanical and electronic system components nowadays requires a basic understanding of cabin electronics and avionics. The course teaches the basics of design and functionality of computers and data networks. Subsequently it focuses on current principles and applications in integrated modular avionics (IMA), aircraft data communication networks (ADCN), cabin electronics and cabin networks: • History of computer and network technology • Layer model in computer technology • Computer architectures (PC, IPC, Embedded Systems) • BIOS, UEFI and operating system (OS) • Programming languages (machine code and high-level languages) • Applications and Application Programming Interfaces • External interfaces (serial, USB, Ethernet) • Layer model in network technology • Network topologies • Network components • Bus access procedures • Integrated Modular Avionics (IMA) and Aircraft Data Communication Networks (ADCN) • Cabin electronics and cabin networks
Literature	- Skript zur Vorlesung - Schnabel, P.: Computertechnik-Fibel: Grundlagen Computertechnik, Mikroprozessortechnik, Halbleiterspeicher, Schnittstellen und Peripherie. Books on Demand; 1. Auflage, 2003 - Schnabel, P.: Netzwerktechnik-Fibel: Grundlagen, Übertragungstechnik und Protokolle, Anwendungen und Dienste, Sicherheit. Books on Demand; 1. Auflage, 2004 - Wüst, K.: Mikroprozessortechnik: Grundlagen, Architekturen und Programmierung von Mikroprozessoren, Mikrocontrollern und Signalprozessoren. Vieweg Verlag; 2. aktualisierte und erweiterte Auflage, 2006

Course L1558: Computer and communication technology in cabin electronics and avionics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	The objective of the lecture with the corresponding exercise is the acquisition of knowledge of computer and communication technology in electronic systems in the cabin and in aircraft. For the system engineer the strong interaction of software, mechanical and electronic system components nowadays requires a basic understanding of cabin electronics and avionics. The course teaches the basics of design and functionality of computers and data networks. Subsequently it focuses on current principles and applications in integrated modular avionics (IMA), aircraft data communication networks (ADCN), cabin electronics and cabin networks: • History of computer and network technology • Layer model in computer technology • Computer architectures (PC, IPC, Embedded Systems) • BIOS, UEFI and operating system (OS) • Programming languages (machine code and high-level languages) • Applications and Application Programming Interfaces • External interfaces (serial, USB, Ethernet) • Layer model in network technology • Network topologies • Network components • Bus access procedures • Integrated Modular Avionics (IMA) and Aircraft Data Communication Networks (ADCN) • Cabin electronics and cabin networks
Literature	- Skript zur Vorlesung - Schnabel, P.: Computertechnik-Fibel: Grundlagen Computertechnik, Mikroprozessortechnik, Halbleiterspeicher, Schnittstellen und Peripherie. Books on Demand; 1. Auflage, 2003 - Schnabel, P.: Netzwerktechnik-Fibel: Grundlagen, Übertragungstechnik und Protokolle, Anwendungen und Dienste, Sicherheit. Books on Demand; 1. Auflage, 2004 - Wüst, K.: Mikroprozessortechnik: Grundlagen, Architekturen und Programmierung von Mikroprozessoren, Mikrocontrollern und Signalprozessoren. Vieweg Verlag; 2. aktualisierte und erweiterte Auflage, 2006

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	Objectives of the problem-oriented course are the acquisition of knowledge on system design using the formal languages SysML/UML, learning about tools for modeling and finally the implementation of a project with methods and tools of Model-Based Systems Engineering (MBSE) on a realistic hardware platform (e.g. Arduino®, Raspberry Pi®): • What is a model? • What is Systems Engineering? • Survey of MBSE methodologies • The modelling languages SysML /UML • Tools for MBSE • Best practices for MBSE • Requirements specification, functional architecture, specification of a solution • From model to software code • Validation and verification: XiL methods • Accompanying MBSE project
Literature	- Skript zur Vorlesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011

Module M1739: Operational Aspekts in Aviation

Courses

Title	Typ	Hrs/wk	CP
Airline Operations (L1310)	Lecture	3	3
Flight Guidance I (Introduction) (L0848)	Lecture	2	2
Flight Guidance I (Introduction) (L0854)	Recitation Section (large)	1	1
Airport Operations (L1276)	Lecture	3	3
Airport Planning (L1275)	Lecture	2	2
Airport Planning (L1469)	Recitation Section (small)	1	1
Aviation and Environment (L2376)	Lecture	3	3

Module Responsible	Prof. Volker Gollnick
Admission Requirements	None
Recommended Previous Knowledge	Air Transportation Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Analysis and description of the interaction between people and aircraft in operation
Skills	Understanding and application of design and calculation methods Understanding of interdisciplinary and integrative interdependencies Evaluation of operational issues in aviation and development of operational solution options
Personal Competence	
Social Competence	Working in teams for focused solutions communication, assertiveness, technical persuasion
Autonomy	Organisation of worksflows and strategies for solutions structured task analysis and definition of solutions
Workload in Hours	Depends on choice of courses
Credit points	6
Assignment for the Following Curricula	Data Science: Specialisation III. Applications: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L1310: Airline Operations

Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick, Dr. Karl Echtermeyer
Language	DE
Cycle	SoSe
Content	1. Introdution and overview 2. Airline business models 3. Interdependencies in flight planning (network management, slot management, netzwork structures, aircraft circulation) 4. Operative flight preparation (weight & balance, payload/range, etc.) 5. fleet policy 6. Aircraft assessment and fleet planning 7. Airline organisation 8. Aircraft maintenance, repair and overhaul
Literature	Volker Gollnick, Dieter Schmitt: The Air Transport System, Springer Berlin Heidelberg New York, 2014 Paul Clark: “Buying the Big Jets”, Ashgate 2008 Mike Hirst: The Air Transport System, AIAA, 2008

Course L0848: Flight Guidance I (Introduction)	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	Introduction and motivation Flight guidance principles (airspace structures, organization of air navigation services, etc.) Cockpit systems and Avionics (cockpit design, cockpit equipment, displays, computers and bus systems) Principles of flight measurement techniques (Measurement of position (geometric methods, distance measurement, direction measurement) Determination of the aircraft attitude (magnetic field- and inertial sensors) Measurement of speed Principles of Navigation Radio navigation Satellite navigation Airspace surveillance (radar systems) Commuication systems Integrated Navigation and Guidance Systems
Literature	Rudolf Brockhaus, Robert Luckner, Wolfgang Alles: "Flugregelung", Springer Berlin Heidelberg New York, 2011 Holger Flühr: "Avionik und Flugsicherungssysteme", Springer Berlin Heidelberg New York, 2013 Volker Gollnick, Dieter Schmitt "Air Transport Systems", Springer Berlin Heidelberg New York, 2016 R.P.G. Collinson „Introduction to Avionics", Springer Berlin Heidelberg New York 2003

Course L0854: Flight Guidance I (Introduction)	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1276: Airport Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick, Dr. Peter Willems
Language	DE
Cycle	WiSe
Content	FA-F Flight Operations Flight Operations - Production Infrastructures Operations Planning Master plan Airport capacity Ground handling Terminal operations
Literature	Richard de Neufville, Amedeo Odoni: Airport Systems, McGraw Hill, 2003

Course L1275: Airport Planning	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Häp
Language	DE
Cycle	WiSe
Content	1. Introduction, definitions, overviewg 2. Runway systems 3. Air space strucutres around airports 4. Airfield lightings, marking and information 5. Airfield and terminal configuration
Literature	N. Ashford, Martin Stanton, Clifton Moore: Airport Operations, John Wiley & Sons, 1991 Richard de Neufville, Amedeo Odoni: Airport Systems, Aviation Week Books, MacGraw Hill, 2003

Course L1469: Airport Planning	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Häp
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L2376: Aviation and Environment	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe

Content	The lecture provides the necessary basics and methods for understanding the interactions between air traffic and the environment, both in terms of the effects of weather / climate on flying and with regard to the effects of air traffic on pollutant emissions, noise and climate.
	
	The following topics are covered:
	
	• Atmospheric physics / chemistry
	    ◦ Structure and statics
	    ◦ Dynamics (water cycle, formation of weather events, high and low pressure areas, wind, gusts and turbulence)
	    ◦ Cloud physics (thermodynamics, contrails)
	    ◦ Radiation physics (energy balance, greenhouse effect)
	    ◦ Photochemistry (ozone chemistry)
	• Impact of weather on flying
	    ◦ Atmospheric influences on flight performance
	    ◦ Flight planning
	    ◦ Disturbances due to weather, e.g. thunderstorms, winter weather (icing), clear air turbulence, visibility
	    ◦ Effects of climate change and adaptation
	• Effects of air traffic on the environment and climate
	    ◦ Aviation pollutant emissions
	    ◦ Effect of emissions on concentrations in the atmosphere
	    ◦ Climate metrics / models and background scenarios
	    ◦ Emissions inventories
	• Mitigation measures
	    ◦ Technological measures, e.g. climate-optimized aircraft design
	    ◦ Alternative fuels
	    ◦ Operational measures, e.g. climate-optimized flight planning
	    ◦ Environmental policy measures, e.g. EU-ETS, CORSIA
	    ◦ Potentials and comparison, concept of eco-efficiency
	• Local environmental impacts
	    ◦ Local air quality (particulate matter, other emissions near the ground)
	    ◦ Noise (noise sources, noise metrics, noise impact, measurement, certification, psychoacoustics, noise mitigation)
	    ◦ Health effects
	• Aspects of sustainability
	    ◦ Other aspects, including life cycle emissions, disposal/recycling
	    ◦ Relation to global goals, e.g. United Nations goals for sustainable development, Paris climate agreement

Literature	• Ruijgrok, G.: Elements of Aircraft Pollution, Delft University Press, 2005 • Friedrich, R., Reis, S.: Emissions of Air Pollutants, Springer 2004 • Janic, M.: The Sustainability of Air Transportation, Ashgate, 2007 • Schumann, U. (ed.): Atmospheric Physics: Background - Methods - Trends, Springer, Berlin, Heidelberg, 2012 • Spiridonov, V., Curic, M.: Fundamentals of Meteorology, Springer, 2021 • Kaltschmitt, M., Neuling, U.: Biokerosene - Status and Prospects, Springer, 2018 • Roedel, W., Wagner, T.: Physik unserer Umwelt: Die Atmosphäre, Springer, 2017 • W. Bräunling: Flugzeugtriebwerke. Springer-Verlag Berlin, Deutschland, 2009 • G. Brüning, X. Hafer, G. Sachs: Flugleistungen, Springer, 1993

Specialization II. Mechatronics

Module M0752: Nonlinear Dynamics

Courses

Title	Typ	Hrs/wk	CP
Nonlinear Dynamics (L0702)	Integrated Lecture	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
Recommended Previous Knowledge	• Calculus • Linear Algebra • Engineering Mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to reflect existing terms and concepts in Nonlinear Dynamics and to develop and research new terms and concepts. • Students are able to denote and expand methods of modeling and analysis for nonlinear dynamical systems.
Skills	• Students are able to apply existing methods and procesures of Nonlinear Dynamics. • Students are able to develop novel methods and procedures for nonlinear dynamical systems.
Personal Competence	
Social Competence	• Students can analyze problems of nonlinear dynamics also in groups. • Students can achieve solution procedures for problems of nonlinear dynamical systems also in groups.
Autonomy	• Students are able to approach given research tasks on the basis of given methods individually. • Students are able to identify and follow up novel research tasks by themselves.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L0702: Nonlinear Dynamics

Typ	Integrated Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	SoSe

Content	Fundamentals of Nonlinear Dynamics
	• One dimensional problems
	  ◦ Linear Stability
	  ◦ Local Bifurcations
	  ◦ Synchronisation
	• Two dimensional problems
	  ◦ Limit Cycles
	  ◦ Global Bifurcations
	• Chaos
	  ◦ Lorenz Equations
	  ◦ Fractals and Strange Attractors
	  ◦ Predictability and Horizons

Literature	Steven Strogatz: Nonlinear Dynamics and Chaos.

Module M1143: Applied Design Methodology in Mechatronics

Courses

Title	Typ	Hrs/wk	CP
Applied Design Methodology in Mechatronics (L1523)	Lecture	2	2
Applied Design Methodology in Mechatronics (L1524)	Project-/problem-based Learning	3	4

Module Responsible	Prof. Thorsten Kern
Admission Requirements	None
Recommended Previous Knowledge	Basics of mechanical design, electrical design or computer-sciences
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Science-based working on interdisciplinary product design considering targeted application of specific product design techniques
Skills	Creative handling of processes used for scientific preparation and formulation of complex product design problems / Application of various product design techniques following theoretical aspects.
Personal Competence	
Social Competence	Students will solve and execute technical-scientific tasks from an industrial context in small design-teams with application of common, creative methodologies.
Autonomy	Students are enabled to optimize the design and development process according to the target and topic of the design Students are educated to operate in a development team Students learn about the right application of creative methods in engineering.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	30 min Presentation for a group design-work
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Product Development and Production: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L1523: Applied Design Methodology in Mechatronics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	SoSe
Content	• Systematic analysis and planning of the design process for products combining a multitude of disciplines • Structure of the engineering process with focus on engineering steps (task-definition, functional decomposition, physical principles, elements for solution, combination to systems and products, execution of design, component-tests, system-tests, product-testing and qualification/validation) • Creative methods (Basics, methods like lead-user-method, 6-3-5, BrainStorming, Intergalactic Thinking, ... - Applications in examples all around mechatronics topics) • Several design-supporting methods and tools (functional strcutures, GALFMOS, AEIOU-method, GAMPFT, simulation and its application, TRIZ, design for SixSigma, continous integration and testing, ...) • Evaluation and final selection of solution (technical and business-considerations, preference-matrix, pair-comparision), dealing with uncertainties, decision-making • Value-analysis • Derivation of architectures and architectural management • Project-tracking and -guidance (project-lead, guiding of employees, organization of multidisciplinary R&D departments, idea-identification, responsibilities and communication) • Project-execution methods (Scrum, Kanbaan, ...) • Presentation-skills • Questions of aesthetic product design and design for subjective requirements (industrial design, color, haptic/optic/acoustic interfaces) • Evaluation of selected methods at practical examples in small teams
Literature	• Definition folgt... • Pahl, G.; Beitz, W.; Feldhusen, J.; Grote, K.-H.: Konstruktionslehre: Grundlage erfolgreicher Produktentwicklung, Methoden und Anwendung, 7. Auflage, Springer Verlag, Berlin 2007 • VDI-Richtlinien: 2206; 2221ff

Course L1524: Applied Design Methodology in Mechatronics	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0605: Computational Structural Dynamics

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Computational Structural Dynamics (L0282)	Lecture	3	4
Computational Structural Dynamics (L0283)	Recitation Section (small)	1	2

Module Responsible	Prof. Alexander Düster
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of partial differential equations is recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to + give an overview of the computational procedures for problems of structural dynamics. + explain the application of finite element programs to solve problems of structural dynamics. + specify problems of computational structural dynamics, to identify them in a given situation and to explain their mathematical and mechanical background.
Skills	Students are able to + model problems of structural dynamics. + select a suitable solution procedure for a given problem of structural dynamics. + apply computational procedures to solve problems of structural dynamics. + verify and critically judge results of computational structural dynamics.
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups. + present and discuss their results in front of others. + give and accept professional constructive criticism.
Autonomy	Students are able to + assess their knowledge by means of exercises and E-Learning. + acquaint themselves with the necessary knowledge to solve research oriented tasks. + to transform the acquired knowledge to similar problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	2h
Assignment for the Following Curricula	Civil Engineering: Specialisation Computational Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory

Course L0282: Computational Structural Dynamics

Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Alexander Düster
Language	DE
Cycle	SoSe
Content	1. Motivation 2. Basics of dynamics 3. Time integration methods 4. Modal analysis 5. Fourier transform 6. Applications
Literature	[1] K.-J. Bathe, Finite-Elemente-Methoden, Springer, 2002. [2] J.L. Humar, Dynamics of Structures, Taylor & Francis, 2012.

Course L0283: Computational Structural Dynamics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Alexander Düster
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0633: Industrial Process Automation

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Industrial Process Automation (L0344)	Lecture	2	3
Industrial Process Automation (L0345)	Recitation Section (small)	2	3

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	mathematics and optimization methods principles of automata principles of algorithms and data structures programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can evaluate and assess discrete event systems. They can evaluate properties of processes and explain methods for process analysis. The students can compare methods for process modelling and select an appropriate method for actual problems. They can discuss scheduling methods in the context of actual problems and give a detailed explanation of advantages and disadvantages of different programming methods. The students can relate process automation to methods from robotics and sensor systems as well as to recent topics like 'cyberphysical systems' and 'industry 4.0'.
Skills	The students are able to develop and model processes and evaluate them accordingly. This involves taking into account optimal scheduling, understanding algorithmic complexity, and implementation using PLCs.
Personal Competence	
Social Competence	The students can independently define work processes within their groups, distribute tasks within the group and develop solutions collaboratively.
Autonomy	The students are able to assess their level of knowledge and to document their work results adequately.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** No · **Bonus** 10 % · **Form** Excercises · **Description**
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0344: Industrial Process Automation	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	- foundations of problem solving and system modeling, discrete event systems - properties of processes, modeling using automata and Petri-nets - design considerations for processes (mutex, deadlock avoidance, liveness) - optimal scheduling for processes - optimal decisions when planning manufacturing systems, decisions under uncertainty - software design and software architectures for automation, PLCs
Literature	J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012 Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010 Hrúz, Zhou: Modeling and Control of Discrete-event Dynamic Systems; Springer 2007 Li, Zhou: Deadlock Resolution in Automated Manufacturing Systems, Springer 2009 Pinedo: Planning and Scheduling in Manufacturing and Services, Springer 2009

Course L0345: Industrial Process Automation	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0746: Microsystem Engineering

Courses

Title	Typ	Hrs/wk	CP
Microsystem Engineering (L0680)	Lecture	2	4
Microsystem Engineering (L0682)	Project-/problem-based Learning	2	2

Module Responsible	Dr. Timo Lipka
Admission Requirements	None
Recommended Previous Knowledge	Basic courses in physics, mathematics and electric engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students know about the most important technologies and materials of MEMS as well as their applications in sensors and actuators.
Skills	Students are able to analyze and describe the functional behaviour of MEMS components and to evaluate the potential of microsystems.
Personal Competence	
Social Competence	Students are able to solve specific problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire particular knowledge using specialized literature and to integrate and associate this knowledge with other fields.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** No; **Bonus** 10 %; **Form** Presentation; **Description**
Examination	Written exam
Examination duration and scale	2h
Assignment for the Following Curricula	Electrical Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0680: Microsystem Engineering	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Dr. Timo Lipka
Language	EN
Cycle	WiSe
Content	Object and goal of MEMS Scaling Rules Lithography Film deposition Structuring and etching Energy conversion and force generation Electromagnetic Actuators Reluctance motors Piezoelectric actuators, bi-metal-actuator Transducer principles Signal detection and signal processing Mechanical and physical sensors Acceleration sensor, pressure sensor Sensor arrays System integration Yield, test and reliability
Literature	M. Kasper: Mikrosystementwurf, Springer (2000) M. Madou: Fundamentals of Microfabrication, CRC Press (1997)

Course L0682: Microsystem Engineering	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Timo Lipka
Language	EN
Cycle	WiSe
Content	Examples of MEMS components Layout consideration Electric, thermal and mechanical behaviour Design aspects
Literature	Wird in der Veranstaltung bekannt gegeben

Module M0751: Vibration Theory

Courses

Title	Typ	Hrs/wk	CP
Vibration Theory (L0701)	Integrated Lecture	4	6

Module Responsible	Prof. Norbert Hoffmann
Admission Requirements	None
Recommended Previous Knowledge	• Calculus • Linear Algebra • Engineering Mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• Students are able to denote terms and concepts of Vibration Theory and develop them further. • Students know methods of modeling and simulation for free, driven, self-excited and parameter driven vibrations. • Students know about concepts of linear and nonlinear vibration problems. • Students know basic tasks of vibration problems of discrete and continuous systems.
Skills	• Students are able to denote methods of Vibration Theory and develop them further. • Students are able to apply and expand methods of modeling and simulation for free, forced, self-excited and parameter driven vibrations. • Students are able to solve linear and nonlinear vibration problems.
Personal Competence	
Social Competence	• Students can analyze vibration problems, work on them, and reach working results also in teams or groups. • Students are able to document the results of vibration studies also in groups.
Autonomy	• Students are able to individually analyze and solve vibration problems. • Students are able to approach individually research tasks in Vibration Theory.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	2 Hours
Assignment for the Following Curricula	Energy Systems: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L0701: Vibration Theory

Typ	Integrated Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	WiSe
Content	Linear and Nonlinear Single and Multiple Degree of Freedom Vibrations • Free vibration • Self-excited vibration • Parameter driven vibration • Forced vibration • Multi degree of freedom vibration • Continuum vibration • Irregular vibration
Literature	German - K. Magnus, K. Popp, W. Sextro: Schwingungen. Physikalische Grundlagen und mathematische Behandlung von Schwingungen. English - K. Magnus: Vibrations.

