Module Handbook

for the study program

Mechanical Engineering M.Sc.

Kleve, May 2021 Rev.3

Content

Curriculum Mechanical Engineering M.Sc.

Curriculum MM		HPW	Type						Examination form		CP	HPW		
			V	SL	S	Ü	Pra	Pro	Attestation	graded		SS 1	WS 2	SS 3
Core Modules														
Module Code	**Common Core Modules**													
3300	Research Methods for Engineers	3	1			1	1		x		5		x	
3301	Numerical Methods of Simulation	3	2			1				x	5		x	
3302	General Management	3	2				1		x		5	x		
3400	Structural Analysis	3	2			1				x	5	x		
Fokusfeld Digital Engineering*														
Module Code	**Core Modules**													
3402	Principles of Software Development	3	2				1			x	5	x		
3401	Heat Transfer	3	2			1				x	5		x	
Module Code	**Focusfield Modules**													
3403	Materials Selection and Simulation	3	2				1			x	5	x		
3407	Computational Multibody Dynamics	3	1				2			x	5	x		
3408	Factory Simulation	3	2			1				x	5	x		
3404	Advanced CAD	3	1				2			x	5		x	
3405	Computational Fluid Dynamics	3	1				2		x		5		x	
3406	Model based Design of Mechatronics Systems	3	1				2		x		5		x	
Fokusfeld Development and Design*														
Module Code	**Core Modules**													
3401	Heat Transfer	3	2			1				x	5		x	
3406	Model based Design of Mechatronics Systems	3	1				2		x		5		x	
Module Code	**Focusfield Modules**													
3409	Design Methodology	3	2			1				x	5		x	
3410	Tribology	3	2				1			x	5	x		
3411	Thermodynamics of Power Systems	3	2			1				x	5	x		
3412	Energy-efficient and Sustainable Drive Systems	3	1			1	1			x	5	x		
3413	Advanced Simulations Technologies	3	1				2			x	5	x		
3404	Advanced CAD	3	1				2			x	5		x	
Fokusfeld Production*														
Module Code	**Core Modules**													
3402	Principles of Software Development	3	2				1			x	5	x		
3608	Sustainability	3	2			1				x	5		x	
Module Code	**Focusfield Modules**													
3408	Factory Simulation	3	2			1				x	5	x		
3415	Production Management	3	2			1				x	5	x		
3416	Machine Tools and Automation	3	2				1			x	5		x	
3417	Manufacturing Technology Development	3	2			1				x	5		x	
3418	Data Analytics	3	2				1			x	5		x	
3603	Human Machine Interaction	3	2				1		x		5	x		
Final Semester														
Module Code	**Module**													
3303	Applied Research Project (ARP)									x	5			x
3304	Master thesis									x	22			x
3305	Colloquium									x	3			x

Explanations

* Die Fakultät behält sich das Recht vor, sowohl eine Mindestteilnehmerzahl für das Zustandekommen eines Fokusfeldes / Wahlbereiches als auch eine Maximalteilnehmerzahl festzulegen. / * The faculty reserves the right to determine a minimum and a maximum number of participants for offering a focus

Abbreviations

HPW Semesterwochenstunden / hours per week

CP Kreditpunkte / credit points

3300 Research Methods for Engineers

Module name:	Research Methods for Engineers
Module code:	3300
Semester:	Winterterm
Module coordinator:	Prof. Dr. Andy Stamm
Lecturer:	Prof. Dr. W. Megill
Language:	English
Place in curriculum:	Common Core Subject
Timetabled hours:	Lectures: 1 HPW Exercises: 1 HPW Practical Training: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h report preparation
Credits:	5
Recommended prerequisites:	Basic courses in programming, electronics, engineering design, CAD, and materials.
Module objectives:	After completing the course the students have experience of project related work and the practical implementation of their acquired knowledge. They can find relevant information independently using a variety of sources. They can construct useful theories, hypotheses and work statements, then document and present their work in a professional manner. They have also learned the practical side of engineering science with introductions to instrumentation and measurement in real environments. They have learned to design and make their own test rigs and to interpret the data obtained with instrumentation they built and debugged themselves.
Content:	• Introduction to Engineering Research • Literature Search & Review • Developing a Research Plan • Statistical Design and Analysis • Optimisation Techniques • Design and Construction of Experimental Apparatus • Instrumentation • Amplifier Design and Data Acquisition • Software Control of Experimental Aparatus • Signal in Noise Considerations • Filter Design: Mechanical, Electrical and Software