Module M0808: Finite Elements Methods

Courses

Title	Typ	Hrs/wk	CP
Finite Element Methods (L0291)	Lecture	2	3
Finite Element Methods (L0804)	Recitation Section (large)	2	3

Module Responsible	Prof. Benedikt Kriegesmann
Admission Requirements	None
Recommended Previous Knowledge	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students possess an in-depth knowledge regarding the derivation of the finite element method and are able to give an overview of the theoretical and methodical basis of the method.
Skills	The students are capable to handle engineering problems by formulating suitable finite elements, assembling the corresponding system matrices, and solving the resulting system of equations.
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	The students are able to independently solve challenging computational problems and develop own finite element routines. Problems can be identified and the results are critically scrutinized.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** No · **Bonus** 20 % · **Form** Midterm · **Description**
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory

Course L0291: Finite Element Methods	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Benedikt Kriegesmann
Language	EN
Cycle	WiSe
Content	- General overview on modern engineering - Displacement method - Hybrid formulation - Isoparametric elements - Numerical integration - Solving systems of equations (statics, dynamics) - Eigenvalue problems - Non-linear systems - Applications - Programming of elements (Matlab, hands-on sessions) - Applications
Literature	Bathe, K.-J. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin

Course L0804: Finite Element Methods	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Benedikt Kriegesmann
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0768: Microsystems Technology in Theory and Practice

Courses

Title	Typ	Hrs/wk	CP
Microsystems Technology (L0724)	Lecture	2	4
Microsystems Technology (L0725)	Project-/problem-based Learning	2	2

Module Responsible	Prof. Hoc Khiem Trieu
Admission Requirements	None
Recommended Previous Knowledge	Basics in physics, chemistry, mechanics and semiconductor technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able • to present and to explain current fabrication techniques for microstructures and especially methods for the fabrication of microsensors and microactuators, as well as the integration thereof in more complex systems • to explain in details operation principles of microsensors and microactuators and • to discuss the potential and limitation of microsystems in application.
Skills	Students are capable • to analyze the feasibility of microsystems, • to develop process flows for the fabrication of microstructures and • to apply them.
Personal Competence	
Social Competence	Students are able to plan and carry out experiments in groups, as well as present and represent the results in front of others. These social skills are practiced both during the preparation phase, in which the groups work out and present the theory, and during the follow-up phase, in which the groups prepare, document and present their practical experiences.
Autonomy	The independence of the students is demanded and promoted in that they have to transfer and apply what they have learned to ever new boundary conditions. This requirement is communicated at the beginning of the semester and consistently practiced until the exam. Students are encouraged to work independently by not being given a solution, but by learning to work out the solution step by step by asking specific questions. Students learn to ask questions independently when they are faced with a problem. They learn to independently break down problems into manageable sub-problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** None; **Form** Subject theoretical and practical work; **Description** Studierenden führen in Kleingruppen ein Laborpraktikum durch. Jede Gruppe präsentiert und diskutiert die Theorie sowie die Ergebniise ihrer Labortätigkeit. vor dem gesamten Kurs.
Examination	Oral exam
Examination duration and scale	30 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Nanoelectronics and Microsystems Technology: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Microelectronics and Microsystems: Core Qualification: Elective Compulsory

Course L0724: Microsystems Technology	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	• Introduction (historical view, scientific and economic relevance, scaling laws) • Semiconductor Technology Basics, Lithography (wafer fabrication, photolithography, improving resolution, next-generation lithography, nano-imprinting, molecular imprinting) • Deposition Techniques (thermal oxidation, epitaxy, electroplating, PVD techniques: evaporation and sputtering; CVD techniques: APCVD, LPCVD, PECVD and LECVD; screen printing) • Etching and Bulk Micromachining (definitions, wet chemical etching, isotropic etch with HNA, electrochemical etching, anisotropic etching with KOH/TMAH: theory, corner undercutting, measures for compensation and etch-stop techniques; plasma processes, dry etching: back sputtering, plasma etching, RIE, Bosch process, cryo process, XeF2 etching) • Surface Micromachining and alternative Techniques (sacrificial etching, film stress, stiction: theory and counter measures; Origami microstructures, Epi-Poly, porous silicon, SOI, SCREAM process, LIGA, SU8, rapid prototyping) • Thermal and Radiation Sensors (temperature measurement, self-generating sensors: Seebeck effect and thermopile; modulating sensors: thermo resistor, Pt-100, spreading resistance sensor, pn junction, NTC and PTC; thermal anemometer, mass flow sensor, photometry, radiometry, IR sensor: thermopile and bolometer) • Mechanical Sensors (strain based and stress based principle, capacitive readout, piezoresistivity, pressure sensor: piezoresistive, capacitive and fabrication process; accelerometer: piezoresistive, piezoelectric and capacitive; angular rate sensor: operating principle and fabrication process) • Magnetic Sensors (galvanomagnetic sensors: spinning current Hall sensor and magneto-transistor; magnetoresistive sensors: magneto resistance, AMR and GMR, fluxgate magnetometer) • Chemical and Bio Sensors (thermal gas sensors: pellistor and thermal conductivity sensor; metal oxide semiconductor gas sensor, organic semiconductor gas sensor, Lambda probe, MOSFET gas sensor, pH-FET, SAW sensor, principle of biosensor, Clark electrode, enzyme electrode, DNA chip) • Micro Actuators, Microfluidics and TAS (drives: thermal, electrostatic, piezo electric and electromagnetic; light modulators, DMD, adaptive optics, microscanner, microvalves: passive and active, micropumps, valveless micropump, electrokinetic micropumps, micromixer, filter, inkjet printhead, microdispenser, microfluidic switching elements, microreactor, lab-on-a-chip, microanalytics) • MEMS in medical Engineering (wireless energy and data transmission, smart pill, implantable drug delivery system, stimulators: microelectrodes, cochlear and retinal implant; implantable pressure sensors, intelligent osteosynthesis, implant for spinal cord regeneration) • Design, Simulation, Test (development and design flows, bottom-up approach, top-down approach, testability, modelling: multiphysics, FEM and equivalent circuit simulation; reliability test, physics-of-failure, Arrhenius equation, bath-tub relationship) • System Integration (monolithic and hybrid integration, assembly and packaging, dicing, electrical contact: wire bonding, TAB and flip chip bonding; packages, chip-on-board, wafer-level-package, 3D integration, wafer bonding: anodic bonding and silicon fusion bonding; micro electroplating, 3D-MID)
Literature	M. Madou: Fundamentals of Microfabrication, CRC Press, 2002 N. Schwesinger: Lehrbuch Mikrosystemtechnik, Oldenbourg Verlag, 2009 T. M. Adams, R. A. Layton:Introductory MEMS, Springer, 2010 G. Gerlach; W. Dötzel: Introduction to microsystem technology, Wiley, 2008

Course L0725: Microsystems Technology	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Hoc Khiem Trieu
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1025: Fluidics

Courses

Title	Typ	Hrs/wk	CP
Fluidics (L1256)	Lecture	2	3
Fluidics (L1371)	Project-/problem-based Learning	1	2
Fluidics (L1257)	Recitation Section (large)	1	1

Module Responsible	Prof. Dieter Krause
Admission Requirements	None
Recommended Previous Knowledge	Good knowledge of mechanics (stereo statics, elastostatics, hydrostatics, kinematics and kinetics), fluid mechanics, and engineering design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After passing the module students are able to • explain structures and functionalities of hydrostatic, pneumatic, and hydrodynamic components, • explain the interaction of hydraulic components in hydraulic systems, • explain open and closed loop control of hydraulic systems, • describe functioning and applications of hydrodynamic torque converters, brakes and clutches as well as centrifugal pumps and aggregates in plant technology
Skills	After passing the module students are able to • analyse and assess hydraulic and pneumatic components and systems, • design and dimension hydraulic systems for mechanical applications, • perform numerical simulations of hydraulic systems based on abstract problem definitions, • select and adapt pump characteristic curves for hydraulic systems • dimension hydrodynamic torque converters and brakes for mechanical aggregates.
Personal Competence	
Social Competence	After passing the module students are able to • discuss and present functional context in groups, • organise teamwork autonomously.
Autonomy	After passing the module students are able to • obtain necessary knowledge for the simulation.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** Yes · **Bonus** None · **Form** Attestation · **Description** Simulation hydrostatischer Systeme
Examination	Written exam
Examination duration and scale	90
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L1256: Fluidics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	**Lecture** Hydrostatics • physical fundamentals • hydraulic fluids • hydrostatic machines • valves • components • hydrostatic transmissions • examples from industry Pneumatics • generation of compressed air • pneumatic motors • Examples of use Hydrodynamics • physical fundamentals • hydraulic continous-flow machines • hydrodynamic transmissions • interoperation of motor and transmission **Exercise** Hydrostatics • reading and design of hydraulic diagrams • dimensioning of hydrostatic traction and working drives • performance calculation Hydrodynamics • calculation / dimensioning of hydrodynamic torque converters • calculation / dimensioning of centrifugal pumps • creating and reading of characteristic curves of pumps and systems Field trip • field trip to a regional company from the hydraulic industry. **Exercise** Numerical simulation of hydrostatic systems • getting to know a numerical simulation environment for hydraulic systems • transformation of a task into a simulation model • simulation of common components • variation of simulation parameters • using simulations for system dimensioning and optimisation • (partly) self-organised teamwork
Literature	Bücher • Murrenhoff, H.: Grundlagen der Fluidtechnik - Teil 1: Hydraulik, Shaker Verlag, Aachen, 2011 • Murrenhoff, H.: Grundlagen der Fluidtechnik - Teil 2: Pneumatik, Shaker Verlag, Aachen, 2006 • Matthies, H.J. Renius, K.Th.: Einführung in die Ölhydraulik, Teubner Verlag, 2006 • Beitz, W., Grote, K.-H.: Dubbel - Taschenbuch für den Maschinenbau, Springer-Verlag, Berlin, aktuelle Auflage Skript zur Vorlesung

Course L1371: Fluidics	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1257: Fluidics	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0563: Robotics

Courses

Title	Typ	Hrs/wk	CP
Robotics: Modelling and Control (L0168)	Integrated Lecture	4	4
Robotics: Modelling and Control (L1305)	Project-/problem-based Learning	2	2

Module Responsible	Dr. Martin Gomse
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of electrical engineering Broad knowledge of mechanics Fundamentals of control theory
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe fundamental properties of robots and solution approaches for multiple problems in robotics.
Skills	Students are able to derive and solve equations of motion for various manipulators. Students can generate trajectories in various coordinate systems. Students can design linear and partially nonlinear controllers for robotic manipulators.
Personal Competence	
Social Competence	Students are able to work goal-oriented in small mixed groups.
Autonomy	Students are able to recognize and improve knowledge deficits independently. With instructor assistance, students are able to evaluate their own knowledge level and define a further course of study.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory:** Yes; **Bonus:** None; **Form:** Subject theoretical and practical work; **Description:** Teilnahme an PBL-Einheiten sowie Erreichen des Gesamtziels und der jeweiligen Session-Ziele
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L0168: Robotics: Modelling and Control

Typ	Integrated Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Dr. Martin Gomse
Language	EN
Cycle	WiSe
Content	Fundamental kinematics of rigid body systems Newton-Euler equations for manipulators Trajectory generation Linear and nonlinear control of robots
Literature	Craig, John J.: Introduction to Robotics Mechanics and Control, Third Edition, Prentice Hall. ISBN 0201-54361-3 Spong, Mark W.; Hutchinson, Seth; Vidyasagar, M. : Robot Modeling and Control. WILEY. ISBN 0-471-64990-2

Course L1305: Robotics: Modelling and Control	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Martin Gomse
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Specialization II. Product Development and Production

Module M1143: Applied Design Methodology in Mechatronics

Courses

Title	Typ	Hrs/wk	CP
Applied Design Methodology in Mechatronics (L1523)	Lecture	2	2
Applied Design Methodology in Mechatronics (L1524)	Project-/problem-based Learning	3	4

Module Responsible	Prof. Thorsten Kern
Admission Requirements	None
Recommended Previous Knowledge	Basics of mechanical design, electrical design or computer-sciences
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Science-based working on interdisciplinary product design considering targeted application of specific product design techniques
Skills	Creative handling of processes used for scientific preparation and formulation of complex product design problems / Application of various product design techniques following theoretical aspects.
Personal Competence	
Social Competence	Students will solve and execute technical-scientific tasks from an industrial context in small design-teams with application of common, creative methodologies.
Autonomy	Students are enabled to optimize the design and development process according to the target and topic of the design Students are educated to operate in a development team Students learn about the right application of creative methods in engineering.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Subject theoretical and practical work
Examination duration and scale	30 min Presentation for a group design-work
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Product Development and Production: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L1523: Applied Design Methodology in Mechatronics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	SoSe
Content	• Systematic analysis and planning of the design process for products combining a multitude of disciplines • Structure of the engineering process with focus on engineering steps (task-definition, functional decomposition, physical principles, elements for solution, combination to systems and products, execution of design, component-tests, system-tests, product-testing and qualification/validation) • Creative methods (Basics, methods like lead-user-method, 6-3-5, BrainStorming, Intergalactic Thinking, ... - Applications in examples all around mechatronics topics) • Several design-supporting methods and tools (functional strcutures, GALFMOS, AEIOU-method, GAMPFT, simulation and its application, TRIZ, design for SixSigma, continous integration and testing, ...) • Evaluation and final selection of solution (technical and business-considerations, preference-matrix, pair-comparision), dealing with uncertainties, decision-making • Value-analysis • Derivation of architectures and architectural management • Project-tracking and -guidance (project-lead, guiding of employees, organization of multidisciplinary R&D departments, idea-identification, responsibilities and communication) • Project-execution methods (Scrum, Kanbaan, ...) • Presentation-skills • Questions of aesthetic product design and design for subjective requirements (industrial design, color, haptic/optic/acoustic interfaces) • Evaluation of selected methods at practical examples in small teams
Literature	• Definition folgt... • Pahl, G.; Beitz, W.; Feldhusen, J.; Grote, K.-H.: Konstruktionslehre: Grundlage erfolgreicher Produktentwicklung, Methoden und Anwendung, 7. Auflage, Springer Verlag, Berlin 2007 • VDI-Richtlinien: 2206; 2221ff

Course L1524: Applied Design Methodology in Mechatronics	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Thorsten Kern
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0604: High-Order FEM

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
High-Order FEM (L0280)	Lecture	3	4
High-Order FEM (L0281)	Recitation Section (large)	1	2

Module Responsible	Prof. Alexander Düster
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of partial differential equations is recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to + give an overview of the different (h, p, hp) finite element procedures. + explain high-order finite element procedures. + specify problems of finite element procedures, to identify them in a given situation and to explain their mathematical and mechanical background.
Skills	Students are able to + apply high-order finite elements to problems of structural mechanics. + select for a given problem of structural mechanics a suitable finite element procedure. + critically judge results of high-order finite elements. + transfer their knowledge of high-order finite elements to new problems.
Personal Competence	
Social Competence	Students are able to + solve problems in heterogeneous groups. + present and discuss their results in front of others. + give and accept professional constructive criticism.
Autonomy	Students are able to + assess their knowledge by means of exercises and E-Learning. + acquaint themselves with the necessary knowledge to solve research oriented tasks. + to transform the acquired knowledge to similar problems.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** No · **Bonus** 10 % · **Form** Presentation · **Description** Forschendes Lernen
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Computational Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Materials Science: Specialisation Modeling: Elective Compulsory Mechanical Engineering and Management: Specialisation Product Development and Production: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Naval Architecture and Ocean Engineering: Core Qualification: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory

Course L0280: High-Order FEM	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Alexander Düster
Language	EN
Cycle	SoSe
Content	1. Introduction 2. Motivation 3. Hierarchic shape functions 4. Mapping functions 5. Computation of element matrices, assembly, constraint enforcement and solution 6. Convergence characteristics 7. Mechanical models and finite elements for thin-walled structures 8. Computation of thin-walled structures 9. Error estimation and hp-adaptivity 10. High-order fictitious domain methods
Literature	[1] Alexander Düster, High-Order FEM, Lecture Notes, Technische Universität Hamburg-Harburg, 164 pages, 2014 [2] Barna Szabo, Ivo Babuska, Introduction to Finite Element Analysis – Formulation, Verification and Validation, John Wiley & Sons, 2011

Course L0281: High-Order FEM	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Alexander Düster
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1343: Structure and properties of fibre-polymer-composites

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Structure and properties of fibre-polymer-composites (L1894)	Lecture	2	3
Structure and properties of fibre-polymer-composites (L2614)	Project-/problem-based Learning	2	2
Structure and properties of fibre-polymer-composites (L2613)	Recitation Section (large)	1	1

Module Responsible	Prof. Bodo Fiedler
Admission Requirements	None
Recommended Previous Knowledge	Basics: chemistry / physics / materials science
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can use the knowledge of fiber-reinforced composites (FRP) and its constituents to play (fiber / matrix) and define the necessary testing and analysis. They can explain the complex relationships structure-property relationship and the interactions of chemical structure of the polymers, their processing with the different fiber types, including to explain neighboring contexts (e.g. sustainability, environmental protection).
Skills	Students are capable of • using standardized calculation methods in a given context to mechanical properties (modulus, strength) to calculate and evaluate the different materials. • approximate sizing using the network theory of the structural elements implement and evaluate. • selecting appropriate solutions for mechanical recycling problems and sizing example stiffness, corrosion resistance.
Personal Competence	
Social Competence	Students can • arrive at funded work results in heterogenius groups and document them. • provide appropriate feedback and handle feedback on their own performance constructively.
Autonomy	Students are able to - assess their own strengths and weaknesses. - assess their own state of learning in specific terms and to define further work steps on this basis. - assess possible consequences of their professional activity.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Materials Science and Engineering: Specialisation Engineering Materials: Elective Compulsory Materials Science: Specialisation Engineering Materials: Elective Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory

Course L1894: Structure and properties of fibre-polymer-composites	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	EN
Cycle	SoSe
Content	- Microstructure and properties of the matrix and reinforcing materials and their interaction - Development of composite materials - Mechanical and physical properties - Mechanics of Composite Materials - Laminate theory - Test methods - Non destructive testing - Failure mechanisms - Theoretical models for the prediction of properties - Application
Literature	Hall, Clyne: Introduction to Composite materials, Cambridge University Press Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press Mallick: Fibre-Reinforced Composites, Marcel Deckker, New York

Course L2614: Structure and properties of fibre-polymer-composites	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	DE/EN
Cycle	SoSe
Content	The students receive the assignment in the form of a material design for test bodies made of fibre composites. Technical and normative requirements are listed in the assignment, all other required information comes from the lectures and exercises or the respective documents (electronically and in conversation). The procedure is specified in a milestone plan and enables the students to plan subtasks and thus work continuously. At the end of the project, different test specimens were tested in tensile or bending tests. In the individual project meetings, the conception (discussion of requirements and risks) is scrutinised. The calculations are analysed, the production methods are evaluated and determined. Materials are selected and the test specimens are manufactured according to standards. The quality and mechanical properties are checked and classified. At the end, a final report is prepared and the results are presented to all participants in the form of a presentation and discussed. Translated with www.DeepL.com/Translator (free version)
Literature	Hall, Clyne: Introduction to Composite materials, Cambridge University Press Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press Mallick: Fibre-Reinforced Composites, Marcel Deckker, New York

Course L2613: Structure and properties of fibre-polymer-composites	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Bodo Fiedler
Language	EN
Cycle	SoSe
Content	The contents of the lecture are repeated and deepened using practical examples. Calculations are carried out together or individually, and the results are discussed critically.
Literature	Hall, Clyne: Introduction to Composite materials, Cambridge University Press Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press Mallick: Fibre-Reinforced Composites, Marcel Deckker, New York

Module M1012: Laboratory of Logistics Engineering and Automatisation

Courses

Title	Typ	Hrs/wk	CP
Laboratory Technical Logistics and Automatisation (L1462)	Seminar	4	6

Module Responsible	Prof. Jochen Kreutzfeldt
Admission Requirements	None
Recommended Previous Knowledge	Bachelor degree in logistics Basics of object-oriented programming language, for example python or Java.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students will acquire the following knowledge: 1. The students know the basic concepts of machine learning (supervised learning, unsupervised learning, reinforcement learning). 2. The students know the necessary steps to implement machine learning models in python. 3. The students know the approaches and hurdles for implementing machine learning in logistics.
Skills	The students will acquire the following skills: 1. The students are able to select technical solutions of machine learning for logistical problems of warehousing, conveying, sorting, order picking and identifying and evaluate the implementability of the alternatives. 2. The students are able to implement selected solutions of machine learning on a model scale. 3. The students are able to estimate the implementation costs of selected solutions of machine learning.
Personal Competence	
Social Competence	The students will acquire the following social skills: 1. The students are able to develop technical solutions for logistical problems and implement them on a model scale within a group of students. 2. The technical solutions from the group can be jointly documented and presented to an audience. 3. The students are able to derive new ideas and improvements from the feedback received related to their developed solution proposals.
Autonomy	The students will acquire the following competencies: 1. Students are able, under the guidance of supervisors, to develop and implement independently solutions of machine learning for logistical problems of warehousing, conveying, sorting, order picking and identifying. 2. The students are able to evaluate their technical solutions and discuss the pros and cons.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written elaboration
Examination duration and scale	Prototype construction in laboratory with documentation (group work)
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Logistics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory

Course L1462: Laboratory Technical Logistics and Automatisation	
Typ	Seminar
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Jochen Kreutzfeldt
Language	DE
Cycle	SoSe
Content	The aim of the seminar is the practical introduction of students in various technical solutions to logistical problems. Above all, the guided development of own solutions is the core task in the laboratory. The problems and solutions will be drawn from the following logistic topics: (1) warehousing (2) conveying (3) sorting (4) order picking (5) identifying The students develop technical solutions in small groups for selected problems and implement them on a lab scale. The solutions are presented to an audience and advantages and disadvantages are discussed. The recorded feedback is then added to the model solution.
Literature	Dembowski, Klaus (2015): Raspberry Pi - Das technische Handbuch. Konfiguration, Hardware, Applikationserstellung. 2., erw. und überarb. Aufl. 2015. Wiesbaden: Springer Vieweg. Follmann, Rüdiger (2014): Das Raspberry Pi Kompendium. 2014. Aufl. Berlin, Heidelberg: Springer Berlin Heidelberg (Xpert.press). Griemert, Rudolf (2015): Fördertechnik. Auswahl und Berechnung von Elementen und Baugruppen. [S.l.]: Morgan Kaufmann. Hompel, Michael ten; Büchter, Hubert; Franzke, Ulrich (2008): Identifikationssysteme und Automatisierung. [Intralogistik]. Berlin, Heidelberg: Springer. Hompel, Michael ten; Beck, Maria; Sadowsky, Volker (2011): Kommissionierung. Materialflusssysteme 2 - Planung und Berechnung der Kommissionierung in der Logistik. Berlin [u.a.]: Springer. Jodin, Dirk; Hompel, Michael ten (2012): Sortier- und Verteilsysteme. Grundlagen, Aufbau, Berechnung und Realisierung. 2. Aufl. Berlin: Springer Berlin. Martin, Heinrich (2014): Transport- und Lagerlogistik. Planung, Struktur, Steuerung und Kosten von Systemen der Intralogistik. 9., vollst. überarb. u. akt. Aufl. 2014. Wiesbaden: Imprint: Springer Vieweg. Purdum, Jack J. (2014): Beginning C for Arduino. Learn C programming for the Arduino. Second edition.: Springer Berlin. McRoberts, Michael (2014): Beginning Arduino. Second edition.: Springer Berlin.

Module M1156: Systems Engineering

Courses

Title	Typ	Hrs/wk	CP
Systems Engineering (L1547)	Lecture	3	4
Systems Engineering (L1548)	Recitation Section (large)	1	2

Module Responsible	Prof. Ralf God
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Aircraft Cabin Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • understand systems engineering process models, methods and tools for the development of complex Systems • describe innovation processes and the need for technology Management • explain the aircraft development process and the process of type certification for aircraft • explain the system development process, including requirements for systems reliability • identify environmental conditions and test procedures for airborne Equipment • value the methodology of requirements-based engineering (RBE) and model-based requirements engineering (MBRE)
Skills	Students are able to: • plan the process for the development of complex Systems • organize the development phases and development Tasks • assign required business activities and technical Tasks • apply systems engineering methods and tools
Personal Competence	
Social Competence	Students are able to: • understand and accept their tasks within a development team • be comfortable with their role their tasks within the overall process • understand and serve their suppliers and customers in large projects • assume responsibility for people and technology in the development of safety-critical systems
Autonomy	Students are able to: • interact and communicate in a development team with division of tasks. • independently research and identify certification specifications • formulate requirements on their own • create test plans on their own and accompany certification processes
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 Minutes
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Compulsory Mechatronics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L1547: Systems Engineering	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	The objective of the lecture with the corresponding exercise is to accomplish the prerequisites for the development and integration of complex systems using the example of commercial aircraft and cabin systems. Competences in the systems engineering process, tools and methods is to be achieved. Regulations, guidelines and certification issues will be known. Key aspects of the course are processes for innovation and technology management, system design, system integration and certification as well as tools and methods for systems engineering: • Innovation processes • IP-protection • Technology management • Systems engineering • Aircraft program • Certification issues • Systems development • Safety objectives and fault tolerance • Environmental and operating conditions • Tools for systems engineering • Requirements-based engineering (RBE) • Model-based requirements engineering (MBRE)
Literature	- Skript zur Vorlesung - diverse Normen und Richtlinien (EASA, FAA, RTCA, SAE) - Hauschildt, J., Salomo, S.: Innovationsmanagement. Vahlen, 5. Auflage, 2010 - NASA Systems Engineering Handbook, National Aeronautics and Space Administration, 2007 - Hinsch, M.: Industrielles Luftfahrtmanagement: Technik und Organisation luftfahrttechnischer Betriebe. Springer, 2010 - De Florio, P.: Airworthiness: An Introduction to Aircraft Certification. Elsevier Ltd., 2010 - Pohl, K.: Requirements Engineering. Grundlagen, Prinzipien, Techniken. 2. korrigierte Auflage, dpunkt.Verlag, 2008

Course L1548: Systems Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1894: Automation Technology and Systems

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Automation Technology and Systems (L2329)	Lecture	4	4
Automation Technology and Systems (L2331)	Project-/problem-based Learning	1	1
Automation Technology and Systems (L2330)	Recitation Section (small)	1	1

Module Responsible	Prof. Thorsten Schüppstuhl
Admission Requirements	None
Recommended Previous Knowledge	without major course assessment
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students • know the characteristic components of an automation systems and have good understanding of their interaction • know methods for a systematical analysis of automation tasks and are able to use them • have special competences in industrial robot based automation systems
Skills	Students are able to... • analyze complex Automation tasks • develop application based concepts and solutions • design subsystems and integrate into one system • investigate and evaluate safety of machinery • create simple programs for robots and programmable logic controllers • design of circuit for pneumatic applications
Personal Competence	
Social Competence	Students are able to ... - find solutions for automation and handling tasks in groups - develop solutions in a production environment with qualified personnel at technical level and represent decisions.
Autonomy	Students are able to ... • analyze automation tasks independently • generate programs for robots and programmable logic devices autonomously • develop solutions for practice oriented tasks of automation independently • design safety concepts for automation applications • assess consequences of their professional actions and responsibilities
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 20 % / Subject theoretical and practical work / Die Studienleistung umfasst die Ergebnisse der PBL basierten Anteile des Moduls sowie der Präsentation in der Gruppe.
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L2329: Automation Technology and Systems

Typ	Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Prof. Thorsten Schüppstuhl
Language	DE
Cycle	SoSe
Content	
Literature	

Course L2331: Automation Technology and Systems	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Thorsten Schüppstuhl
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L2330: Automation Technology and Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Thorsten Schüppstuhl
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0563: Robotics

Courses

Title	Typ	Hrs/wk	CP
Robotics: Modelling and Control (L0168)	Integrated Lecture	4	4
Robotics: Modelling and Control (L1305)	Project-/problem-based Learning	2	2

Module Responsible	Dr. Martin Gomse
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of electrical engineering Broad knowledge of mechanics Fundamentals of control theory
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe fundamental properties of robots and solution approaches for multiple problems in robotics.
Skills	Students are able to derive and solve equations of motion for various manipulators. Students can generate trajectories in various coordinate systems. Students can design linear and partially nonlinear controllers for robotic manipulators.
Personal Competence	
Social Competence	Students are able to work goal-oriented in small mixed groups.
Autonomy	Students are able to recognize and improve knowledge deficits independently. With instructor assistance, students are able to evaluate their own knowledge level and define a further course of study.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory**: Yes; **Bonus**: None; **Form**: Subject theoretical and practical work; **Description**: Teilnahme an PBL-Einheiten sowie Erreichen des Gesamtziels und der jeweiligen Session-Ziele
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L0168: Robotics: Modelling and Control

Typ	Integrated Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Dr. Martin Gomse
Language	EN
Cycle	WiSe
Content	Fundamental kinematics of rigid body systems Newton-Euler equations for manipulators Trajectory generation Linear and nonlinear control of robots
Literature	Craig, John J.: Introduction to Robotics Mechanics and Control, Third Edition, Prentice Hall. ISBN 0201-54361-3 Spong, Mark W.; Hutchinson, Seth; Vidyasagar, M. : Robot Modeling and Control. WILEY. ISBN 0-471-64990-2

Course L1305: Robotics: Modelling and Control	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Martin Gomse
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0808: Finite Elements Methods

Courses

Title	Typ	Hrs/wk	CP
Finite Element Methods (L0291)	Lecture	2	3
Finite Element Methods (L0804)	Recitation Section (large)	2	3

Module Responsible	Prof. Benedikt Kriegesmann
Admission Requirements	None
Recommended Previous Knowledge	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students possess an in-depth knowledge regarding the derivation of the finite element method and are able to give an overview of the theoretical and methodical basis of the method.
Skills	The students are capable to handle engineering problems by formulating suitable finite elements, assembling the corresponding system matrices, and solving the resulting system of equations.
Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	The students are able to independently solve challenging computational problems and develop own finite element routines. Problems can be identified and the results are critically scrutinized.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** No / 20 % / Midterm /
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory

Course L0291: Finite Element Methods	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Benedikt Kriegesmann
Language	EN
Cycle	WiSe
Content	- General overview on modern engineering - Displacement method - Hybrid formulation - Isoparametric elements - Numerical integration - Solving systems of equations (statics, dynamics) - Eigenvalue problems - Non-linear systems - Applications - Programming of elements (Matlab, hands-on sessions) - Applications
Literature	Bathe, K.-J. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin

Course L0804: Finite Element Methods	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Benedikt Kriegesmann
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1024: Methods of Product Development

Courses

Title	Typ	Hrs/wk	CP
Methods of Product Development (L1254)	Lecture	3	3
Methods of Product Development (L1255)	Project-/problem-based Learning	2	3

Module Responsible	Prof. Dieter Krause
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of Integrated product development and applying CAE systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After passing the module students are able to: • explain technical terms of design methodology, • describe essential elements of construction management, • describe current problems and the current state of research of integrated product development.
Skills	After passing the module students are able to: • select and apply proper construction methods for non-standardized solutions of problems as well as adapt new boundary conditions, • solve product development problems with the assistance of a workshop based approach, • choose and execute appropriate moderation techniques.
Personal Competence	
Social Competence	After passing the module students are able to: • prepare and lead team meetings and moderation processes, • work in teams on complex tasks, • represent problems and solutions and advance ideas.
Autonomy	After passing the module students are able to: • give a structured feedback and accept a critical feedback, • implement the accepted feedback autonomous.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Oral exam
Examination duration and scale	30 Minuten
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L1254: Methods of Product Development	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	**Lecture** The lecture extends and enhances the learned content of the module “Integrated Product Development and lightweight design” and is based on the knowledge and skills acquired there. Topics of the course include in particular: • Methods of product development, • Presentation techniques, • Industrial Design, • Design for variety • Modularization methods, • Design catalogs, • Adapted QFD matrix, • Systematic material selection, • Assembly oriented design, Construction management • CE mark, declaration of conformity including risk assessment, • Patents, patent rights, patent monitoring • Project management (cost, time, quality) and escalation principles, • Development management for mechatronics, • Technical Supply Chain Management. **Exercise (PBL)** In the exercise the content presented in the lecture “Integrated Product Development II” and methods of product development and design management will be enhanced. Students learn an independently moderated and workshop based approach through industry related practice examples to solve complex and currently existing issues in product development. They will learn the ability to apply important methods of product development and design management autonomous and acquire further expertise in the field of integrated product development. Besides personal skills, such as teamwork, guiding discussions and representing work results will be acquired through the workshop based structure of the event under its own planning and management.
Literature	• Andreasen, M.M., Design for Assembly, Berlin, Springer 1985. • Ashby, M. F.: Materials Selection in Mechanical Design, München, Spektrum 2007. • Beckmann, H.: Supply Chain Management, Berlin, Springer 2004. • Hartmann, M., Rieger, M., Funk, R., Rath, U.: Zielgerichtet moderieren. Ein Handbuch für Führungskräfte, Berater und Trainer, Weinheim, Beltz 2007. • Pahl, G., Beitz, W.: Konstruktionslehre, Berlin, Springer 2006. • Roth, K.H.: Konstruieren mit Konstruktionskatalogen, Band 1-3, Berlin, Springer 2000. • Simpson, T.W., Siddique, Z., Jiao, R.J.: Product Platform and Product Family Design. Methods and Applications, New York, Springer 2013.

Course L1255: Methods of Product Development	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1025: Fluidics

Courses

Title	Typ	Hrs/wk	CP
Fluidics (L1256)	Lecture	2	3
Fluidics (L1371)	Project-/problem-based Learning	1	2
Fluidics (L1257)	Recitation Section (large)	1	1

Module Responsible	Prof. Dieter Krause
Admission Requirements	None
Recommended Previous Knowledge	Good knowledge of mechanics (stereo statics, elastostatics, hydrostatics, kinematics and kinetics), fluid mechanics, and engineering design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After passing the module students are able to • explain structures and functionalities of hydrostatic, pneumatic, and hydrodynamic components, • explain the interaction of hydraulic components in hydraulic systems, • explain open and closed loop control of hydraulic systems, • describe functioning and applications of hydrodynamic torque converters, brakes and clutches as well as centrifugal pumps and aggregates in plant technology
Skills	After passing the module students are able to • analyse and assess hydraulic and pneumatic components and systems, • design and dimension hydraulic systems for mechanical applications, • perform numerical simulations of hydraulic systems based on abstract problem definitions, • select and adapt pump characteristic curves for hydraulic systems • dimension hydrodynamic torque converters and brakes for mechanical aggregates.
Personal Competence	
Social Competence	After passing the module students are able to • discuss and present functional context in groups, • organise teamwork autonomously.
Autonomy	After passing the module students are able to • obtain necessary knowledge for the simulation.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** Yes · **Bonus** None · **Form** Attestation · **Description** Simulation hydrostatischer Systeme
Examination	Written exam
Examination duration and scale	90
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L1256: Fluidics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	**Lecture** Hydrostatics • physical fundamentals • hydraulic fluids • hydrostatic machines • valves • components • hydrostatic transmissions • examples from industry Pneumatics • generation of compressed air • pneumatic motors • Examples of use Hydrodynamics • physical fundamentals • hydraulic continous-flow machines • hydrodynamic transmissions • interoperation of motor and transmission **Exercise** Hydrostatics • reading and design of hydraulic diagrams • dimensioning of hydrostatic traction and working drives • performance calculation Hydrodynamics • calculation / dimensioning of hydrodynamic torque converters • calculation / dimensioning of centrifugal pumps • creating and reading of characteristic curves of pumps and systems Field trip • field trip to a regional company from the hydraulic industry. **Exercise** Numerical simulation of hydrostatic systems • getting to know a numerical simulation environment for hydraulic systems • transformation of a task into a simulation model • simulation of common components • variation of simulation parameters • using simulations for system dimensioning and optimisation • (partly) self-organised teamwork
Literature	Bücher • Murrenhoff, H.: Grundlagen der Fluidtechnik - Teil 1: Hydraulik, Shaker Verlag, Aachen, 2011 • Murrenhoff, H.: Grundlagen der Fluidtechnik - Teil 2: Pneumatik, Shaker Verlag, Aachen, 2006 • Matthies, H.J. Renius, K.Th.: Einführung in die Ölhydraulik, Teubner Verlag, 2006 • Beitz, W., Grote, K.-H.: Dubbel - Taschenbuch für den Maschinenbau, Springer-Verlag, Berlin, aktuelle Auflage Skript zur Vorlesung

Course L1371: Fluidics	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1257: Fluidics	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0633: Industrial Process Automation

Courses

Title	Typ	Hrs/wk	CP
Industrial Process Automation (L0344)	Lecture	2	3
Industrial Process Automation (L0345)	Recitation Section (small)	2	3

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	mathematics and optimization methods principles of automata principles of algorithms and data structures programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can evaluate and assess discrete event systems. They can evaluate properties of processes and explain methods for process analysis. The students can compare methods for process modelling and select an appropriate method for actual problems. They can discuss scheduling methods in the context of actual problems and give a detailed explanation of advantages and disadvantages of different programming methods. The students can relate process automation to methods from robotics and sensor systems as well as to recent topics like 'cyberphysical systems' and 'industry 4.0'.
Skills	The students are able to develop and model processes and evaluate them accordingly. This involves taking into account optimal scheduling, understanding algorithmic complexity, and implementation using PLCs.
Personal Competence	
Social Competence	The students can independently define work processes within their groups, distribute tasks within the group and develop solutions collaboratively.
Autonomy	The students are able to assess their level of knowledge and to document their work results adequately.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory** No; **Bonus** 10 %; **Form** Excercises; **Description**
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0344: Industrial Process Automation	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	- foundations of problem solving and system modeling, discrete event systems - properties of processes, modeling using automata and Petri-nets - design considerations for processes (mutex, deadlock avoidance, liveness) - optimal scheduling for processes - optimal decisions when planning manufacturing systems, decisions under uncertainty - software design and software architectures for automation, PLCs
Literature	J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012 Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010 Hrúz, Zhou: Modeling and Control of Discrete-event Dynamic Systems; Springer 2007 Li, Zhou: Deadlock Resolution in Automated Manufacturing Systems, Springer 2009 Pinedo: Planning and Scheduling in Manufacturing and Services, Springer 2009

Course L0345: Industrial Process Automation	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1170: Phenomena and Methods in Materials Science

Courses

Title	Typ	Hrs/wk	CP
Experimental Methods for the Characterization of Materials (L1580)	Lecture	2	2
Phase equilibria and transformations (L1579)	Lecture	2	2
Übung zu Phänomene und Methoden der Materialwissenschaft (L2991)	Recitation Section (large)	2	2

Module Responsible	Prof. Jörg Weißmüller
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in Materials Science, e.g. Werkstoffwissenschaft I/II
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students will be able to explain the properties of advanced materials along with their applications in technology, in particular metallic, ceramic, polymeric, semiconductor, modern composite materials (biomaterials) and nanomaterials.
Skills	The students will be able to select material configurations according to the technical needs and, if necessary, to design new materials considering architectural principles from the micro- to the macroscale. The students will also gain an overview on modern materials science, which enables them to select optimum materials combinations depending on the technical applications.
Personal Competence	
Social Competence	The students are able to present solutions to specialists and to develop ideas further.
Autonomy	The students are able to ... • assess their own strengths and weaknesses. • gather new necessary expertise by their own.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Materials Science: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory

Course L1580: Experimental Methods for the Characterization of Materials

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Shan Shi
Language	EN
Cycle	WiSe
Content	• Structural characterization by photons, neutrons and electrons (in particular X-ray and neutron scattering, electron microscopy, tomography) • Mechanical and thermodynamical characterization methods (indenter measurements, mechanical compression and tension tests, specific heat measurements) • Characterization of optical, electrical and magnetic properties (spectroscopy, electrical conductivity and magnetometry)
Literature	William D. Callister und David G. Rethwisch, Materialwissenschaften und Werkstofftechnik, Wiley&Sons, Asia (2011). William D. Callister, Materials Science and Technology, Wiley& Sons, Inc. (2007).