	• Numerical Treatment of Experimental Data • Qualitative Research Methods • Report Writing and Presentation • Collaborative Working & Resource Planning; Gantt Charts; Online Collaboration Tools
Assessment:	Attestation: continuous assessment
Forms of media:	Webex/Moodle
Literature:	Lecture notes - Thiel DV (2014) Research methods for engineers. Cambridge UP. ISBN 978-1-139-54232-6 - Horowitz & Hill. The art of electronics. Cambridge UP. ISBN 978-0-521-80926-9

3301 Numerical Methods for Simulation

Module name:	Numerical Methods for Simulation
Module code:	3301
Semester:	Winterterm
Module coordinator:	Prof. Dr. Alexander Struck
Lecturer:	Prof. Dr. Alexander Struck Dr. T. Camps
Language:	English
Place in curriculum:	Common Core module
Timetabled hours:	Lectures: 2 HPW Exercises: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	
Module objectives:	• Learning standard concepts of mathematical modelling and computer simulation • Getting an overview of numerical methods for solving algebraic differential and differential-algebraic equations, being able to select, apply and evaluate different numerical algorithms for ordinary and partial differential equations • Developing computer models for small problems and investigating benefits and limitations of the models and their simulation
Content:	• If needed, presentation of numbers in a computer: integers and floating point variables; roundoff errors, loss of significant digits, error propagation • Differentials and differential equations by finite differences, transformation to iterative algebraic equations • Iterative solution of linear systems • Iterative solution of non-linear systems, Newton’s Method, Newton-Raphson • Integration schemes for ordinary and partial differential equations: forward and backward Eulerpredictor-corrector, Runge-Kutta, implicit vs. explicit schemes • Stability, accuracy and consistency of integration schemes • Fixed-point iteration

	• Numerical Solution in real-time systems • Numerical Computation of Eigenvalues, mathematics for machine learning
Assessment:	Graded: Written Exam on Campus (in planning, not fixed, for more information: homepage/moodle) or oral exam
Forms of media:	Webex/Moodle
Literature:	1. Forman S. Acton (2005) *Real Computing Made Real – Preventing Errors in Scientific and Engineering Calculations*. Mineola. Dover Publications. 2. Richard Burden and Douglas Faires (2011) *Numerical Analysis*. 9th international edition. Brooks/Cole. 3. Parviz Moin (2010) *Fundamentals of Engineering Numerical Analysis*. 2nd edition. Cambridge. Cambridge University Press. 4. Cleve Moler, *Numerical Computation with Matlab*, free pdf from https://de.mmathworks.com/moler/chapters.html 5. Teukolsky, Press: Numerical Recipes, Princeton University Press

3302 General Management

Module name:	General Management
Module code:	3302
Semester:	Summerterm
Module coordinator:	Prof. Dr.-Ing. Dirk Untiedt
Lecturer:	Prof. Dr.-Ing. Dirk Untiedt
Language:	English
Place in curriculum:	Core subject
Timetabled hours:	Lectures: 2 HPW Practical Training: 1 HPW
Workload:	45 h attendance 65 h preparation and review 40 h report preparation
Credits:	5
Recommended prerequisites:	None
Module objectives:	In addition to the corporate management mostly three management functions for any kind of company can be distinguished with respect to general Management: • Marketing Management • Finance Management and • Production management Students know the main tools, methods and instruments of general management. They have the ability to use them effectively. They are able to formulate strategies and implementation plans on all strategy levels and in specific contexts.
Content:	• Fundamentals of General Management • Strategy Formulation • Operations • Finance and Controlling • Human Resource Management • Change Management • Marketing and Sales
Assessment:	Attestation: Written reports and oral presentations
Forms of media:	Whiteboard, PowerPoint, Business Simulation Software
Literature:	• Lecture notes • David Hunger; Thomas L. Wheelen: Essentials of Strategic Management. Pearson Education, Inc.

	Publishing as Prentice Hall, 5th international edition 2010.

3303 Applied Research Project - ARP

Module name:	Applied Research Project - ARP
Module code:	3303
Semester:	Summerterm
Module coordinator:	Prof. Prof. Dr. Dirk Nissing Prof. Dr. Alexander Klein Prof. Dr. William Megill Prof. Dr. Ronny Hartanto
Lecturer:	Project dependent
Language:	English
Place in curriculum:	Core Subject
Timetabled hours:	none
Workload:	150 h
Credits:	5
Recommended prerequisites:	
Module objectives:	The students demonstrate their capability to work independently on an applied research subject in alignment with their course of study, meeting all topical and scientific requirements in a limited period of time. They have the ability to self-analyze and assess the results and make recommendations for improvements. They are able to organize their workflow in order to meet the demands of the problems formulated in their project, as well as to monitor progress and make necessary amendments. Additionally students are able to improve their documentation skills, thus documenting their approach and their results to meet the requirements of a scientific publication.
Content:	The project content depends on the chosen topic and is agreed upon with the supervisor. Documentation is granted by an adequately sized description of the topic/problem, the chosen approach, used methods and results.
Assessment:	Graded: Written documentation, research results, proceeded data and charts, prototypes, software code, blueprints where applicable.
Forms of media:	Raw data, slide deck, written documentation
Literature:	

3304 Master Thesis

Module name:	Master Thesis
Module code:	3304
Semester:	Summerterm
Module coordinator:	Prof. Prof. Dr. Dirk Nissing Prof. Dr. Alexander Klein Prof. Dr. William Megill Prof. Dr. Ronny Hartanto
Lecturer:	Project dependent
Language:	English
Place in curriculum:	Core Subject
Timetabled hours:	none
Workload:	660 h
Credits:	22
Recommended prerequisites:	At least 50 credit points in the respective courses. Successfully passed “Applied Research Project”.
Module objectives:	The students demonstrate their capability to work independently on a scientific subject in alignment with their course of study, meeting all topical and scientific requirements in a limited period of time. Scientific methods and approaches are used in order to work on the subject and they have the ability to analyze and assess the results. They are able to organize their workflow in order to meet the demands of the problems formulated in their theses, as well as to monitor progress and make necessary amendments. Additionally students are able to improve their documentation skills, thus documenting their approach and their results to meet the requirements of a scientific publication.
Content:	The Thesis content depends on the chosen topic and is agreed upon with the supervisor. Documentation is granted by an adequately sized description of the topic/problem, the chosen approach, used methods and results.
Assessment:	Graded: Written thesis
Forms of media:	Written thesis
Literature:	

3305 Colloquium

Module name:	Colloquium
Module code:	3305
Semester:	Summerterm
Module coordinator:	Prof. Prof. Dr. Dirk Nissing Prof. Dr. Alexander Klein Prof. Dr. William Megill Prof. Dr. Ronny Hartanto
Lecturer:	Supervisor of the Master Thesis
Language:	English
Place in curriculum:	Core Subject
Timetabled hours:	none
Workload:	90 h
Credits:	3
Recommended prerequisites:	At least 87 credits
Module objectives:	The students are able to defend the results of the Master Thesis place their work in a context of scientific applications and present their results in a proper form for the audience. They motivate their approach and make estimations, how assumptions and simplifications may affect the validity of their results. Additionally, students are able to analyze questions concerning their thesis and results and answer them properly in the context of professional and extra-professional reference.
Content:	The content is aligned with the content of the Master Thesis, in addition methodological discussions.
Assessment:	Graded: Oral examination
Forms of media:	Whiteboard, PowerPoint, Projector, other relevant media
Literature:	