Course L1579: Phase equilibria and transformations	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Jörg Weißmüller
Language	DE
Cycle	WiSe
Content	Fundamentals of statistical physics, formal structure of phenomenological thermodynamics, simple atomistic models and free-energy functions of solid solutions and compounds. Corrections due to nonlocal interaction (elasticity, gradient terms). Phase equilibria and alloy phase diagrams as consequence thereof. Simple atomistic considerations for interaction energies in metallic solid solutions. Diffusion in real systems. Kinetics of phase transformations for real-life boundary conditions. Partitioning, stability and morphology at solidification fronts. Order of phase transformations; glass transition. Phase transitions in nano- and microscale systems.
Literature	D.A. Porter, K.E. Easterling, “Phase transformations in metals and alloys”, New York, CRC Press, Taylor & Francis, 2009, 3. Auflage Peter Haasen, „Physikalische Metallkunde“ , Springer 1994 Herbert B. Callen, “Thermodynamics and an introduction to thermostatistics”, New York, NY: Wiley, 1985, 2. Auflage. Robert W. Cahn und Peter Haasen, "Physical Metallurgy", Elsevier 1996 H. Ibach, “Physics of Surfaces and Interfaces” 2006, Berlin: Springer.

Course L2991: Übung zu Phänomene und Methoden der Materialwissenschaft	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Shan Shi
Language	DE
Cycle	WiSe
Content	Practice problems to practice and deepen the skills and content taught in the module. Exercises explore mathematical details in greater depth with the aim of familiarizing students with equations/concepts and how to apply them in practice (e.g. defining thermodynamic potentials and relationships, calculating enthalpy and entropy of a solid solution, constructing phase diagrams, ...).
Literature	D.A. Porter, K.E. Easterling, “Phase transformations in metals and alloys”, New York, CRC Press, Taylor & Francis, 2009, 3. Auflage Peter Haasen, „Physikalische Metallkunde“ , Springer 1994 Herbert B. Callen, “Thermodynamics and an introduction to thermostatistics”, New York, NY: Wiley, 1985, 2. Auflage. Robert W. Cahn und Peter Haasen, "Physical Metallurgy", Elsevier 1996 H. Ibach, “Physics of Surfaces and Interfaces” 2006, Berlin: Springer. William D. Callister und David G. Rethwisch, Materialwissenschaften und Werkstofftechnik, Wiley&Sons, Asia (2011). William D. Callister, Materials Science and Technology, Wiley& Sons, Inc. (2007).

Module M0739: Factory Planning & Production Logistics

Courses

Title	Typ	Hrs/wk	CP
Factory Planning (L1445)	Lecture	3	3
Production Logistics (L1446)	Lecture	2	3

Module Responsible	Prof. Jochen Kreutzfeldt
Admission Requirements	None
Recommended Previous Knowledge	Bachelor degree in logistics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students will acquire the following knowledge: 1. The students know the latest trends and developments in the planning of factories. 2. The students can explain basic procedures of factory planning and are able to deploy these procedures while considering different conditions. 3. The students know different methods of factory planning and are able to deal critically with these methods.
Skills	The students will acquire the following skills: 1. The students are able to analyze factories and other material flow systems with regard to new development and the need for change of these logistical systems. 2. The students are able to plan and redesign factories and other material handling systems. 3. The students are able to develop procedures for the implementation of new and revised material flow systems.
Personal Competence	
Social Competence	The students will acquire the following social skills: 1. The students are able to develop plans for the development of new and improvement of existing material flow systems within a group. 2. The developed planning proposal from the group work can be documented and presented together. 3. The students are able to derive suggestions for improvement from the feedback on the planning proposals and can even provide constructive criticism themselves.
Autonomy	The students will acquire the following independent competencies: 1. The students can plan and re-design material flow systems using existing planning procedures. 2. The students can evaluate independently the strengths and weaknesses of several techniques for factory planning and choose appropriate methods in a given context. 3. The students are able to carry out autonomously new plans and transformations of material flow systems.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory International Management and Engineering: Specialisation II. Logistics: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L1445: Factory Planning	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Jochen Kreutzfeldt
Language	DE
Cycle	WiSe
Content	The lecture gives an introduction into the planning of factories and material flows. The students will learn process models and methods to plan new factories and improve existing material flow systems. The course includes three basic topics: (1) Analysis of factory and material flow systems (2) Development and re-planning of factory and material flow systems (3) Implementation and realization of factory planning The students are introduced into several different methods and models per topic. Practical examples and planning exercises deepen the methods and explain the application of factory planning. The special requirements of factory planning in an international context are discussed. Specific requirements of Current trends and issues in the factory planning round off the lecture.
Literature	Bracht, Uwe; Wenzel, Sigrid; Geckler, Dieter (2018): Digitale Fabrik: Methoden und Praxisbeispiele. 2. Aufl.: Springer, Berlin. Helbing, Kurt W. (2010): Handbuch Fabrikprojektierung. Berlin, Heidelberg: Springer Berlin Heidelberg. Lotter, Bruno; Wiendahl, Hans-Peter (2012): Montage in der industriellen Produktion: Optimierte Abläufe, rationelle Automatisierung. 2. Aufl.: Springer, Berlin. Müller, Egon; Engelmann, Jörg; Löffler, Thomas; Jörg, Strauch (2009): Energieeffiziente Fabriken planen und betreiben. Berlin, Heidelberg: Springer Berlin Heidelberg. Schenk, Michael; Müller, Egon; Wirth, Siegfried (2014): Fabrikplanung und Fabrikbetrieb. Methoden für die wandlungsfähige, vernetzte und ressourceneffiziente Fabrik. 2. Aufl. Berlin [u.a.]: Springer Vieweg. Wiendahl, Hans-Peter; Reichardt, Jürgen; Nyhuis, Peter (2014): Handbuch Fabrikplanung: Konzept, Gestaltung und Umsetzung wandlungsfähiger Produktionsstätten. 2. Aufl. Carl Hanser Verlag.

Course L1446: Production Logistics	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dipl.-Ing. Arnd Schirrmann
Language	DE
Cycle	WiSe
Content	• Introduction: situation, significance and main innovation focuses of logistics in a production company, aspects of procurement, production, distribution and disposal logistics, production and transport networks • Logistics as a production strategy: logistics-oriented method of working in a factory, throughput time, corporate strategy, structured networking, reducing complexity, integrated organization, integrated product and production logistics (IPPL) • Logistics-compatible production and process structuring; logistics-compatible product, material flow, information and organizational structures • Logistics-oriented production control: situation and development tendencies, logistics and cybernetics, market-oriented production planning, control, monitoring, PPS systems and production control, cybernetic production organization and control, production logistics control systems. • Production logistics planning: key performance indicators, developing a production logistics concept, computerized aids to planning production logistics, IPPL functions, economic efficiency of logistics projects • Production logistics controlling: production logistics and controlling, material flow-oriented cost transparency, cost controlling (process cost accounting, costs model in IPPL), process controlling (integrated production system, methods and tools, MEPOT.net method portal)
Literature	Pawellek, G.: Produktionslogistik: Planung - Steuerung - Controlling. Carl Hanser Verlag 2007

Module M0867: Production Planning & Control and Digital Enterprise

Courses

Title	Typ	Hrs/wk	CP
The Digital Enterprise (L0932)	Lecture	2	2
Production Planning and Control (L0929)	Lecture	2	2
Production Planning and Control (L0930)	Recitation Section (small)	1	1
Exercise: The Digital Enterprise (L0933)	Recitation Section (small)	1	1

Module Responsible	Prof. Hermann Lödding
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of Production and Quality Management
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can explain the contents of the module in detail and take a critical position to them.
Skills	Students are capable of choosing and applying models and methods from the module to industrial problems.
Personal Competence	
Social Competence	Students can develop joint solutions in mixed teams and present them to others.
Autonomy	-
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 Minuten
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Production and Logistics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory

Course L0932: The Digital Enterprise

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Robert Rost
Language	DE
Cycle	WiSe
Content	Due to the developments of Industry 4.0, digitalization and interconnectivity become a strategic advantage for companies in the international competition. This lecture focuses on the relevant modules and enables the participants to evaluate current developments in this context. In particular, knowledge management, simulation, process modelling and virtual technologies are covered. Content: • Business Process Management and Data Modelling, Simulation • Knowledge and Competence Management • Process Management (PPC, Workflow Management) • Computer Aided Planning (CAP) and NC-Programming • Virtual Reality (VR) and Augmented Reality (AR) • Computer Aided Quality Management (CAQ) • Industry 4.0
Literature	Scheer, A.-W.: ARIS - vom Geschäftsprozeß zum Anwendungssystem. Springer-Verlag, Berlin 4. Aufl. 2002 Schuh, G. et. al.: Produktionsplanung und -steuerung, Springer-Verlag. Berlin 3. Auflage 2006 Becker, J.; Luczak, H.: Workflowmanagement in der Produktionsplanung und -steuerung. Springer-Verlag, Berlin 2004 Pfeifer, T; Schmitt, R.: Masing Handbuch Qualitätsmanagement. Hanser-Verlag, München 5. Aufl. 2007 Kühn, W.: Digitale Fabrik. Hanser-Verlag, München 2006

Course L0929: Production Planning and Control	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Hermann Lödding
Language	DE
Cycle	WiSe
Content	• Models of Production and Inventory Management • Production Programme Planning and Lot Sizing • Order and Capacity Scheduling • Selected Strategies of PPC • Manufacturing Control • Production Controlling • Supply Chain Management
Literature	• Vorlesungsskript • Lödding, H: Verfahren der Fertigungssteuerung, Springer 2008 • Nyhuis, P.; Wiendahl, H.-P.: Logistische Kennlinien, Springer 2002

Course L0930: Production Planning and Control	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Hermann Lödding
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0933: Exercise: The Digital Enterprise	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Robert Rost
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	Siehe korrespondierende Vorlesung See interlocking course

Specialization II. Renewable Energy

Module M0512: Use of Solar Energy

Courses

Title	Typ	Hrs/wk	CP
Energy Meteorology (L0016)	Lecture	1	1
Energy Meteorology (L0017)	Recitation Section (small)	1	1
Collector Technology (L0018)	Lecture	2	2
Solar Power Generation (L0015)	Lecture	2	2

Module Responsible	Prof. Martin Kaltschmitt
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	With the completion of this module, students will be able to deal with technical foundations and current issues and problems in the field of solar energy and explain and evaulate these critically in consideration of the prior curriculum and current subject specific issues. In particular they can professionally describe the processes within a solar cell and explain the specific features of application of solar modules. Furthermore, they can provide an overview of the collector technology in solar thermal systems.
Skills	Students can apply the acquired theoretical foundations of exemplary energy systems using solar radiation. In this context, for example they can assess and evaluate potential and constraints of solar energy systems with respect to different geographical assumptions. They are able to dimension solar energy systems in consideration of technical aspects and given assumptions. Using module-comprehensive knowledge students can evalute the economic and ecologic conditions of these systems. They can select calculation methods within the radiation theory for these topics.
Personal Competence	
Social Competence	Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module.
Autonomy	Students can independently exploit sources and acquire the particular knowledge about the subject area with respect to emphasis fo the lectures. Furthermore, with the assistance of lecturers, they can discrete use calculation methods for analysing and dimensioning solar energy systems. Based on this procedure they can concrete assess their specific learning level and can consequently define the further workflow.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** 20 %; **Form** Written elaboration; **Description** Ausarbeitung Kollektortechnik
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Energy Systems: Specialisation Energy Systems: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory

Course L0016: Energy Meteorology	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Volker Matthias, Dr. Beate Geyer
Language	DE
Cycle	SoSe

Content	• Introduction: radiation source Sun, Astronomical Foundations, Fundamentals of radiation
	• Structure of the atmosphere
	• Properties and laws of radiation
	  ◦ Polarization
	  ◦ Radiation quantities
	  ◦ Planck's radiation law
	  ◦ Wien's displacement law
	  ◦ Stefan-Boltzmann law
	  ◦ Kirchhoff's law
	  ◦ Brightness temperature
	  ◦ Absorption, reflection, transmission
	• Radiation balance, global radiation, energy balance
	• Atmospheric extinction
	• Mie and Rayleigh scattering
	• Radiative transfer
	• Optical effects in the atmosphere
	• Calculation of the sun and calculate radiation on inclined surfaces

Literature	• Helmut Kraus: Die Atmosphäre der Erde • Hans Häckel: Meteorologie • Grant W. Petty: A First Course in Atmosheric Radiation • Martin Kaltschmitt, Wolfgang Streicher, Andreas Wiese: Renewable Energy • Alexander Löw, Volker Matthias: Skript Optik Strahlung Fernerkundung

Course L0017: Energy Meteorology	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Beate Geyer
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0018: Collector Technology	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Agis Papadopoulos
Language	DE
Cycle	SoSe
Content	• Introduction: Energy demand and application of solar energy. • Heat transfer in the solar thermal energy: conduction, convection, radiation. • Collectors: Types, structure, efficiency, dimensioning, concentrated systems. • Energy storage: Requirements, types. • Passive solar energy: components and systems. • Solar thermal low temperature systems: collector variants, construction, calculation. • Solar thermal high temperature systems: Classification of solar power plants construction. • Solar air conditioning.
Literature	• Vorlesungsskript. • Kaltschmitt, Streicher und Wiese (Hrsg.). Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte, 5. Auflage, Springer, 2013. • Stieglitz und Heinzel .Thermische Solarenergie: Grundlagen, Technologie, Anwendungen. Springer, 2012. • Von Böckh und Wetzel. Wärmeübertragung: Grundlagen und Praxis, Springer, 2011. • Baehr und Stephan. Wärme- und Stoffübertragung. Springer, 2009. • de Vos. Thermodynamics of solar energy conversion. Wiley-VCH, 2008. • Mohr, Svoboda und Unger. Praxis solarthermischer Kraftwerke. Springer, 1999.

Course L0015: Solar Power Generation	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Martin Schlecht, Prof. Alf Mews, Roman Fritsches-Baguhl
Language	DE
Cycle	SoSe
Content	Photovoltaics: 1. Introduction 2. Primary energies and consumption, available solar energy 3. Physics of the ideal solar cell 4. Light absorption, PN transition, characteristic sizes of the solar cell, efficiency 5. Physics of the real solar cell 6. Charge carrier recombination, characteristic curves, barrier layer recombination, equivalent circuit diagram 7. Increasing efficiency 8. Methods for increasing the quantum yield and reducing recombination 9. Hetero- and tandem structures 10. Heterojunction, Schottky, electrochemical, MIS and SIS cell, tandem cell 11. Concentrator cells 12. Concentrator optics and tracking systems, concentrator cells 13. Technology and properties: solar cell types, manufacturing, monocrystalline silicon and gallium arsenide, polycrystalline silicon and silicon thin film cells, thin film cells on carriers (amorphous silicon, CIS, electrochemical cells) 14. Modules 15. Switches Concentrating solar power plants: 1. Introduction 2. Point focused technologies 3. Line focused technologies 4. Design of CSP projects
Literature	• A. Götzberger, B. Voß, J. Knobloch: Sonnenenergie: Photovoltaik, Teubner Studienskripten, Stuttgart, 1995 • A. Götzberger: Sonnenenergie: Photovoltaik : Physik und Technologie der Solarzelle, Teubner Stuttgart, 1994 • H.-J. Lewerenz, H. Jungblut: Photovoltaik, Springer, Berlin, Heidelberg, New York, 1995 • A. Götzberger: Photovoltaic solar energy generation, Springer, Berlin, 2005 • C. Hu, R. M. White: Solar Cells, Mc Graw Hill, New York, 1983 • H.-G. Wagemann: Grundlagen der photovoltaischen Energiewandlung: Solarstrahlung, Halbleitereigenschaften und Solarzellenkonzepte, Teubner, Stuttgart, 1994 • R. J. van Overstraeten, R.P. Mertens: Physics, technology and use of photovoltaics, Adam Hilger Ltd, Bristol and Boston, 1986 • B. O. Seraphin: Solar energy conversion Topics of applied physics V 01 31, Springer, Berlin, Heidelberg, New York, 1995 • P. Würfel: Physics of Solar cells, Principles and new concepts, Wiley-VCH, Weinheim 2005 • U. Rindelhardt: Photovoltaische Stromversorgung, Teubner-Reihe Umwelt, Stuttgart 2001 • V. Quaschning: Regenerative Energiesysteme, Hanser, München, 2003 • G. Schmitz: Regenerative Energien, Ringvorlesung TU Hamburg-Harburg 1994/95, Institut für Energietechnik

Module M0513: System Aspects of Renewable Energies

Courses

Title	Typ	Hrs/wk	CP
Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage (L0021)	Lecture	2	2
Energy Trading (L0019)	Lecture	1	1
Energy Trading (L0020)	Recitation Section (small)	1	1
Deep Geothermal Energy (L0025)	Lecture	2	2

Module Responsible	Prof. Martin Kaltschmitt
Admission Requirements	None
Recommended Previous Knowledge	Module: Technical Thermodynamics I Module: Technical Thermodynamics II
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe the processes in energy trading and the design of energy markets and can critically evaluate them in relation to current subject specific problems. Furthermore, they are able to explain the basics of thermodynamics of electrochemical energy conversion in fuel cells and can establish and explain the relationship to different types of fuel cells and their respective structure. Students can compare this technology with other energy storage options. In addition, students can give an overview of the procedure and the energetic involvement of deep geothermal energy.
Skills	Students can apply the learned knowledge of storage systems for excessive energy to explain for various energy systems different approaches to ensure a secure energy supply. In particular, they can plan and calculate domestic, commercial and industrial heating equipment using energy storage systems in an energy-efficient way and can assess them in relation to complex power systems. In this context, students can assess the potential and limits of geothermal power plants and explain their operating mode. Furthermore, the students are able to explain the procedures and strategies for marketing of energy and apply it in the context of other modules on renewable energy projects. In this context they can unassistedly carry out analysis and evaluations of energie markets and energy trades.
Personal Competence	
Social Competence	Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module.
Autonomy	Students can independently exploit sources , acquire the particular knowledge about the subject area and transform it to new questions.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	3 hours written exam
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory

Course L0021: Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Fröba
Language	DE
Cycle	SoSe
Content	1. Introduction to electrochemical energy conversion 2. Function and structure of electrolyte 3. Low-temperature fuel cell ∘ Types ∘ Thermodynamics of the PEM fuel cell ∘ Cooling and humidification strategy 4. High-temperature fuel cell ∘ The MCFC ∘ The SOFC ∘ Integration Strategies and partial reforming 5. Fuels ∘ Supply of fuel ∘ Reforming of natural gas and biogas ∘ Reforming of liquid hydrocarbons 6. Energetic Integration and control of fuel cell systems
Literature	• Hamann, C.; Vielstich, W.: Elektrochemie 3. Aufl.; Weinheim: Wiley - VCH, 2003

Course L0019: Energy Trading	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Michael Sagorje, Dr. Sven Orlowski
Language	DE
Cycle	SoSe
Content	• Basic concepts and tradable products in energy markets • Primary energy markets • Electricity Markets • European Emissions Trading Scheme • Influence of renewable energy • Real options • Risk management Within the exercise the various tasks are actively discussed and applied to various cases of application.
Literature	

Course L0020: Energy Trading	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Michael Sagorje, Dr. Sven Orlowski
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0025: Deep Geothermal Energy	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Ben Norden
Language	DE
Cycle	SoSe
Content	1. Introduction to the deep geothermal use 2. Geological Basics I 3. Geological Basics II 4. Geology and thermal aspects 5. Rock Physical Aspects 6. Geochemical aspects 7. Exploration of deep geothermal reservoirs 8. Drilling technologies, piping and expansion 9. Borehole Geophysics 10. Underground system characterization and reservoir engineering 11. Microbiology and Upper-day system components 12. Adapted investment concepts, cost and environmental aspect
Literature	• Dipippo, R.: Geothermal Power Plants: Principles, Applications, Case Studies and Environmental Impact. Butterworth Heinemann; 3rd revised edition. (29. Mai 2012) • www.geo-energy.org • Edenhofer et al. (eds): Renewable Energy Sources and Climate Change Mitigation; Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2012. • Kaltschmitt et al. (eds): Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Springer, 5. Aufl. 2013. • Kaltschmitt et al. (eds): Energie aus Erdwärme. Spektrum Akademischer Verlag; Auflage: 1999 (3. September 2001) • Huenges, E. (ed.): Geothermal Energy Systems: Exploration, Development, and Utilization. Wiley-VCH Verlag GmbH & Co. KGaA; Auflage: 1. Auflage (19. April 2010)