3400 Structural Analysis

Module name:	Structural Analysis
Module code:	3400
Semester:	Summerterm
Module coordinator:	Prof. Dr.-Ing. Henning Schütte
Lecturer:	Prof. Dr.-Ing. Henning Schütte
Language:	English
Place in curriculum:	Core subject
Timetabled hours:	Lectures: 2 HPW Exercise: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	Advanced Engineering Mathematics, Basic Courses in Statics, Mechanics of Materials and Dynamics
Module objectives:	After completing the course the students are able to: • reduce the basic set of fundamental equations of continuum mechanics to one and two-dimensional problems • reduce static engineering problems to models of beams, plates and shells with their corresponding boundary conditions and solve them • reduce dynamics engineering problems to vibrations of lumped mass systems and assess their modes, eigenfrequencies and answers to excitations
Content:	• Stress analysis under general loading conditions • Energy methods in continuum mechanics (Virtual Work, Stability, Menabrea, Castigliano, Method of Virtual Forces) • Modal analysis and forced excitation analysis of lumped mass systems of springs, rods and beams.
Assessment:	Graded: Written examination
Forms of media:	Whiteboard, PowerPoint, Projector
Literature:	Lecture notes - Gross,Hauger,Schnell: Engineering Mechanics - Bruhns: Advanced Mechanics of Solids, Springer 2002 - Dresig,Holzweißig: Dynamics of Machinery: Theory and Applications, Springer 2010

3401 Heat Transfer

Module name:	Heat Transfer
Module code:	3401
Semester:	Winterterm
Module coordinator:	Prof. Dr.-Ing. Joachim Gebel
Lecturer:	Prof. Dr.-Ing. Joachim Gebel
Language:	English
Place in curriculum:	Core subject
Timetabled hours:	Lectures: 2 HPW Exercise: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	Fundamentals of Thermodynamics Fundamentals of Fluid Mechanics
Module objectives:	On completion of this module the student will be able to: • explain the scientific principles underlying conduction and convection and determine heat transfer coefficients for both conduction and convection processes; • analyse and solve practical problems related to conduction, forced convection, free convection and convection with phase change (boiling and condensation); • analyse the thermal performance of heat exchangers and recognise and evaluate the conflicting requirements of heat transfer optimisation and pressure drop minimisation; • design or select a heat exchanger to perform a predetermined task; • recognise basic laboratory procedures and safety and conduct laboratory experiments as a group.
Content:	1 Review on thermodynamics 1.1 First law of thermodynamics 1.2 Second law of thermodynamics 1.3 Efficiency of heat engines 2 Conduction 2.1 One-dimensional, steady state conduction 2.2 Two-dimensional, steady state conduction 2.3 Transient conduction

	3 Convection 3.1 Forced convection 3.2 Free convection 4 Boiling and condensation 5 Heat exchangers 5.1 Overall heat transfer coefficient 5.2 Heat exchanger analysis - Log Mean Temperature Difference - NTU-Method 5.3 Heat exchanger types and heat exchanger design 6 Practical Training 6.1 Determination of overall heat transfer coefficient of different heat exchanger types 6.2 Comparison of plate heat exchanger, tubular heat exchanger, shell and tube heat exchanger, finned cross-flow heat exchanger, and stirred tank with double jacket and coiled tube
Assessment:	Graded: Written digital examination
Forms of media:	Moodle
Literature:	F.P. Incropera, D.P. Dewitt, Th.L. Bergmann, A.S. Lavine Incropera's Principles of Heat and Mass Transfer John Wiley & Sons, 8th edition, 2017 ISBN 978-1-119-38291-1 Hans Dieter Baehr, Karl Stephan Heat and Mass Transfer Springer, 3rd revised edition, 2011 ISBN 978-3-642-44401-2 Peter von Böckh, Thomas Wetzel Heat Transfer – Basics and Practice Springer, 3rd revised edition, 2012 ISBN 978-3-642-19182-4