Module M0518: Waste and Energy

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Waste Recycling Technologies (L0047)	Lecture	2	2
Waste Recycling Technologies (L0048)	Recitation Section (small)	1	2
Waste to Energy (L0049)	Project-/problem-based Learning	2	2

Module Responsible	Prof. Kerstin Kuchta
Admission Requirements	None
Recommended Previous Knowledge	Basics of process engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe and explain in detail techniques, processes and concepts for treatment and energy recovery from wastes.
Skills	The students are able to select suitable processes for the treatment and energy recovery of wastes. They can evaluate the efforts and costs for processes and select economically feasible treatment Concepts. Students are able to evaluate alternatives even with incomplete information. Students are able to prepare systematic documentation of work results in form of reports, presentations and are able to defend their findings in a group.
Personal Competence	
Social Competence	Students can participate in subject-specific and interdisciplinary discussions, develop cooperated solutions and defend their own work results in front of others and promote the scientific development of collegues. Furthermore, they can give and accept professional constructive criticism.
Autonomy	Students can independently tap knowledge of the subject area and transform it to new questions. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** Yes · **Bonus** 20 % · **Form** Written elaboration · **Description**
Examination	Presentation
Examination duration and scale	PowerPoint presentation (10-15 minutes)
Assignment for the Following Curricula	Environmental Engineering: Specialisation Energy and Resources: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Joint European Master in Environmental Studies - Cities and Sustainability: Core Qualification: Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory

Course L0047: Waste Recycling Technologies

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	SoSe
Content	• Fundamentals on primary and secondary production of raw materials (steel, aluminum, phosphorous, copper, precious metals, rare metals) • Use and demand of metals and minerals in industry and society • collection systems and concepts • quota and efficiency • Advanced sorting technologies • mechanical pretreatment • advanced treatment • Chemical analysis of Critical Materials in post-consumer products • Analytical tools in Resource Management (Material Flow Analysis, Recycling Performance Indicators, Criticality Assessment, statistical analysis of uncertainties)
Literature	

Course L0048: Waste Recycling Technologies	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	SoSe
Content	• Fundamentals on primary and secondary production of raw materials (steel, aluminum, phosphorous, copper, precious metals, rare metals) • Use and demand of metals and minerals in industry and society • collection systems and concepts • quota and efficiency • Advanced sorting technologies • mechanical pretreatment • advanced treatment • Chemical analysis of Critical Materials in post-consumer products • Analytical tools in Resource Management (Material Flow Analysis, Recycling Performance Indicators, Criticality Assessment, statistical analysis of uncertainties)
Literature	

Course L0049: Waste to Energy	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Rüdiger Siechau
Language	EN
Cycle	SoSe

Content	• Project-based lecture
	• Introduction into the " Waste to Energy " consisting of:
	  ◦ Thermal Process (incinerator , RDF combustion)
	  ◦ Biological processes (Wet-/Dryfermentation)
	  ◦ technology , energy , emissions, approval , etc.
	• Group work
	  ◦ design of systems/plants for energy recovery from waste
	  ◦ The following points are to be processed :
	    ▪ Input: waste (fraction collection and transportation, current quantity , material flows , possible amount of development)
	    ▪ Plant (design, process diagram , technology, energy production)
	    ▪ Output (energy quantity / type , by-products)
	    ▪ Costs and revenues
	    ▪ Climate and resource protection (CO2 balance , substitution of primary raw materials / fossil fuels)
	    ▪ Location and approval (infrastructure , expiration authorization procedure)
	    ▪ Focus at the whole concept (advantages, disadvantages , risks and opportunities , discussion)
	• Grading: No Exam , but presentation of the results of the working group

Literature	**Literatur:** Einführung in die Abfallwirtschaft; Martin Kranert, Klaus Cord-Landwehr (Hrsg.); Vieweg + Teubner Verlag; 2010 Powerpoint-Folien in Stud IP **Literature:** Introduction to Waste Management; Kranert Martin , Klaus Cord - Landwehr (Ed.), Vieweg + Teubner Verlag , 2010 PowerPoint slides in Stud IP

Module M0749: Waste Treatment and Solid Matter Process Technology

Courses

Title	Typ	Hrs/wk	CP
Solid Matter Process Technology for Biomass (L0052)	Lecture	2	2
Thermal Waste Treatment (L0320)	Lecture	2	2
Thermal Waste Treatment (L1177)	Recitation Section (large)	1	2

Module Responsible	Prof. Kerstin Kuchta
Admission Requirements	None
Recommended Previous Knowledge	Basics of • thermo dynamics • fluid dynamics • chemistry
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can name, describe current issue and problems in the field of thermal waste treatment and particle process engineering and contemplate them in the context of their field. The industrial application of unit operations as part of process engineering is explained by actual examples of waste incineration technologies and solid biomass processes. Compostion, particle sizes, transportation and dosing, drying and agglomeration of renewable resources and wastes are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, electricity , heat and mineral recyclables.
Skills	The students are able to select suitable processes for the treatment of wastes or raw material with respect to their characteristics and the process aims. They can evaluate the efforts and costs for processes and select economically feasible treatment concepts.
Personal Competence	
Social Competence	Students can • respectfully work together as a team and discuss technical tasks • participate in subject-specific and interdisciplinary discussions, • develop cooperated solutions • promote the scientific development and accept professional constructive criticism.
Autonomy	Students can independently tap knowledge of the subject area and transform it to new questions. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory

Course L0052: Solid Matter Process Technology for Biomass	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Werner Sitzmann
Language	DE
Cycle	SoSe
Content	The industrial application of unit operations as part of process engineering is explained by actual examples of solid biomass processes. Size reduction, transportation and dosing, drying and agglomeration of renewable resources are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, when making Btl - and WPC - products. Aspects of explosion protection and plant design complete the lecture.
Literature	Kaltschmitt M., Hartmann H. (Hrsg.): Energie aus Bioamsse, Springer Verlag, 2001, ISBN 3-540-64853-4 Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, Schriftenreihe Nachwachsende Rohstoffe, Fachagentur Nachwachsende Rohstoffe e.V. www.nachwachsende-rohstoffe.de Bockisch M.: Nahrungsfette und -öle, Ulmer Verlag, 1993, ISBN 380000158175

Course L0320: Thermal Waste Treatment	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	SoSe
Content	• Introduction, actual state-of-the-art of waste incineration, aims. legal background, reaction principals • basics of incineration processes: waste composition, calorific value, calculation of air demand and flue gas composition • Incineration techniques: grate firing, ash transfer, boiler • Flue gas cleaning: Volume, composition, legal frame work and emission limits, dry treatment, scrubber, de-nox techniques, dioxin elimination, Mercury elimination • Ash treatment: Mass, quality, treatment concepts, recycling, disposal
Literature	Thomé-Kozmiensky, K. J. (Hrsg.): Thermische Abfallbehandlung Bande 1-7. EF-Verlag für Energie- und Umwelttechnik, Berlin, 196 - 2013.

Course L1177: Thermal Waste Treatment	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1878: Sustainable energy from wind and water

Courses

Title	Typ	Hrs/wk	CP
Offshore Geotechnical Engineering (L0067)	Lecture	1	1
Hydro Power Use (L0013)	Lecture	1	1
Wind Turbine Plants (L0011)	Lecture	2	3
Wind Energy Use - Focus Offshore (L0012)	Lecture	1	1

Module Responsible	Dr. Marvin Scherzinger
Admission Requirements	None
Recommended Previous Knowledge	Module: Technical Thermodynamics I, Module: Technical Thermodynamics II, Module: Fundamentals of Fluid Mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	By ending this module students can explain in detail knowledge of wind turbines with a particular focus of wind energy use in offshore conditions and can critical comment these aspects in consideration of current developments. Furthermore, they are able to describe fundamentally the use of water power to generate electricity. The students reproduce and explain the basic procedure in the implementation of renewable energy projects in countries outside Europe. Through active discussions of various topics within the seminar of the module, students improve their understanding and the application of the theoretical background and are thus able to transfer what they have learned in practice.
Skills	Students are able to apply the acquired theoretical foundations on exemplary water or wind power systems and evaluate and assess technically the resulting relationships in the context of dimensioning and operation of these energy systems. They can in compare critically the special procedure for the implementation of renewable energy projects in countries outside Europe with the in principle applied approach in Europe and can apply this procedure on exemplary theoretical projects.
Personal Competence	
Social Competence	Students can discuss scientific tasks subjet-specificly and multidisciplinary within a seminar.
Autonomy	Students can independently exploit sources in the context of the emphasis of the lecture material to clear the contents of the lecture and to acquire the particular knowledge about the subject area.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Compulsory

Course L0067: Offshore Geotechnical Engineering	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Jan Dührkop
Language	DE
Cycle	SoSe
Content	• Overview and Introduction Offshore Geotechnics • Introduction to Soil Mechanics • Offshore soil investigation • Focus on cyclical effects • Geotechnical design of offshore foundations • Monopiles • Jackets • Heavyweight foundations • Geotechnical preliminary exploration for the use of lift boats and platforms
Literature	• Randolph, M. and Gourvenec, S (2011): Offshore Geotechnical Engineering. Spon Press. • Poulos H.G. (1988): Marine Geotechnics. Unwin Hyman, London • BSH-Standard Baugrunderkundung für Offshore-Windenergieparks • Lesny K. (2010): Foundations for Offshore Wind Turbines. VGE Verlag, Essen. • EA-Pfähle (2012): Empfehlungen des Arbeitskreises Pfähle der DGGT. Ernst & Sohn, Berlin.

Course L0013: Hydro Power Use	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Stefan Achleitner
Language	DE
Cycle	SoSe
Content	• Introduction, importance of water power in the national and global context • Physical basics: Bernoulli's equation, usable height of fall, hydrological measures, loss mechanisms, efficiencies • Classification of Hydropower: Flow and Storage hydropower, low and high pressure systems • Construction of hydroelectric power plants: description of the individual components and their technical system interaction • Structural engineering components; representation of dams, weirs, dams, power houses, computer systems, etc. • Energy Technical Components: Illustration of the different types of hydraulic machinery, generators and grid connection • Hydropower and the Environment • Examples from practice
Literature	• Schröder, W.; Euler, G.; Schneider, K.: Grundlagen des Wasserbaus; Werner, Düsseldorf, 1999, 4. Auflage • Quaschning, V.: Regenerative Energiesysteme: Technologie - Berechnung - Simulation; Carl Hanser, München, 2011, 7. Auflage • Giesecke, J.; Heimerl, S.; Mosony, E.: Wasserkraftanlagen - Planung, Bau und Betrieb; Springer, Berlin, Heidelberg, 2009, 5. Auflage • von König, F.; Jehle, C.: Bau von Wasserkraftanlagen - Praxisbezogene Planungsunterlagen; C. F. Müller, Heidelberg, 2005, 4. Auflage • Strobl, T.; Zunic, F.: Wasserbau: Aktuelle Grundlagen - Neue Entwicklungen; Springer, Berlin, Heidelberg, 2006

Course L0011: Wind Turbine Plants	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Rudolf Zellermann
Language	DE
Cycle	SoSe
Content	• Historical development • Wind: origins, geographic and temporal distribution, locations • Power coefficient, rotor thrust • Aerodynamics of the rotor • Operating performance • Power limitation, partial load, pitch and stall control • Plant selection, yield prediction, economy • Excursion
Literature	Gasch, R., Windkraftanlagen, 4. Auflage, Teubner-Verlag, 2005

Course L0012: Wind Energy Use - Focus Offshore	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Martin Skiba
Language	DE
Cycle	SoSe
Content	• Introduction, importance of offshore wind power generation, Specific requirements for offshore engineering • Physical fundamentals for utilization of wind energy • Design and operation of offshore wind turbines, presentation of different concepts of offshore wind turbines, representation of the individual system components and their system-technical relationships • Foundation engineering, offshore site investigation, presentation of different concepts of offshore foundation structures, planning and fabrication of foundation structures • Electrical infrastructure of an offshore wind farm, Inner Park cabling, offshore substation, grid connection • Installation of offshore wind farms, installation techniques and auxiliary devices, construction logistics • Development and planning of offshore wind farms • Operation and optimization of offshore wind farms • Day excursion
Literature	• Gasch, R.; Twele, J.: Windkraftanlagen - Grundlagen, Entwurf, Planung und Betrieb; Vieweg + Teubner, Stuttgart, 2007, 7. Auflage • Molly, J. P.: Windenergie - Theorie, Anwendung, Messung; C. F. Müller, Heidel-berg, 1997, 3. Auflage • Hau, E.: Windkraftanalagen; Springer, Berlin, Heidelberg, 2008, 4.Auflage • Heier, S.: Windkraftanlagen - Systemauslegung, Integration und Regelung; Vieweg + Teubner, Stuttgart, 2009, 5. Auflage • Jarass, L.; Obermair, G.M.; Voigt, W.: Windenergie: Zuverlässige Integration in die Energieversorgung; Springer, Berlin, Heidelberg, 2009, 2. Auflage

Module M0508: Fluid Mechanics and Ocean Energy

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Energy from the Ocean (L0002)	Lecture	2	2
Fluid Mechanics II (L0001)	Lecture	2	4

Module Responsible	Prof. Michael Schlüter
Admission Requirements	None
Recommended Previous Knowledge	Technische Thermodynamik I-II Wärme- und Stoffübertragung
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to describe different applications of fluid mechanics for the field of Renewable Energies. They are able to use the fundamentals of fluid mechanics for calculations of certain engineering problems in the field of ocean energy. The students are able to estimate if a problem can be solved with an analytical solution and what kind of alternative possibilities are available (e.g. self-similarity, empirical solutions, numerical methods).
Skills	Students are able to use the governing equations of Fluid Dynamics for the design of technical processes. Especially they are able to formulate momentum and mass balances to optimize the hydrodynamics of technical processes. They are able to transform a verbal formulated message into an abstract formal procedure.
Personal Competence	
Social Competence	The students are able to discuss a given problem in small groups and to develop an approach. They are able to solve a problem within a team, to prepare a poster with the results and to present the poster.
Autonomy	Students are able to define independently tasks for problems related to fluid mechanics. They are able to work out the knowledge that is necessary to solve the problem by themselves on the basis of the existing knowledge from the lecture.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	**Compulsory**: No; **Bonus**: 10 %; **Form**: Group discussion; **Description**:
Examination	Written exam
Examination duration and scale	3h
Assignment for the Following Curricula	Energy Systems: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory

Course L0002: Energy from the Ocean

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Moustafa Abdel-Maksoud
Language	DE
Cycle	WiSe

Content

1. Introduction to ocean energy conversion
2. Wave properties
   - Linear wave theory
   - Nonlinear wave theory
   - Irregular waves
   - Wave energy
   - Refraction, reflection and diffraction of waves
3. Wave energy converters
   - Overview of the different technologies
   - Methods for design and calculation
4. Ocean current turbine

Literature

- Cruz, J., Ocean wave energy, Springer Series in Green Energy and Technology, UK, 2008.
- Brooke, J., Wave energy conversion, Elsevier, 2003.
- McCormick, M.E., Ocean wave energy conversion, Courier Dover Publications, USA, 2013.
- Falnes, J., Ocean waves and oscillating systems, Cambridge University Press,UK, 2002.
- Charlier, R. H., Charles, W. F., Ocean energy. Tide and tidal Power. Berlin, Heidelberg, 2009.
- Clauss, G. F., Lehmann, E., Östergaard, C., Offshore Structures. Volume 1, Conceptual Design. Springer-Verlag, Berlin 1992

Course L0001: Fluid Mechanics II	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	DE
Cycle	WiSe
Content	• Differential equations for momentum-, heat and mass transfer • Examples for simplifications of the Navier-Stokes Equations • Unsteady momentum transfer • Free shear layer, turbulence and free jets • Flow around particles - Solids Process Engineering • Coupling of momentum and heat transfer - Thermal Process Engineering • Rheology – Bioprocess Engineering • Coupling of momentum- and mass transfer – Reactive mixing, Chemical Process Engineering • Flow threw porous structures - heterogeneous catalysis • Pumps and turbines - Energy- and Environmental Process Engineering • Wind- and Wave-Turbines - Renewable Energy • Introduction into Computational Fluid Dynamics
Literature	1. Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971. 2. Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion. Frankfurt: Sauerländer 1972. 3. Crowe, C. T.: Engineering fluid mechanics. Wiley, New York, 2009. 4. Durst, F.: Strömungsmechanik: Einführung in die Theorie der Strömungen von Fluiden. Springer-Verlag, Berlin, Heidelberg, 2006. 5. Fox, R.W.; et al.: Introduction to Fluid Mechanics. J. Wiley & Sons, 1994. 6. Herwig, H.: Strömungsmechanik: Eine Einführung in die Physik und die mathematische Modellierung von Strömungen. Springer Verlag, Berlin, Heidelberg, New York, 2006. 7. Herwig, H.: Strömungsmechanik: Einführung in die Physik von technischen Strömungen: Vieweg+Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2008. 8. Kuhlmann, H.C.: Strömungsmechanik. München, Pearson Studium, 2007 9. Oertl, H.: Strömungsmechanik: Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele. Vieweg+ Teubner / GWV Fachverlage GmbH, Wiesbaden, 2009. 10. Schade, H.; Kunz, E.: Strömungslehre. Verlag de Gruyter, Berlin, New York, 2007. 11. Truckenbrodt, E.: Fluidmechanik 1: Grundlagen und elementare Strömungsvorgänge dichtebeständiger Fluide. Springer-Verlag, Berlin, Heidelberg, 2008. 12. Schlichting, H. : Grenzschicht-Theorie. Springer-Verlag, Berlin, 2006. 13. van Dyke, M.: An Album of Fluid Motion. The Parabolic Press, Stanford California, 1882.

Module M1294: Bioenergy

Courses

Title	Typ	Hrs/wk	CP
Biofuels Process Technology (L0061)	Lecture	1	1
Biofuels Process Technology (L0062)	Recitation Section (small)	1	1
World Market for Commodities from Agriculture and Forestry (L1769)	Lecture	1	1
Thermal Biomass Utilization (L1767)	Lecture	2	2
Thermal Biomass Utilization (L2386)	Practical Course	1	1

Module Responsible	Prof. Martin Kaltschmitt
Admission Requirements	None
Recommended Previous Knowledge	none
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to reproduce an in-depth outline of energy production from biomass, aerobic and anaerobic waste treatment processes, the gained products and the treatment of produced emissions.
Skills	Students can apply the learned theoretical knowledge of biomass-based energy systems to explain relationships for different tasks, like dimesioning and design of biomass power plants. In this context, students are also able to solve computational tasks for combustion, gasification and biogas, biodiesel and bioethanol use.
Personal Competence	
Social Competence	Students can participate in discussions to design and evaluate energy systems using biomass as an energy source.
Autonomy	Students can independently exploit sources with respect to the emphasis of the lectures. They can choose and aquire the for the particular task useful knowledge. Furthermore, they can solve computational tasks of biomass-based energy systems independently with the assistance of the lecture. Regarding to this they can assess their specific learning level and can consequently define the further workflow.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	See table below
Examination	Written exam
Examination duration and scale	3 hours written exam
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Energy Systems: Specialisation Energy Systems: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory

Course achievement:

Compulsory	Bonus	Form	Description
Yes	None	Subject theoretical and practical work	
No	10 %	Presentation	

Course L0061: Biofuels Process Technology	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Oliver Lüdtke
Language	DE
Cycle	WiSe

Content	• General introduction
	• What are biofuels?
	• Markets & trends
	• Legal framework
	• Greenhouse gas savings
	• Generations of biofuels
	  ◦ first-generation bioethanol
	    ▪ raw materials
	    ▪ fermentation distillation
	  ◦ biobutanol / ETBE
	  ◦ second-generation bioethanol
	    ▪ bioethanol from straw
	  ◦ first-generation biodiesel
	    ▪ raw materials
	    ▪ Production Process
	    ▪ Biodiesel & Natural Resources
	  ◦ HVO / HEFA
	  ◦ second-generation biodiesel
	    ▪ Biodiesel from Algae
	• Biogas as fuel
	  ◦ the first biogas generation
	    ▪ raw materials
	    ▪ fermentation
	    ▪ purification to biomethane
	  ◦ Biogas second generation and gasification processes
	• Methanol / DME from wood and Tall oil ©

Literature	• Skriptum zur Vorlesung • Drapcho, Nhuan, Walker; Biofuels Engineering Process Technology • Harwardt; Systematic design of separations for processing of biorenewables • Kaltschmitt; Hartmann; Energie aus Biomasse: Grundlagen, Techniken und Verfahren • Mousdale; Biofuels - Biotechnology, Chemistry and Sustainable Development • VDI Wärmeatlas

Course L0062: Biofuels Process Technology	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Oliver Lüdtke
Language	DE
Cycle	WiSe

Content	• Life Cycle Assessment
	  ◦ Good example for the evaluation of CO2 savings potential by alternative fuels - Choice of system boundaries and databases
	• Bioethanol production
	  ◦ Application task in the basics of thermal separation processes (rectification, extraction) will be discussed. The focus is on a column design, including heat demand, number of stages, reflux ratio ...
	• Biodiesel production
	  ◦ Procedural options for solid / liquid separation, including basic equations for estimating power, energy demand, selectivity and throughput
	• Biomethane production
	  ◦ Chemical reactions that are relevant in the production of biofuels, including equilibria, activation energies, shift reactions

Literature	Skriptum zur Vorlesung

Course L1769: World Market for Commodities from Agriculture and Forestry	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Michael Köhl, Bernhard Chilla
Language	DE
Cycle	WiSe
Content	1) Markets for Agricultural Commodities What are the major markets and how are markets functioning Recent trends in world production and consumption. World trade is growing fast. Logistics. Bottlenecks. The major countries with surplus production Growing net import requirements, primarily of China, India and many other countries. Tariff and non-tariff market barriers. Government interferences. 2) Closer Analysis of Individual Markets Thomas Mielke will analyze in more detail the global vegetable oil markets, primarily palm oil, soya oil, rapeseed oil, sunflower oil. Also the raw material (the oilseed) as well as the by-product (oilmeal) will be included. The major producers and consumers. Vegetable oils and oilmeals are extracted from the oilseed. The importance of vegetable oils and animal fats will be highlighted, primarily in the food industry in Europe and worldwide. But in the past 15 years there have also been rapidly rising global requirements of oils & fats for non-food purposes, primarily as a feedstock for biodiesel but also in the chemical industry. Importance of oilmeals as an animal feed for the production of livestock and aquaculture Oilseed area, yields per hectare as well as production of oilseeds. Analysis of the major oilseeds worldwide. The focus will be on soybeans, rapeseed, sunflowerseed, groundnuts and cottonseed. Regional differences in productivity. The winners and losers in global agricultural production. 3) Forecasts: Future Global Demand & Production of Vegetable Oils Big challenges in the years ahead: Lack of arable land for the production of oilseeds, grains and other crops. Competition with livestock. Lack of water. What are possible solutions? Need for better education & management, more mechanization, better seed varieties and better inputs to raise yields. The importance of prices and changes in relative prices to solve market imbalances (shortage situations as well as surplus situations). How does it work? Time lags. Rapidly rising population, primarily the number of people considered “middle class” in the years ahead. Higher disposable income will trigger changing diets in favour of vegetable oils and livestock products. Urbanization. Today, food consumption per caput is partly still very low in many developing countries, primarily in Africa, some regions of Asia and in Central America. What changes are to be expected? The myth and the realities of palm oil in the world of today and tomorrow. Labour issues curb production growth: Some examples: 1) Shortage of labour in oil palm plantations in Malaysia. 2) Structural reforms overdue for the agriculture in India, China and other countries to become more productive and successful, thus improving the standard of living of smallholders.
Literature	Lecture material

Course L1767: Thermal Biomass Utilization	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Martin Kaltschmitt
Language	DE
Cycle	WiSe

Content	Goal of this course is it to discuss the physical, chemical, and biological as well as the technical, economic, and environmental basics of all options to provide energy from biomass from a German and international point of view. Additionally different system approaches to use biomass for energy, aspects to integrate bioenergy within the energy system, technical and economic development potentials, and the current and expected future use within the energy system are presented.
	
	The course is structured as follows:
	
	• Biomass as an energy carrier within the energy system; use of biomass in Germany and world-wide, overview on the content of the course
	• Photosynthesis, composition of organic matter, plant production, energy crops, residues, organic waste
	• Biomass provision chains for woody and herbaceous biomass, harvesting and provision, transport, storage, drying
	• Thermo-chemical conversion of solid biofuels
	    ◦ Basics of thermo-chemical conversion
	    ◦ Direct thermo-chemical conversion through combustion: combustion technologies for small and large scale units, electricity generation technologies, flue gas treatment technologies, ashes and their use
	    ◦ Gasification: Gasification technologies, producer gas cleaning technologies, options to use the cleaned producer gas for the provision of heat, electricity and/or fuels
	    ◦ Fast and slow pyrolysis: Technologies for the provision of bio-oil and/or for the provision of charcoal, oil cleaning technologies, options to use the pyrolysis oil and charcoal as an energy carrier as well as a raw material
	• Physical-chemical conversion of biomass containing oils and/or fats: Basics, oil seeds and oil fruits, vegetable oil production, production of a biofuel with standardized characteristics (trans-esterification, hydrogenation, co-processing in existing refineries), options to use this fuel, options to use the residues (i.e. meal, glycerine)
	• Bio-chemical conversion of biomass
	    ◦ Basics of bio-chemical conversion
	    ◦ Biogas: Process technologies for plants using agricultural feedstock, sewage sludge (sewage gas), organic waste fraction (landfill gas), technologies for the provision of bio methane, use of the digested slurry
	    ◦ Ethanol production: Process technologies for feedstock containing sugar, starch or celluloses, use of ethanol as a fuel, use of the stillage

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

Course L2386: Thermal Biomass Utilization	
Typ	Practical Course
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Martin Kaltschmitt, Dr. Marvin Scherzinger
Language	DE
Cycle	WiSe
Content	The experiments of the practical lab course illustrate the different aspects of heat generation from biogenic solid fuels. First, different biomasses (e.g. wood, straw or agricultural residues) will be investigated; the focus will be on the calorific value of the biomass. Furthermore, the used biomass will be pelletized, the pellet properties analysed and a combustion test carried out on a pellet combustion system. The gaseous and solid pollutant emissions, especially the particulate matter emissions, are measured and the composition of the particulate matter is investigated in a further experiment. Another focus of the practical course is the consideration of options for the reduction of particulate matter emissions from biomass combustion. In the practical course, a method for particulate matter reduction will be developed and tested. All experiments will be evaluated and the results presented. Within the practical lab course the students discuss different technical-scientific tasks, both subject-specifically and interdisciplinary. They discuss various approaches to solving the problem and advise on the theoretical or practical implementation.
Literature	- Kaltschmitt, Martin; Hartmann, Hans; Hofbauer, Hermann: Energie aus Biomasse: Grundlagen, Techniken und Verfahren. 3. Auflage. Berlin Heidelberg: Springer Science & Business Media, 2016. -ISBN 978-3-662-47437-2 - Versuchsskript

Specialization II. Process Engineering and Biotechnology

Module M0513: System Aspects of Renewable Energies

Courses

Title	Typ	Hrs/wk	CP
Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage (L0021)	Lecture	2	2
Energy Trading (L0019)	Lecture	1	1
Energy Trading (L0020)	Recitation Section (small)	1	1
Deep Geothermal Energy (L0025)	Lecture	2	2

Module Responsible	Prof. Martin Kaltschmitt
Admission Requirements	None
Recommended Previous Knowledge	Module: Technical Thermodynamics I Module: Technical Thermodynamics II
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe the processes in energy trading and the design of energy markets and can critically evaluate them in relation to current subject specific problems. Furthermore, they are able to explain the basics of thermodynamics of electrochemical energy conversion in fuel cells and can establish and explain the relationship to different types of fuel cells and their respective structure. Students can compare this technology with other energy storage options. In addition, students can give an overview of the procedure and the energetic involvement of deep geothermal energy.
Skills	Students can apply the learned knowledge of storage systems for excessive energy to explain for various energy systems different approaches to ensure a secure energy supply. In particular, they can plan and calculate domestic, commercial and industrial heating equipment using energy storage systems in an energy-efficient way and can assess them in relation to complex power systems. In this context, students can assess the potential and limits of geothermal power plants and explain their operating mode. Furthermore, the students are able to explain the procedures and strategies for marketing of energy and apply it in the context of other modules on renewable energy projects. In this context they can unassistedly carry out analysis and evaluations of energie markets and energy trades.
Personal Competence	
Social Competence	Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module.
Autonomy	Students can independently exploit sources , acquire the particular knowledge about the subject area and transform it to new questions.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	3 hours written exam
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Aeronautics: Core Qualification: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory

Course L0021: Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Fröba
Language	DE
Cycle	SoSe
Content	1. Introduction to electrochemical energy conversion 2. Function and structure of electrolyte 3. Low-temperature fuel cell ◦ Types ◦ Thermodynamics of the PEM fuel cell ◦ Cooling and humidification strategy 4. High-temperature fuel cell ◦ The MCFC ◦ The SOFC ◦ Integration Strategies and partial reforming 5. Fuels ◦ Supply of fuel ◦ Reforming of natural gas and biogas ◦ Reforming of liquid hydrocarbons 6. Energetic Integration and control of fuel cell systems
Literature	• Hamann, C.; Vielstich, W.: Elektrochemie 3. Aufl.; Weinheim: Wiley - VCH, 2003

Course L0019: Energy Trading	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Michael Sagorje, Dr. Sven Orlowski
Language	DE
Cycle	SoSe
Content	• Basic concepts and tradable products in energy markets • Primary energy markets • Electricity Markets • European Emissions Trading Scheme • Influence of renewable energy • Real options • Risk management Within the exercise the various tasks are actively discussed and applied to various cases of application.
Literature	

Course L0020: Energy Trading	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Michael Sagorje, Dr. Sven Orlowski
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0025: Deep Geothermal Energy	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Ben Norden
Language	DE
Cycle	SoSe
Content	1. Introduction to the deep geothermal use 2. Geological Basics I 3. Geological Basics II 4. Geology and thermal aspects 5. Rock Physical Aspects 6. Geochemical aspects 7. Exploration of deep geothermal reservoirs 8. Drilling technologies, piping and expansion 9. Borehole Geophysics 10. Underground system characterization and reservoir engineering 11. Microbiology and Upper-day system components 12. Adapted investment concepts, cost and environmental aspect
Literature	• Dipippo, R.: Geothermal Power Plants: Principles, Applications, Case Studies and Environmental Impact. Butterworth Heinemann; 3rd revised edition. (29. Mai 2012) • www.geo-energy.org • Edenhofer et al. (eds): Renewable Energy Sources and Climate Change Mitigation; Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2012. • Kaltschmitt et al. (eds): Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Springer, 5. Aufl. 2013. • Kaltschmitt et al. (eds): Energie aus Erdwärme. Spektrum Akademischer Verlag; Auflage: 1999 (3. September 2001) • Huenges, E. (ed.): Geothermal Energy Systems: Exploration, Development, and Utilization. Wiley-VCH Verlag GmbH & Co. KGaA; Auflage: 1. Auflage (19. April 2010)

Module M0874: Wastewater Systems

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Biological Wastewater Treatment (L0517)	Lecture	2	2
Biological Wastewater Treatment (L3122)	Recitation Section (large)	1	1
Advanced Wastewater Treatment (L0357)	Lecture	2	2
Advanced Wastewater Treatment (L0358)	Recitation Section (large)	1	1

Module Responsible	Prof. Ralf Otterpohl
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of wastewater management and the key processes involved in wastewater treatment.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to outline key areas of the full range of treatment systems in waste water management, as well as their mutual dependence for sustainable water protection. They can describe relevant economic, environmental and social factors.
Skills	Students are able to pre-design and explain the available wastewater treatment processes and the scope of their application in municipal and for some industrial treatment plants.
Personal Competence	
Social Competence	Social skills are not targeted in this module.
Autonomy	Students are in a position to work on a subject and to organize their work flow independently. They can also present on this subject.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Structural Engineering: Elective Compulsory Civil Engineering: Specialisation Geotechnical Engineering: Elective Compulsory Civil Engineering: Specialisation Coastal Engineering: Elective Compulsory Civil Engineering: Specialisation Water and Traffic: Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Environmental Engineering: Specialisation Water Quality and Water Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Cities: Compulsory

Course L0517: Biological Wastewater Treatment

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Joachim Behrendt
Language	DE/EN
Cycle	SoSe
Content	Charaterisation of Wastewater Metobolism of Microorganisms Kinetic of mirobiotic processes Calculation of bioreactor for wastewater treatment Concepts of Wastewater treatment Design of WWTP Excursion to a WWTP Biofilms Biofim Reactors Anaerobic Wastewater and sldge treatment resources oriented sanitation technology Future challenges of wastewater treatment
Literature	**Gujer, Willi** Siedlungswasserwirtschaft : mit 84 Tabellen ISBN: 3540343296 (Gb.) URL: http://www.gbv.de/dms/bs/toc/516261924.pdf URL: http://deposit.d-nb.de/cgi-bin/dokserv?id=2842122&prov=M&dok_var=1&dok_ext=htm Berlin [u.a.] : Springer, 2007 TUB_HH_Katalog **Henze, Mogens**

Wastewater treatment : biological and chemical processes
ISBN: 3540422285 (Pp.)
Berlin [u.a.] : Springer, 2002
TUB_HH_Katalog
Imhoff, Karl (Imhoff, Klaus R.;)
Taschenbuch der Stadtentwässerung : mit 10 Tafeln
ISBN: 3486263331 ((Gb.))
München [u.a.] : Oldenbourg, 1999
TUB_HH_Katalog
Lange, Jörg (Otterpohl, Ralf; Steger-Hartmann, Thomas;)
Abwasser : Handbuch zu einer zukunftsfähigen Wasserwirtschaft
ISBN: 3980350215 (kart.) URL: http://www.gbv.de/du/services/agi/52567E5D44DA0809C12570220050BF25/000000700334
Donaueschingen-Pfohren : Mall-Beton-Verl., 2000
TUB_HH_Katalog
Mudrack, Klaus (Kunst, Sabine;)
Biologie der Abwasserreinigung : 18 Tabellen
ISBN: 382741427X URL: http://www.gbv.de/du/services/agi/94B581161B6EC747C1256E3F005A8143/420000114903
Heidelberg [u.a.] : Spektrum, Akad. Verl., 2003
TUB_HH_Katalog
Tchobanoglous, George (Metcalf & Eddy, Inc., ;)
Wastewater engineering : treatment and reuse
ISBN: 0070418780 (alk. paper) ISBN: 0071122508 (ISE (*pbk))
Boston [u.a.] : McGraw-Hill, 2003
TUB_HH_Katalog
Henze, Mogens
Activated sludge models ASM1, ASM2, ASM2d and ASM3
ISBN: 1900222248
London : IWA Publ., 2002
TUB_HH_Katalog
Kunz, Peter
Umwelt-Bioverfahrenstechnik
Vieweg, 1992
Bauhaus-Universität., Arbeitsgruppe Weiterbildendes Studium Wasser und Umwelt (Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall, ;)
Abwasserbehandlung : Gewässerbelastung, Bemessungsgrundlagen, Mechanische Verfahren, Biologische Verfahren, Reststoffe aus der Abwasserbehandlung, Kleinkläranlagen
ISBN: 3860682725 URL: http://www.gbv.de/dms/weimar/toc/513989765_toc.pdf URL: http://www.gbv.de/dms/weimar/abs/513989765_abs.pdf
Weimar : Universitätsverl, 2006
TUB_HH_Katalog
Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall
DWA-Regelwerk
Hennef : DWA, 2004
TUB_HH_Katalog
Wiesmann, Udo (Choi, In Su; Dombrowski, Eva-Maria;)
Fundamentals of biological wastewater treatment
ISBN: 3527312196 (Gb.) URL: http://deposit.ddb.de/cgi-bin/dokserv?id=2774611&prov=M&dok_var=1&dok_ext=htm
Weinheim : WILEY-VCH, 2007
TUB_HH_Katalog

Course L3122: Biological Wastewater Treatment	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Joachim Behrendt
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0357: Advanced Wastewater Treatment	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Joachim Behrendt
Language	EN
Cycle	SoSe
Content	Survey on advanced wastewater treatment reuse of reclaimed municipal wastewater Precipitation Flocculation Depth filtration Membrane Processes Activated carbon adsorption Ozonation "Advanced Oxidation Processes" Disinfection
Literature	Metcalf & Eddy, Wastewater Engineering: Treatment and Reuse, McGraw-Hill, Boston 2003 Wassertechnologie, H.H. Hahn, Springer-Verlag, Berlin 1987 Membranverfahren: Grundlagen der Modul- und Anlagenauslegung, T. Melin und R. Rautenbach, Springer-Verlag, Berlin 2007 Trinkwasserdesinfektion: Grundlagen, Verfahren, Anlagen, Geräte, Mikrobiologie, Chlorung, Ozonung, UV-Bestrahlung, Membranfiltration, Qualitätssicherung, W. Roeske, Oldenbourg-Verlag, München 2006 Organische Problemstoffe in Abwässern, H. Gulyas, GFEU, Hamburg 2003

Course L0358: Advanced Wastewater Treatment	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Joachim Behrendt
Language	EN
Cycle	SoSe
Content	Aggregate organic compounds (sum parameters) Industrial wastewater Processes for industrial wastewater treatment Precipitation Flocculation Activated carbon adsorption Recalcitrant organic compounds
Literature	Metcalf & Eddy, Wastewater Engineering: Treatment and Reuse, McGraw-Hill, Boston 2003 Wassertechnologie, H.H. Hahn, Springer-Verlag, Berlin 1987 Membranverfahren: Grundlagen der Modul- und Anlagenauslegung, T. Melin und R. Rautenbach, Springer-Verlag, Berlin 2007 Trinkwasserdesinfektion: Grundlagen, Verfahren, Anlagen, Geräte, Mikrobiologie, Chlorung, Ozonung, UV-Bestrahlung, Membranfiltration, Qualitätssicherung, W. Roeske, Oldenbourg-Verlag, München 2006 Organische Problemstoffe in Abwässern, H. Gulyas, GFEU, Hamburg 2003

Module M1335: BIO II: Artificial Joint Replacement

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Artificial Joint Replacement (L1306)	Lecture	2	3

Module Responsible	Prof. Michael Morlock
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of orthopedic and surgical techniques and mechanical basics is recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain the diseases and injuries that can make joint replacement necessary. In addition, students know the surgical alternatives.
Skills	The students can explain the advantages and disadvantages of different kinds of endoprotheses.
Personal Competence	
Social Competence	The students are able to discuss issues related to endoprothese with student mates and the teachers.
Autonomy	The students are able to acquire information on their own. They can also judge the information with respect to its credibility.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Orientation Studies: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L1306: Artificial Joint Replacement	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock
Language	DE
Cycle	SoSe
Content	Contents 1. INTRODUCTION (meaning, aim, basics, general history of the artificial joint replacement) 2. FUNCTIONAL ANALYSIS (The human gait, human work, sports activity) 3. THE HIP JOINT (anatomy, biomechanics, joint replacement of the shaft side and the socket side, evolution of implants) 4. THE KNEE JOINT (anatomy, biomechanics, ligament replacement, joint replacement femoral, tibial and patellar components) 5. THE FOOT (anatomy, biomechanics, joint replacement, orthopedic procedures) 6. THE SHOULDER (anatomy, biomechanics, joint replacement) 7. THE ELBOW (anatomy, biomechanics, joint replacement) 8. THE HAND (anatomy, biomechanics, joint replacement) 9. TRIBOLOGY OF NATURAL AND ARTIFICIAL JOINTS (corrosion, friction, wear)
Literature	Kapandji, I..: Funktionelle Anatomie der Gelenke (Band 1-4), Enke Verlag, Stuttgart, 1984. Nigg, B., Herzog, W.: Biomechanics of the musculo-skeletal system, John Wiley&Sons, New York 1994 Nordin, M., Frankel, V.: Basic Biomechanics of the Musculoskeletal System, Lea&Febiger, Philadelphia, 1989. Czichos, H.: Tribologiehandbuch, Vieweg, Wiesbaden, 2003. Sobotta und Netter für Anatomie der Gelenke