3402 Principles of Software Development

Module name:	Principles of Software Development
Module code:	3402
Courses (where applicable):	
Semester:	Summerterm
Module coordinator:	Prof. Dr. Ronny Hartanto
Lecturer:	Prof. Dr. Ronny Hartanto
Language:	English
Place in curriculum:	Focus Core subject
Timetabled hours:	Principles of Software Development Lectures: 2 HPW Practical: 1 HPW
Workload:	45 h attendance 45 h preparation and review 30 h homework and lab review 30 h exam preparation
Credits:	5
Recommended prerequisites:	Good knowledge in programming (C++, Java, C, etc.) Basic knowledge in object-oriented programming (OOP)
Module objectives:	• Students are familiar with different software process models. • Students are able to classify different aspects of software-related process activities and can recognize the importance of the roles of the parties involved into these processes. • Students are able to derive the software specifications from the requirements of a software project. • Students are familiar with different UML diagrams • Students can develop system model of a software project using graphical modelling (UML) • Students can develop test procedures for software projects. • Students can develop software using reusable software development technique, e.g. using open source libraries • Students can apply some of design pattern techniques • Students can use software repository system for daily purpose, e.g. revision system for a software project
Content:	• Software processes - Software process models (Waterfall model, incremental model, reuse-oriented software design)

	- Process activities (Specification, Design and implementation, Verification, Software evolution) - Coping with change • Agile Development • Requirements Engineering - Functional and non-functional requirements - Requirements specification - Requirements management • Design and Implementation • Design Patterns • Reusable Software Development Technique • System Modelling - Graphical Modelling perspectives (external, interaction, structural and behavioural) - Unified Modelling Language / UML diagrams (activity, use case, sequence, class and state) • Software testing • Software development tools
Assessment:	Graded: Continuous assessment (10%: project and quizzes) and written examination (90%)
Forms of media:	Whiteboard, PowerPoint, Projector, PC-Pool
Literature:	I. Somerville, “Software Engineering”. 10th edition. Pearson 2016 J. Rumbaugh, I. Jacobson, G. Booch, “The Unified Modeling Language Reference Manual”, 2nd edition. Addison-Wesley 2005 S. McConnell, “Code Complete”. 2nd edition. Microsoft Press Redmond, WA, USA 2004. E. Gamma, R. Helm, R. Johnson, J. Vlissides, “Design Patterns: Elements of Reusable Object-Oriented Software”. Addison-Wesley 1995 B. Stroustrup, “The C++ Programming Language”. 4th edition. Addison-Wesley 2013. H. Partsch, “Requirements Engineering systematisch”. Springer 2010 J. A. Whittaker, “How to break software: a practical guide to testing”. Addison-Wesley 2002

3403 Materials Selection and Simulation

Module name:	Materials Selection and Simulation
Module code:	3403
Semester:	Summerterm
Module coordinator:	Prof. Dr.-Ing. Henning Schütte
Lecturer:	Prof. Dr.-Ing. Henning Schütte
Language:	English
Place in curriculum:	Core subject
Timetabled hours:	Lectures: 2 HPW Practical Training: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	Introductory courses in Material Science, Design and Mechanics
Module objectives:	After completing the course the students are able to: • classify materials according to specific applications, e.g. according to specific design codes • understand tools and keys for proper selection of materials for specific applications • detect limits of materials and present proper alternative selection • identify standard procedures and benchmarks for materials classification and selection • apply basic materials property calculations • identify and apply proper simulation models and tools, especially FEM based analysis
Content:	• General ideas of materials selection • Methods and procedures • Determination of requirements • Information sources and databases • Evaluation, validation and decision • Risk evaluation and control • Overview and application of modelling approaches simulation methods, FEM based evaluation, risk and failure models • Assessment
Assessment:	Graded: 100% continuous assessment

Forms of media:	Whiteboard, PowerPoint, Projector
Literature:	- Lecture notes - Michael Ashby: Materials Selection in Mechanical Design. Butterworth Heinemann; 4th revised edition 2010 - Huei-Huang Lee : Finite Element Simulations with ANSYS Workbench 17 - Guangming Zhang: Engineering Analysis with ANSYS Workbench 18