Module M0617: High Pressure Chemical Engineering

Courses

Title	Typ	Hrs/wk	CP
High pressure plant and vessel design (L1278)	Lecture	2	2
Industrial Processes Under High Pressure (L0116)	Lecture	2	2
Advanced Separation Processes (L0094)	Lecture	2	2

Module Responsible	Dr. Monika Johannsen
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of Chemistry, Chemical Engineering, Fluid Process Engineering, Thermal Separation Processes, Thermodynamics, Heterogeneous Equilibria
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After a successful completion of this module, students can: • explain the influence of pressure on the properties of compounds, phase equilibria, and production processes, • describe the thermodynamic fundamentals of separation processes with supercritical fluids, • exemplify models for the description of solid extraction and countercurrent extraction, • discuss parameters for optimization of processes with supercritical fluids.
Skills	After successful completion of this module, students are able to: • compare separation processes with supercritical fluids and conventional solvents, • assess the application potential of high-pressure processes at a given separation task, • include high pressure methods in a given multistep industrial application, • estimate economics of high-pressure processes in terms of investment and operating costs, • perform an experiment with a high pressure apparatus under guidance, • evaluate experimental results, • prepare an experimental protocol.
Personal Competence	
Social Competence	After successful completion of this module, students are able to: • present a scientific topic from an original publication in teams of 2 and defend the contents together.
Autonomy	
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** Yes; **Bonus** 15 %; **Form** Presentation; **Description**
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L1278: High pressure plant and vessel design	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Hans Häring
Language	DE/EN
Cycle	SoSe
Content	1. Basic laws and certification standards 2. Basics for calculations of pressurized vessels 3. Stress hypothesis 4. Selection of materials and fabrication processes 5. vessels with thin walls 6. vessels with thick walls 7. Safety installations 8. Safety analysis Applications: - subsea technology (manned and unmanned vessels) - steam vessels - heat exchangers - LPG, LEG transport vessels
Literature	Apparate und Armaturen in der chemischen Hochdrucktechnik, Springer Verlag Spain and Paauwe: High Pressure Technology, Vol. I und II, M. Dekker Verlag AD-Merkblätter, Heumanns Verlag Bertucco; Vetter: High Pressure Process Technology, Elsevier Verlag Sherman; Stadtmuller: Experimental Techniques in High-Pressure Research, Wiley & Sons Verlag Klapp: Apparate- und Anlagentechnik, Springer Verlag

Course L0116: Industrial Processes Under High Pressure	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Carsten Zetzl
Language	EN
Cycle	SoSe
Content	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 Learning Outcomes: After a successful completion of this module, the student should be able to - understand of the influences of pressure on properties of compounds, phase equilibria, and production processes. - Apply high pressure approches in the complex process design tasks - Estimate Efficiency of high pressure alternatives with respect to investment and operational costs Performance Record: 1. Presence (28 h) 2. Oral presentation of original scientific article (15 min) with written summary 3. Written examination and Case study (2+3 : 32 h Workload) Workload: 60 hours total
Literature	Literatur: 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 L0094: Advanced Separation Processes	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Monika Johannsen
Language	EN
Cycle	SoSe
Content	• 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)
Literature	G. Brunner: Gas Extraction. An Introduction to Fundamentals of Supercritical Fluids and the Application to Separation Processes. Steinkopff, Darmstadt, Springer, New York, 1994.

Module M1179: Medical Basics and Pathology

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Medical Basics and Pathology I (L1599)	Lecture	2	2
Medical Basics and Pathology II (L1600)	Lecture	2	2
Medical Basics and Pathology III (L1602)	Lecture	2	2

Module Responsible	Dr. Peter Hübener
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 minutes
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Biomedical Engineering: Core Qualification: Compulsory

Course L1599: Medical Basics and Pathology I

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Julian Schulze zur Wiesch
Language	DE
Cycle	SoSe
Content	Upon successful completion of the course, participants should be able to describe the foundations of the organization of the German health system and to describe different ways of treatment in the hospital. They should be able to describe the anatomy, physiology and basic diagnostic possibilities for the following organ system: heart / circulatory system, lungs, digestive tract, kidney, including the technical possibilities of monitoring heart-lung function, in the emergency department,in the monitoring stations and in intensive care and the basics of cardiopulmonary resuscitation. Furthermore, the anatomy and physiology of the nervous system will be explored. The importance and possibilities of preventive medicine of serious public health problems are described. Students prepare their own sub-themes in the form of small lectures and discuss various clinical cases on these topics interactively as problem-based learning.This course/Lecture by excursions into our emergency room, our endoscopy unit, mini-laparoscopy and our ICU as well as out patient clinics.
Literature	Wird in der Veranstaltung bekannt gegeben

Course L1600: Medical Basics and Pathology II	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Johannes Kluwe
Language	DE
Cycle	WiSe
Content	Major diseases of • the gastrointestinal system and the liver, • the hormone system, • the kidneys. The lecture will focus on pathophysiology, symptoms, diagnostic and therapeutic principles of these diseases. I Gastrointestinal tract and liver: • Gastrointestinal bleeding: causes, symptoms, endoscopic treatment options • Colorectal cancer: basics, principle of prophylactic screening, therapy • Liver diseases / liver cirrhosis: causes, symptoms, complications, therapeutic options II Hormones: • Diabetes mellitus type 1 and 2: pathophysiology, complications, basics of glucose metabolism, therapeutic principles • Thyroid gland - hyper- and hypothyreoidism: causes, symptoms diagnostics, therapy III Kidneys • Functions and failure, diagnostics, principles of renal replacement therapy
Literature	Wird in der Veranstaltung bekannt gegeben

Course L1602: Medical Basics and Pathology III	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Kevin Roedl
Language	DE
Cycle	WiSe
Content	a) Basic understanding of the pathology/pathophysiology of cardiac diseases and their stage-adapted treatments: coronary heart disease, myocardial infarction, mitral valve insufficiencies, aortic valve stenosis b) Basic understanding of the pathology/pathophysiology of pulmonary diseases and their stage-adapted treatments: asthma, chronic obstructive pulmonary disease, pneumonia, bronchial cancer c) Basic understanding of infectious diseases, immune-system and autoimmune diseases
Literature	Skript zur Vorlesung.

Module M0914: Technical Microbiology

Courses

Title	Typ	Hrs/wk	CP
Applied Molecular Biology (L0877)	Lecture	2	3
Technical Microbiology (L0999)	Lecture	2	2
Technical Microbiology (L1000)	Recitation Section (large)	1	1

Module Responsible	Prof. Johannes Gescher
Admission Requirements	None
Recommended Previous Knowledge	Bachelor with basic knowledge in microbiology and genetics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After successfully finishing this module, students are able • to give an overview of genetic processes in the cell • to explain the application of industrial relevant biocatalysts • to explain and prove genetic differences between pro- and eukaryotes
Skills	After successfully finishing this module, students are able • to explain and use advanced molecularbiological methods • to recognize problems in interdisciplinary fields
Personal Competence	
Social Competence	Students are able to • write protocols and PBL-summaries in teams • to lead and advise members within a PBL-unit in a group • develop and distribute work assignments for given problems
Autonomy	Students are able to • search information for a given problem by themselves • prepare summaries of their search results for the team • make themselves familiar with new topics
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	60 min exam
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0877: Applied Molecular Biology	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	SoSe
Content	Lecture and PBL - Methods in genetics / molecular cloning - Industrial relevance of microbes and their biocatalysts - Biotransformation at extreme conditions - Genomics - Protein engineering techniques - Synthetic biology
Literature	Relevante Literatur wird im Kurs zur Verfügung gestellt. Grundwissen in Molekularbiologie, Genetik, Mikrobiologie und Biotechnologie erforderlich. Lehrbuch: Brock - Mikrobiologie / Microbiology (Madigan et al.)

Course L0999: Technical Microbiology	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	SoSe
Content	• History of microbiology and biotechnology • Enzymes • Molecular biology • Fermentation • Downstream Processing • Industrial microbiological processes • Technical enzyme application • Biological Waste Water treatment
Literature	**Microbiology**, 2013, Madigan, M., Martinko, J. M., Stahl, D. A., Clark, D. P. (eds.), formerly „Brock“, Pearson **Industrielle Mikrobiologie**, 2012, Sahm, H., Antranikian, G., Stahmann, K.-P., Takors, R. (eds.) Springer Berlin, Heidelberg, New York, Tokyo. **Angewandte Mikrobiologie**, 2005, Antranikian, G. (ed.), Springer, Berlin, Heidelberg, New York, Tokyo.

Course L1000: Technical Microbiology	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0749: Waste Treatment and Solid Matter Process Technology

Courses

Title	Typ	Hrs/wk	CP
Solid Matter Process Technology for Biomass (L0052)	Lecture	2	2
Thermal Waste Treatment (L0320)	Lecture	2	2
Thermal Waste Treatment (L1177)	Recitation Section (large)	1	2

Module Responsible	Prof. Kerstin Kuchta
Admission Requirements	None
Recommended Previous Knowledge	Basics of • thermo dynamics • fluid dynamics • chemistry
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can name, describe current issue and problems in the field of thermal waste treatment and particle process engineering and contemplate them in the context of their field. The industrial application of unit operations as part of process engineering is explained by actual examples of waste incineration technologies and solid biomass processes. Compostion, particle sizes, transportation and dosing, drying and agglomeration of renewable resources and wastes are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, electricity , heat and mineral recyclables.
Skills	The students are able to select suitable processes for the treatment of wastes or raw material with respect to their characteristics and the process aims. They can evaluate the efforts and costs for processes and select economically feasible treatment concepts.
Personal Competence	
Social Competence	Students can • respectfully work together as a team and discuss technical tasks • participate in subject-specific and interdisciplinary discussions, • develop cooperated solutions • promote the scientific development and accept professional constructive criticism.
Autonomy	Students can independently tap knowledge of the subject area and transform it to new questions. They are capable, in consultation with supervisors, to assess their learning level and define further steps on this basis. Furthermore, they can define targets for new application-or research-oriented duties in accordance with the potential social, economic and cultural impact.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Civil Engineering: Specialisation Water and Traffic: Elective Compulsory Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Compulsory Water and Environmental Engineering: Specialisation Cities: Elective Compulsory

Course L0052: Solid Matter Process Technology for Biomass	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Werner Sitzmann
Language	DE
Cycle	SoSe
Content	The industrial application of unit operations as part of process engineering is explained by actual examples of solid biomass processes. Size reduction, transportation and dosing, drying and agglomeration of renewable resources are described as important unit operations when producing solid fuels and bioethanol, producing and refining edible oils, when making Btl - and WPC - products. Aspects of explosion protection and plant design complete the lecture.
Literature	Kaltschmitt M., Hartmann H. (Hrsg.): Energie aus Bioamsse, Springer Verlag, 2001, ISBN 3-540-64853-4 Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz, Schriftenreihe Nachwachsende Rohstoffe, Fachagentur Nachwachsende Rohstoffe e.V. www.nachwachsende-rohstoffe.de Bockisch M.: Nahrungsfette und -öle, Ulmer Verlag, 1993, ISBN 380000158175

Course L0320: Thermal Waste Treatment	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	SoSe
Content	• Introduction, actual state-of-the-art of waste incineration, aims. legal background, reaction principals • basics of incineration processes: waste composition, calorific value, calculation of air demand and flue gas composition • Incineration techniques: grate firing, ash transfer, boiler • Flue gas cleaning: Volume, composition, legal frame work and emission limits, dry treatment, scrubber, de-nox techniques, dioxin elimination, Mercury elimination • Ash treatment: Mass, quality, treatment concepts, recycling, disposal
Literature	Thomé-Kozmiensky, K. J. (Hrsg.): Thermische Abfallbehandlung Bande 1-7. EF-Verlag für Energie- und Umwelttechnik, Berlin, 196 - 2013.

Course L1177: Thermal Waste Treatment	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Kerstin Kuchta
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0896: Bioprocess and Biosystems Engineering

Courses

Title	Typ	Hrs/wk	CP
Bioreactor Design and Operation (L1034)	Lecture	2	2
Bioreactors and Biosystems Engineering (L1037)	Project-/problem-based Learning	1	2
Biosystems Engineering (L1036)	Lecture	2	2

Module Responsible	Prof. Ralf Pörtner
Admission Requirements	None
Recommended Previous Knowledge	Knowledge of bioprocess engineering and process engineering at bachelor level
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After completion of this module, participants will be able to: • differentiate between different kinds of bioreactors and describe their key features • identify 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 • recall and define the advanced methods of modern systems-biological approaches • connect the multiple "omics"-methods and evaluate their application for biological questions • recall the fundamentals of modeling and simulation of biological networks and biotechnological processes and to discuss their methods • 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.
Skills	After completion of this module, participants will be able to: • 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 • combine the different modeling methods into an overall modeling 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.
Personal Competence	
Social Competence	After completion of this module, participants will be able to debate technical questions in small teams to enhance the ability to take position to their own opinions and increase their capacity for teamwork. The students can reflect their specific knowledge orally and discuss it with other students and teachers.
Autonomy	After completion of this module, participants will be able to solve a technical problem in teams of approx. 8-12 persons independently including a presentation of the results. •
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory Chemical and Bioprocess Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Process Engineering: Core Qualification: Compulsory

Course L1034: Bioreactor Design and Operation	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Ralf Pörtner, Dr. Johannes Möller
Language	EN
Cycle	SoSe
Content	**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 • demonstration in laboratory and pilot plant **Sterile operation:** • theory of sterilisation processes • different sterilisation methods • sterilisation of reactor and probes • 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 • Miniplant technologies **Team work with presentation:** • Operation mode of selected bioprocesses (e.g. fundamentals of batch, fed-batch and continuous cultivation)
Literature	• Storhas, Winfried, Bioreaktoren und periphere Einrichtungen, Braunschweig: Vieweg, 1994 • Chmiel, Horst, Bioprozeßtechnik; Springer 2011 • Krahe, Martin, Biochemical Engineering, Ullmann‘s Encyclopedia of Industrial Chemistry • Pauline M. Doran, Bioprocess Engineering Principles, Second Edition, Academic Press, 2013 • Other lecture materials to be distributed

Course L1037: Bioreactors and Biosystems Engineering	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Ralf Pörtner, Dr. Johannes Möller
Language	EN
Cycle	SoSe
Content	**Introduction to Biosystems Engineering (Exercise)** **Experimental basis and methods for biosystems analysis** • 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 processin • Technical and economic overall assessment of bioproduction processes
Literature	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 Lecture materials to be distributed

Course L1036: Biosystems Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Johannes Gescher
Language	EN
Cycle	SoSe
Content	**Introduction to Biosystems Engineering** **Experimental basis and methods for biosystems analysis** • 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 processin • Technical and economic overall assessment of bioproduction processes
Literature	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 Lecture materials to be distributed

Module M0630: Robotics and Navigation in Medicine

Courses

Title	Typ	Hrs/wk	CP
Robotics and Navigation in Medicine (L0335)	Lecture	2	3
Robotics and Navigation in Medicine (L0338)	Project Seminar	2	2
Robotics and Navigation in Medicine (L0336)	Recitation Section (small)	1	1

Module Responsible	Prof. Alexander Schlaefer
Admission Requirements	None
Recommended Previous Knowledge	• principles of math (algebra, analysis/calculus) • principles of programming, e.g., in Java or C++ • solid R or Matlab skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can explain kinematics and tracking systems in clinical contexts and illustrate systems and their components in detail. Systems can be evaluated with respect to collision detection and safety and regulations. Students can assess typical systems regarding design and limitations.
Skills	The students are able to design and evaluate navigation systems and robotic systems for medical applications.
Personal Competence	
Social Competence	The students are able to grasp practical tasks in groups, develop solution strategies independently, define work processes and work on them collaboratively. The students are able to collaboratively organize their work processes and software solutions using virtual communication and software management tools. The students can critically reflect on the results of other groups, make constructive suggestions for improvement, and also incorporate them into their own work.
Autonomy	The students can assess their level of knowledge and independently control their learning processes on this basis as well as document their work results. They can critically evaluate the results achieved and present them in an appropriate argumentative manner to the other groups.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / 10 % / Written elaboration Yes / 10 % / Presentation
Examination	Written exam
Examination duration and scale	90 minutes
Assignment for the Following Curricula	Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Data Science: Specialisation III. Applications: Elective Compulsory Data Science: Specialisation IV. Special Focus Area: Elective Compulsory Electrical Engineering: Specialisation Medical Technology: Elective Compulsory Computer Science in Engineering: Specialisation II. Engineering Science: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0335: Robotics and Navigation in Medicine	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	- kinematics - calibration - tracking systems - navigation and image guidance - motion compensation The seminar extends and complements the contents of the lecture with respect to recent research results.
Literature	Spong et al.: Robot Modeling and Control, 2005 Troccaz: Medical Robotics, 2012 Further literature will be given in the lecture.

Course L0338: Robotics and Navigation in Medicine	
Typ	Project Seminar
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0336: Robotics and Navigation in Medicine	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1702: Process Imaging

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Process Imaging (L2723)	Lecture	3	3
Process Imaging (L2724)	Project-/problem-based Learning	3	3

Module Responsible	Prof. Alexander Penn
Admission Requirements	None
Recommended Previous Knowledge	No special prerequisites needed
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	**Content:** The module focuses primarily on discussing established imaging techniques including (a) optical and infrared imaging, (b) magnetic resonance imaging, (c) X-ray imaging and tomography, and (d) ultrasound imaging but also covers a range of more recent imaging modalities. The students will learn: 1. what these imaging techniques can measure (such as sample density or concentration, material transport, chemical composition, temperature), 2. how the measurements work (physical measurement principles, hardware requirements, image reconstruction), and 3. how to determine the most suited imaging methods for a given problem. **Learning goals:** After the successful completion of the course, the students shall: 1. understand the physical principles and practical aspects of the most common imaging methods, 2. be able to assess the pros and cons of these methods with regard to cost, complexity, expected contrasts, spatial and temporal resolution, and based on this assessment 3. be able to identify the most suited imaging modality for any specific engineering challenge in the field of chemical and bioprocess engineering.
Skills	
Personal Competence	
Social Competence	In the problem-based interactive course, students work in small teams and set up two process imaging systems and use these systems to measure relevant process parameters in different chemical and bioprocess engineering applications. The teamwork will foster interpersonal communication skills.
Autonomy	Students are guided to work in self-motivation due to the challenge-based character of this module. A final presentation improves presentation skills.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation C - Bioeconomic Process Engineering, Focus Energy and Bioprocess Technology: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems, Focus Signal Processing: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Mechatronics: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory

Course L2723: Process Imaging	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Alexander Penn
Language	EN
Cycle	SoSe
Content	
Literature	Wang, M. (2015). Industrial Tomography. Cambridge, UK: Woodhead Publishing. Available as e-book in the library of TUHH: https://katalog.tub.tuhh.de/Record/823579395

Course L2724: Process Imaging	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Alexander Penn, Dr. Stefan Benders
Language	EN
Cycle	SoSe
Content	**Content:** The module focuses primarily on discussing established imaging techniques including (a) optical and infrared imaging, (b) magnetic resonance imaging, (c) X-ray imaging and tomography, and (d) ultrasound imaging and also covers a range of more recent imaging modalities. The students will learn: 1. what these imaging techniques can measure (such as sample density or concentration, material transport, chemical composition, temperature), 2. how the measurements work (physical measurement principles, hardware requirements, image reconstruction), and 3. how to determine the most suited imaging methods for a given problem. **Learning goals:** After the successful completion of the course, the students shall: 1. understand the physical principles and practical aspects of the most common imaging methods, 2. be able to assess the pros and cons of these methods with regard to cost, complexity, expected contrasts, spatial and temporal resolution, and based on this assessment 3. be able to identify the most suited imaging modality for any specific engineering challenge in the field of chemical and bioprocess engineering.
Literature	Wang, M. (2015). Industrial Tomography. Cambridge, UK: Woodhead Publishing. Available as e-book in the library of TUHH: https://katalog.tub.tuhh.de/Record/823579395

Module M0541: Process and Plant Engineering II

Courses

Title	Typ	Hrs/wk	CP
Process and Plant Engineering II (L0097)	Lecture	2	4
Process and Plant Engineering II (L0098)	Recitation Section (large)	2	2

Module Responsible	Prof. Mirko Skiborowski
Admission Requirements	None
Recommended Previous Knowledge	unit operation of thermal and mechanical separation chemical reactor engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	students can: -present process control concepts of apparatus and complex process plants - classifyprocess models and model equations - explain numerical methods and their use in simulation tasks - explain the solving strategy of flowsheet simulation - explain, present and discuss projects phases within the planning of processes - present and explain the critical path method
Skills	students are capable of: - formulation of targets of process control concepts and the translation into industrial practice - design and evaluation of process control concepts and structures - analyse the model structure ans parameters from the process simulation - optimization of calculation sequence with respect to flowsheet simulation
Personal Competence	
Social Competence	students are capable of: • develop solutions in heterogeneous small groups
Autonomy	students are capable of: • taping new knowledge on a special subject by literature research
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 Min.
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Core Qualification: Compulsory

Course L0097: Process and Plant Engineering II	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Mirko Skiborowski, Dr. Thomas Waluga
Language	DE
Cycle	WiSe
Content	1. **Process optimization** Application areas Formulation of constrained optimization Solving strategy Classes of optimization tasks 2. **Process control** Typical control functions of equipment and apparatus in process engineering Structures of control systems Plantwide control 3. **Process Modeling** Process models (steady state and dynamic behaviour) Degrees of freedom Examples from industrial practice 4. **Process simulation** Structured approach Numerical methods Flowsheeting Solution methods Examples for experimental validation in industrial practice Application of flowsheet simulation 5. **Plant design and construction** Introduction Industrial project implementation Project execution: Applied aspects in industrial use critical path method
Literature	Literatur (Planung und Bau von Produktionsanlagen): G. Barnecker, Planung und Bau verfahrenstechnischer Anlagen, Springer Verlag, 2001 F.P. Helmus, Anlagenplanung, Wiley-VCH Verlag, Weinheim, 2003 E. Klapp, Apparate- und Anlagentechnik, Springer -Verlag, Berlin, 1980 P. Rinza, Projektmanagement: Planung, Überwachung und Steuerung von technischen und nichttechnischen Vorhaben, Düsseldorf,VDI-Verlag, 1994 K. Sattler, W. Kasper, Verfahrentechnische Anlagen, Wiley-VCH Verlag, Weinheim, 2000 G.H. Vogel, Verfahrensentwicklung, Wiley-VCH, Weinheim, 2002 K.H. Weber, Inbetriebnahme verfahrenstechnischer Anlagen, VDI Verlag, Düsseldorf, 1996 E. Wegener, Montagegerechte Anlagenplanung, Wiley-VCH Verlag, Weinheim, 2003

Course L0098: Process and Plant Engineering II	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Mirko Skiborowski, Dr. Thomas Waluga
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0540: Transport Processes

Courses

Title	Typ	Hrs/wk	CP
Multiphase Flows (L0104)	Lecture	2	2
Reactor Design Using Local Transport Processes (L0105)	Project-/problem-based Learning	2	2
Heat & Mass Transfer in Process Engineering (L0103)	Lecture	2	2

Module Responsible	Prof. Michael Schlüter
Admission Requirements	None
Recommended Previous Knowledge	All lectures from the undergraduate studies, especially mathematics, chemistry, thermodynamics, fluid mechanics, heat- and mass transfer.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • describe transport processes in single- and multiphase flows and they know the analogy between heat- and mass transfer as well as the limits of this analogy. • explain the main transport laws and their application as well as the limits of application. • describe how transport coefficients for heat- and mass transfer can be derived experimentally. • compare different multiphase reactors like trickle bed reactors, pipe reactors, stirring tanks and bubble column reactors. • are known. The Students are able to perform mass and energy balances for different kind of reactors. Further more the industrial application of multiphase reactors for heat- and mass transfer are known.
Skills	The students are able to: • optimize multiphase reactors by using mass- and energy balances, • use transport processes for the design of technical processes, • to choose a multiphase reactor for a specific application.
Personal Competence	
Social Competence	The students are able to discuss in international teams in english and develop an approach under pressure of time.
Autonomy	Students are able to define independently tasks, to solve the problem "design of a multiphase reactor". The knowledge that s necessary is worked out by the students themselves on the basis of the existing knowledge from the lecture. The students are able to decide by themselves what kind of equation and model is applicable to their certain problem. They are able to organize their own team and to define priorities for different tasks.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	15 min Presentation + 90 min multiple choice written examen
Assignment for the Following Curricula	Bioprocess Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Process Engineering: Core Qualification: Compulsory

Course L0104: Multiphase Flows	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	• Interfaces in MPF (boundary layers, surfactants) • Hydrodynamics & pressure drop in Film Flows • Hydrodynamics & pressure drop in Gas-Liquid Pipe Flows • Hydrodynamics & pressure drop in Bubbly Flows • Mass Transfer in Film Flows • Mass Transfer in Gas-Liquid Pipe Flows • Mass Transfer in Bubbly Flows • Reactive mass Transfer in Multiphase Flows • Film Flow: Application Trickle Bed Reactors • Pipe Flow: Application Turbular Reactors • Bubbly Flow: Application Bubble Column Reactors
Literature	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 L0105: Reactor Design Using Local Transport Processes	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	In this Problem-Based Learning unit the students have to design a multiphase reactor for a fast chemical reaction concerning optimal hydrodynamic conditions of the multiphase flow. The four students in each team have to: • collect and discuss material properties and equations for design from the literature, • calculate the optimal hydrodynamic design, • check the plausibility of the results critically, • write an exposé with the results. This exposé will be used as basis for the discussion within the oral group examen of each team.
Literature	see actual literature list in StudIP with recent published papers

Course L0103: Heat & Mass Transfer in Process Engineering	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	EN
Cycle	WiSe
Content	• Introduction - Transport Processes in Chemical Engineering • Molecular Heat- and Mass Transfer: Applications of Fourier's and Fick's Law • Convective Heat and Mass Transfer: Applications in Process Engineering • Unsteady State Transport Processes: Cooling & Drying • Transport at fluidic Interfaces: Two Film, Penetration, Surface Renewal • Transport Laws & Balance Equations with turbulence, sinks and sources • Experimental Determination of Transport Coefficients • Design and Scale Up of Reactors for Heat- and Mass Transfer • Reactive Mass Transfer • Processes with Phase Changes – Evaporization and Condensation • Radiative Heat Transfer - Fundamentals • Radiative Heat Transfer - Solar Energy
Literature	1. Baehr, Stephan: Heat and Mass Transfer, Wiley 2002. 2. Bird, Stewart, Lightfood: Transport Phenomena, Springer, 2000. 3. John H. Lienhard: A Heat Transfer Textbook, Phlogiston Press, Cambridge Massachusetts, 2008. 4. Myers: Analytical Methods in Conduction Heat Transfer, McGraw-Hill, 1971. 5. Incropera, De Witt: Fundamentals of Heat and Mass Transfer, Wiley, 2002. 6. Beek, Muttzall: Transport Phenomena, Wiley, 1983. 7. Crank: The Mathematics of Diffusion, Oxford, 1995. 8. Madhusudana: Thermal Contact Conductance, Springer, 1996. 9. Treybal: Mass-Transfer-Operation, McGraw-Hill, 1987.

Module M0542: Fluid Mechanics in Process Engineering

Courses

Title	Typ	Hrs/wk	CP
Applications of Fluid Mechanics in Process Engineering (L0106)	Recitation Section (large)	2	2
Fluid Mechanics II (L0001)	Lecture	2	4

Module Responsible	Prof. Michael Schlüter
Admission Requirements	None
Recommended Previous Knowledge	• Mathematics I-III • Fundamentals in Fluid Mechanics • Technical Thermodynamics I-II • Heat- and Mass Transfer
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to describe different applications of fluid mechanics in Process Engineering, Bioprocess Engineering, Energy- and Environmental Process Engineering and Renewable Energies. They are able to use the fundamentals of fluid mechanics for calculations of certain engineering problems. The students are able to estimate if a problem can be solved with an analytical solution and what kind of alternative possibilities are available (e.g. self-similarity in an example of free jets, empirical solutions in an example with the Forchheimer equation, numerical methods in an example of Large Eddy Simulation.
Skills	Students are able to use the governing equations of Fluid Dynamics for the design of technical processes. Especially they are able to formulate momentum and mass balances to optimize the hydrodynamics of technical processes. They are able to transform a verbal formulated message into an abstract formal procedure.
Personal Competence	
Social Competence	The students are able to discuss a given problem in small groups and to develop an approach.
Autonomy	Students are able to define independently tasks for problems related to fluid mechanics. They are able to work out the knowledge that is necessary to solve the problem by themselves on the basis of the existing knowledge from the lecture.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Process Engineering: Core Qualification: Compulsory

Course L0106: Applications of Fluid Mechanics in Process Engineering

Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	DE
Cycle	WiSe
Content	The Exercise-Lecture will bridge the gap between the theoretical content from the lecture and practical calculations. For this aim a special exercise is calculated at the blackboard that shows how the theoretical knowledge from the lecture can be used to solve real problems in Process Engineering.
Literature	1. Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971. 2. Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion. Frankfurt: Sauerländer 1972. 3. Crowe, C. T.: Engineering fluid mechanics. Wiley, New York, 2009. 4. Durst, F.: Strömungsmechanik: Einführung in die Theorie der Strömungen von Fluiden. Springer-Verlag, Berlin, Heidelberg, 2006. 5. Fox, R.W.; et al.: Introduction to Fluid Mechanics. J. Wiley & Sons, 1994. 6. Herwig, H.: Strömungsmechanik: Eine Einführung in die Physik und die mathematische Modellierung von Strömungen. Springer Verlag, Berlin, Heidelberg, New York, 2006. 7. Herwig, H.: Strömungsmechanik: Einführung in die Physik von technischen Strömungen: Vieweg+Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2008. 8. Kuhlmann, H.C.: Strömungsmechanik. München, Pearson Studium, 2007 9. Oertl, H.: Strömungsmechanik: Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele. Vieweg+ Teubner / GWV Fachverlage GmbH, Wiesbaden, 2009. 10. Schade, H.; Kunz, E.: Strömungslehre. Verlag de Gruyter, Berlin, New York, 2007. 11. Truckenbrodt, E.: Fluidmechanik 1: Grundlagen und elementare Strömungsvorgänge dichtebeständiger Fluide. Springer-Verlag, Berlin, Heidelberg, 2008. 12. Schlichting, H. : Grenzschicht-Theorie. Springer-Verlag, Berlin, 2006. 13. van Dyke, M.: An Album of Fluid Motion. The Parabolic Press, Stanford California, 1882. 14. White, F.: Fluid Mechanics, Mcgraw-Hill, ISBN-10: 0071311211, ISBN-13: 978-0071311212, 2011.

Course L0001: Fluid Mechanics II	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Michael Schlüter
Language	DE
Cycle	WiSe
Content	• Differential equations for momentum-, heat and mass transfer • Examples for simplifications of the Navier-Stokes Equations • Unsteady momentum transfer • Free shear layer, turbulence and free jets • Flow around particles - Solids Process Engineering • Coupling of momentum and heat transfer - Thermal Process Engineering • Rheology – Bioprocess Engineering • Coupling of momentum- and mass transfer – Reactive mixing, Chemical Process Engineering • Flow threw porous structures - heterogeneous catalysis • Pumps and turbines - Energy- and Environmental Process Engineering • Wind- and Wave-Turbines - Renewable Energy • Introduction into Computational Fluid Dynamics
Literature	1. Brauer, H.: Grundlagen der Einphasen- und Mehrphasenströmungen. Verlag Sauerländer, Aarau, Frankfurt (M), 1971. 2. Brauer, H.; Mewes, D.: Stoffaustausch einschließlich chemischer Reaktion. Frankfurt: Sauerländer 1972. 3. Crowe, C. T.: Engineering fluid mechanics. Wiley, New York, 2009. 4. Durst, F.: Strömungsmechanik: Einführung in die Theorie der Strömungen von Fluiden. Springer-Verlag, Berlin, Heidelberg, 2006. 5. Fox, R.W.; et al.: Introduction to Fluid Mechanics. J. Wiley & Sons, 1994. 6. Herwig, H.: Strömungsmechanik: Eine Einführung in die Physik und die mathematische Modellierung von Strömungen. Springer Verlag, Berlin, Heidelberg, New York, 2006. 7. Herwig, H.: Strömungsmechanik: Einführung in die Physik von technischen Strömungen: Vieweg+Teubner Verlag / GWV Fachverlage GmbH, Wiesbaden, 2008. 8. Kuhlmann, H.C.: Strömungsmechanik. München, Pearson Studium, 2007 9. Oertl, H.: Strömungsmechanik: Grundlagen, Grundgleichungen, Lösungsmethoden, Softwarebeispiele. Vieweg+ Teubner / GWV Fachverlage GmbH, Wiesbaden, 2009. 10. Schade, H.; Kunz, E.: Strömungslehre. Verlag de Gruyter, Berlin, New York, 2007. 11. Truckenbrodt, E.: Fluidmechanik 1: Grundlagen und elementare Strömungsvorgänge dichtebeständiger Fluide. Springer-Verlag, Berlin, Heidelberg, 2008. 12. Schlichting, H. : Grenzschicht-Theorie. Springer-Verlag, Berlin, 2006. 13. van Dyke, M.: An Album of Fluid Motion. The Parabolic Press, Stanford California, 1882.

Module M1334: BIO II: Biomaterials

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Biomaterials (L0593)	Lecture	2	3

Module Responsible	Prof. Michael Morlock
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of orthopedic and surgical techniques is recommended.
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students can describe the materials of the human body and the materials being used in medical engineering, and their fields of use.
Skills	The students can explain the advantages and disadvantages of different kinds of biomaterials.
Personal Competence	
Social Competence	The students are able to discuss issues related to materials being present or being used for replacements with student mates and the teachers.
Autonomy	The students are able to acquire information on their own. They can also judge the information with respect to its credibility.
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Credit points	3
Course achievement	None
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Bio- and Medical Technology: Elective Compulsory

Course L0593: Biomaterials	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Michael Morlock, Prof. Kaline Pagnan Furlan, Prof. Shan Shi
Language	EN
Cycle	WiSe
Content	Topics to be covered include: 1. Introduction (Importance, nomenclature, relations) 2. Biological materials 2.1 Basics (components, testing methods) 2.2 Bone (composition, development, properties, influencing factors) 2.3 Cartilage (composition, development, structure, properties, influencing factors) 2.4 Fluids (blood, synovial fluid) 3 Biological structures 3.1 Menisci of the knee joint 3.2 Intervertebral discs 3.3 Teeth 3.4 Ligaments 3.5 Tendons 3.6 Skin 3.7 Nervs 3.8 Muscles 4. Replacement materials 4.1 Basics (history, requirements, norms) 4.2 Steel (alloys, properties, reaction of the body) 4.3 Titan (alloys, properties, reaction of the body) 4.4 Ceramics and glas (properties, reaction of the body) 4.5 Plastics (properties of PMMA, HDPE, PET, reaction of the body) 4.6 Natural replacement materials Knowledge of composition, structure, properties, function and changes/adaptations of biological and technical materials (which are used for replacements in-vivo). Acquisition of basics for theses work in the area of biomechanics.
Literature	Hastings G and Ducheyne P.: Natural and living biomaterials. Boca Raton: CRC Press, 1984. Williams D.: Definitions in biomaterials. Oxford: Elsevier, 1987. Hastings G.: Mechanical properties of biomaterials: proceedings held at Keele University, September 1978. New York: Wiley, 1998. Black J.: Orthopaedic biomaterials in research and practice. New York: Churchill Livingstone, 1988. Park J. Biomaterials: an introduction. New York: Plenum Press, 1980. Wintermantel, E. und Ha, S.-W : Biokompatible Werkstoffe und Bauweisen. Berlin, Springer, 1996.

Module M0519: Particle Technology and Solid Matter Process Technology

Courses			
Title	**Typ**	**Hrs/wk**	**CP**
Advanced Particle Technology II (L0051)	Project-/problem-based Learning	1	1
Advanced Particle Technology II (L0050)	Lecture	2	2
Experimental Course Particle Technology (L0430)	Practical Course	3	3

Module Responsible	Prof. Stefan Heinrich
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge of solids processes and particle technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	After completion of the module the students will be able to describe and explain processes for solids processing in detail based on microprocesses on the particle level.
Skills	Students are able to choose process steps and apparatuses for the focused treatment of solids depending on the specific characteristics. They furthermore are able to adapt these processes and to simulate them.
Personal Competence	
Social Competence	Students are able to present results from small teamwork projects in an oral presentation and to discuss their knowledge with scientific researchers.
Autonomy	Students are able to analyze and solve problems regarding solid particles independently or in small groups.
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Written elaboration / fünf Berichte (pro Versuch ein Bericht) à 5-10 Seiten
Examination	Written exam
Examination duration and scale	120 minutes
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Bioprocess Engineering: Specialisation B - Industrial Bioprocess Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Materials Science: Specialisation Nano and Hybrid Materials: Elective Compulsory Process Engineering: Core Qualification: Compulsory

Course L0051: Advanced Particle Technology II

Typ	Project-/problem-based Learning
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Stefan Heinrich
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0050: Advanced Particle Technology II

Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Stefan Heinrich
Language	DE/EN
Cycle	WiSe
Content	• Exercise in form of "Project based Learning" • Agglomeration, particle size enlargement • advanced particle size reduction • Advanced theorie of fluid/particle flows • CFD-methods for the simulation of disperse fluid/solid flows, Euler/Euler methids, Descrete Particle Modeling • Treatment of simulation problems with distributed properties, solution of population balances
Literature	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.

Course L0430: Experimental Course Particle Technology	
Typ	Practical Course
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Stefan Heinrich
Language	DE/EN
Cycle	WiSe
Content	• Fluidization • Agglomeration • Granulation • Drying • Determination of mechanical properties of agglomerats
Literature	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.

Thesis

Module M1801: Master thesis (dual study program)

Courses			
Title	**Typ**	**Hrs/wk**	**CP**

Module Responsible	Professoren der TUHH
Admission Requirements	None
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Dual students ... • ... use the specialised knowledge (facts, theories and methods) from their field of study and the acquired professional knowledge confidently to deal with technical and practical professional issues. • ... can explain the relevant approaches and terminologies in depth in one or more of their subject's specialist areas, describe current developments and take a critical stance. • ... formulate their own research assignment to tackle a professional problem and contextualise it within their subject area. They ascertain the current state of research and critically assess it.
Skills	Dual students ... • ... can select suitable methods for the respective subject-related professional problem, apply them and develop them further as required. • ... assess knowledge and methods acquired during their studies (including practical phases) and apply their expertise to complex and/or incompletely defined problems in a solution- and application-oriented manner. • ... acquire new academic knowledge in their subject area and critically evaluate it.
Personal Competence	
Social Competence	Dual students ... • ... can present a professional problem in the form of an academic question in a structured, comprehensible and factually correct manner, both in writing and orally, for a specialist audience and for professional stakeholders. • ... answer questions as part of a professional discussion in an expert, appropriate manner. They represent their own points of view and assessments convincingly.
Autonomy	Dual students ... • ... can structure their own project into work packages, work through them at an academic level and reflect on them with regard to feasible courses of action for professional practice. • ... work in-depth in a partially unknown area within the discipline and acquire the information required to do so. • ... apply the techniques of academic work comprehensively in their own research work when dealing with an operational problem and question.
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0
Credit points	30
Course achievement	None
Examination	Thesis
Examination duration and scale	According to General Regulations
Assignment for the Following Curricula	Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Data Science: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory International Management and Engineering: Thesis: Compulsory Logistics, Infrastructure and Mobility: Thesis: Compulsory Aeronautics: Thesis: Compulsory Materials Science and Engineering: Thesis: Compulsory Materials Science: Thesis: Compulsory Mechanical Engineering and Management: Thesis: Compulsory Mechatronics: Thesis: Compulsory Biomedical Engineering: Thesis: Compulsory Microelectronics and Microsystems: Thesis: Compulsory Product Development, Materials and Production: Thesis: Compulsory Renewable Energies: Thesis: Compulsory Naval Architecture and Ocean Engineering: Thesis: Compulsory Theoretical Mechanical Engineering: Thesis: Compulsory

	Process Engineering: Thesis: Compulsory Water and Environmental Engineering: Thesis: Compulsory