3404 Advanced Computer-Aided Design

Module name:	Advanced Computer-Aided Design
Module code:	3404
Courses (where applicable):	
Semester:	Winterterm
Module coordinator:	Prof. Dr.-Ing. Stéphane Danjou
Lecturer:	Prof. Dr.-Ing. Stéphane Danjou
Language:	English
Place in curriculum:	Elective Focus Field “Digital Engineering” Elective Focus Field “Development and Design”
Timetabled hours:	Lecture: 1 HPW Practical Training: 2 HPW
Workload:	45 h attendance 70 h preparation and review 35 h exam preparation
Credits:	5
Recommended prerequisites:	Basic knowledge in a CAD system from previous studies, ideally in SolidWorks
Module objectives:	This course provides students with knowledge of advanced Computer-aided Design techniques to realise, communicate and share mechanical design information, and equips them with the necessary skills for using the CAD system SolidWorks to carry out these tasks efficiently. After completion of the module students are able to generate complex solid models and assemblies, and they are able to modify and update an existing design. They understand the different 3D modelling methodologies and can apply the appropriate modelling strategy for different applications. In addition, students are able to generate surface models with the help of different types of faces and curves. They can select the right surface construction technique for a given geometry. Beside advanced modelling techniques, students are able to integrate calculations into a CAD model and know different techniques to ensure the design intent and how to automate modelling steps. Students understand the concept of Product Lifecycle Management and how CAD is related to this, and students know the principles of Product Data Management systems and how CAD files are organized inside companies.
Content:	• Solid representation schemes in CAD systems • Advanced sweep features • Advanced loft features

	• Advanced surface modelling - Ruled surfaces - Lofted surfaces - Swept surfaces - Filled surfaces - Boundary and freeform surfaces • Hybrid modelling (combined solid/surface modelling) • Modelling methodologies - Top-down assembly modelling - Bottom-up assembly modelling - Design in context approach - External referencing in CAD systems - Model Based Definition in CAD systems • Knowledge-based Engineering techniques • Automation techniques for 3D CAD modelling tasks • Methods and systems for Product Lifecycle Management (PLM) • Fundamental functionality of Product Data Management (PDM) systems and their applications • PDM systems for vaulting and version control of engineering data
Assessment:	Graded: Written digital examination
Forms of media:	Webex/Moodle
Literature:	Paul Tran: SOLIDWORKS 2017 Advanced Techniques. SDC Publications, 2016. ISBN: 9781630570590 K.-H. Chang: Product Design Modeling using CAD/CAE: The Computer Aided Engineering Design Series. Amsterdam: Elsevier, 2014. ISBN: 978-0-12-398513-2 I. Stroud, H. Nagy: Solid modelling and CAD systems: How to survive a CAD system. Springer, 2011. ISBN: 978-0-85729-258-2 Course materials from the lecturer

3405 Computational Fluid Dynamics

Module name:	Computational Fluid Dynamics
Module code:	3405
Semester:	Winter term
Module coordinator:	Prof. Dr.-Ing. Joachim Gebel
Lecturer:	Jan Lehmkuhl (external lecturer)
Language:	English
Place in curriculum:	Focus field subject
Timetabled hours:	Lectures: 1 HPW Exercise: 2 HPW
Workload:	60 h attendance 90 h preparation and review
Credits:	5
Recommended prerequisites:	Advanced Engineering Mathematics 3301 Numerical Methods for Simulation 3411 Thermodynamics of Power Systems 3401 Heat Transfer 3402 Principles of Software Development 3404 Advanced CAD

Module objectives:	On completion of this module the student will be able to
	• run CFD calculations with open-source tools and version control. This contains
	  o to create a mesh
	  o to setup a calculation
	  o to run a calculation
	  o to post-process a CFD simulation to extract the needed information
	• understand the basic concept of
	  o Navier-Stokes equation
	  o Incompressible and compressible fluid flow applications
	  o Convergence behaviour in CFD
	  o Steady state and transient flow behaviour and their impacts to the simulation
	  o Turbulence modelling
	  o errors and uncertainties in CFD
	• create a CFD project and
	  o to pose appropriate questions

	◦ to chase the problem ◦ to write an appropriate report
Content:	The main focus of this introduction module is to enable the student to run a successful CFD project. To achieve this goal the student needs three major skills, which are addressed in this course and described in more detail in the objectives. 1. Practical skills to run a CFD calculation 2. Understanding of some basic theory to formulate right statements 3. Project management skills to achieve goals and not to run impressive but useless simulations The used toolset in this course is complete open-source and available on all three major operating systems (Linux, Windows, MacOS). Therefore everyone should be able run small simulations on their private computers, which is necessary for the course. The used tools are: • "git" as version control system (git-scm.com/) • "Visual Studio Code" as editor (https://code.visualstudio.com) • "FreeCAD" as CAD solution (https://freecadweb.org/) • "CfdOF-FreeCAD-Plugin" as graphical CFD preprocessor (https://github.com/jaheyns/CfdOF) • "OpenFOAM" as CFD solver (https://openfoam.org/) • "ParaView" as postprocessor (https://www.paraview.org/)
Assessment:	Graded: 50% continuous assessment, i.e. finishing tutorial problems at home and presenting them in class 50% final project work and calculation report
Forms of media:	Webex/Moodle
Literature:	Moukalled, F. 2016 The Finite Volume Method in Computational *Fluid* Dynamics: An Advanced Introduction with OpenFOAM® and Matlab http://dx.doi.org/10.1007/978-3-319-16874-6 Laurien, Eckart, 2018 Numerische Strömungsmechanik http://dx.doi.org/10.1007/978-3-658-21060-1

3406 Model Based Design of Mechatronic Systems

Module name:	Model Based Design of Mechatronic Systems
Module code:	3406
Semester:	Winterterm
Module coordinator:	Prof. Dr.-Ing. Dirk Nissing
Lecturer:	Prof. Dr.-Ing. Dirk Nissing
Language:	English
Place in curriculum:	Elective Focus Field “Digital Engineering” Core Field “Development and Design”
Timetabled hours:	Lecture: 1 HPW Practical Training: 2 HPW
Workload:	45 h attendance 80 h preparation and review 25 h exam preparation
Credits:	5
Prerequisites:	
Module objectives:	After completion of the module students are able to differentiate between various modelling techniques, such as white box and black box modelling, and they are able to decide for a modelling technique based on given requirements. Students are able to apply the method of decomposition for complex system structures, dividing them into sub-modules, which allows modelling and simulations in bigger teams. They understand the principles, approaches and methods of theoretical modelling and experimental modelling (system identification). They have the knowledge of using and implementing the “System Identification” method by considering a practical example. Furthermore, the basics to specify the IT-part of a complex system are introduced. This contains database interface, App-design and IT security. Ultimately, students are able to interpret, evaluate and assess the simulation results and models and they have the experience and knowledge to identify and develop required changes of the model.
Content:	• Modelling - Theoretical modelling - Experimental modelling • Principles of decomposition of a complex system / problem (V-model) - Decomposition into sub-modules - Interface definition - Assignment of simulation tasks - Integration of simulation modules

	- Synthesis of simulated system • Simulation of electric power transmission drive - Electric motor - Parameterization - Investigation of disturbances - Model verification - Extension of the model • Identification with parametric models - Least square parameter estimation - Implementation of a real problem: system identification, system validation and verification • IT-interfaces
Assessment:	Attestation: continuous assessment and homework
Forms of media:	Webex Moodle
Literature:	James B. Dabney, Thomas L. Harman: Mastering Simulink®. Pearson Education 2004. ISBN 0-13-142477-7. Rolf Isermann, Marco Münchhoff: Identification of Dynamic Systems. Springer 2011. ISBN 978-3-540-78878-2. Lennart Ljung: System Identification. Prentice Hall 2009. ISBN 0-13-656695-2. Course Materials from the Lecturers

3407 Computational Multibody Dynamics

Module name:	Computational Multibody Dynamics
Module code:	3407
Semester:	Summerterm
Module coordinator:	Prof. Dr. Thorsten Brandt
Lecturer:	Prof. Dr. Thorsten Brandt
Language:	English
Place in curriculum:	Fokusfeld
Timetabled hours:	Lectures: 1 HPW Practical Training: 2 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	Fundamentals of Mechanics and Engineering Mathematics at the undergraduate level as wells as fundamental programming skills
Module objectives:	After successfully finishing the module, students are familiar with the fundamentals of multibody dynamics. They are able to apply concepts from linear algebra such as vectors and matrices to mechanical systems. The kinematics of technical joints such as revolute joints can be modeled by algebraic constraints by the student. The student is also able to model the dynamics of constraint multibody dynamic systems. Furthermore, the student is able to develop basic programming code and to simulate multibody dynamic systems and to interpret the simulation results.
Content:	The course focuses on the modelling and numerical simulation of dynamic multibody systems. Main subjects are: • Definitions: bodies, joints, and coordinates • Kinematics: rotation, translation • Kinematic constraints • Dynamics • Development of multibody dynamics simulation code • Application of multibody simulation software • Analysis of multibody dynamic systems
Assessment:	Graded: Written or oral examination
Forms of media:	Whiteboard, PowerPoint, Projector
Literature:	P. E. Nikravesh: Planar Multibody Dynamics - Formulation, Programming, and Application, CRC press,2008 Lecture Notes

3408 Factory Simulation

Module name:	Factory Simulation
Module code:	3408
Courses (where applicable):	
Semester:	Summerterm
Module coordinator:	Prof. Dr.-Ing. Alexander Klein MBA
Lecturer:	Christian Berendonk
Language:	English
Place in curriculum:	
Timetabled hours:	Lectures: 2 HPW Tutorials: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	
Module objectives:	After completing the course the students are able to: • Understand the benefits and areas of use of discrete-event factory simulation (material flow simulation) • Transform a factory-related problem (question) from prose into a precise question that can be answered by using the factory simulation methods • Create models, write methods (codes, rules) • Analyse results and draw conclusions
Content:	• Basics about simulation • Difference between DE method, agent-based simulation and system dynamics approach • Difference between static calculation of production capacity and cost and dynamic simulation • Problem examples • Practical use of a factory simulation tool along the above-mentioned module objectives
Assessment:	Graded: Continuous assessment
Forms of media:	Whiteboard, PowerPoint, Projector, Computer lab
Literature:	• Lecture notes • Tutorials Siemens plant simulation and forums • Tutorials Simul8 and forums • Steffen Bangsoff or similar book (translated extracts)

3409 Design Methodology

Module name:	Design Methodology
Module code:	3409
Semester:	Winterterm
Module coordinator:	Prof. Dr.-Ing. P. Kisters
Lecturer:	Prof. Dr.-Ing. R. Schmetz
Language:	English
Place in curriculum:	Compulsory optional subject: Design & Development
Timetabled hours:	Lectures: 2 HPW Exercise: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	
Module objectives:	The module introduces modern techniques and methods for product development based on the German guideline VDI 2221. After completing the module, the students know different methods to analyse, solve and control design problems. The students are aware of common obstacles in the design process and they now way how to overcome problems during the design phase. They realize the importance of the early phase of a design process. The students are familiar with simultaneous and virtual product design approaches. Besides, they are able to optimize solution based on methodical analysis of designs and improve the product architecture. They how to come to decisions and how to evaluate them. Hence, the students are prepared to take over a responsible position in a design development process.
Content:	• Introduction of design methodologies for different engineering fields • Strategic planning of a product design process • Methods for Product Development - Analysis tools for minimum design - Work with technical-physical principle solutions - Expert system for the improvement of energy efficiency • Design for X - Impact of different design targets on design and process • Portfolio management - Risk and Change Management - Modular Design - Platform strategies

	- Carry-over-part strategies • Verification and validation in the design process - The need for verification and validation - Continuous validation - Methods for validation • Lean development - Basic principles of lean development - Interactions and potentials • Decision making in development processes - Requirements for decision making - The process of decision making - Evaluation methods for the decision making process • Assurance of development targets - Preventive assurance: FMEA - Reactive assurance: cause and chain analysis
Assessment:	Graded: Final written examination
Forms of media:	Moodle
Literature:	Pahl, G.; Beitz, W.; Feldhusen, J.; Grote, K.-H.: Engineering Design – a systematic approach, third edition, Springer Verlag, Berlin, 2014 VDI-Richtlinie VDI 2221- Blatt 1: Entwicklung technischer Produkte und Systeme – Modell der Produktentwicklung, März 2018 VDI-Richtlinie VDI 2221- Blatt 2: Entwicklung technischer Produkte und Systeme- Gestaltung individueller Produktentwicklungsprozesse, März 2018 Ehrlenspiel, K.: Integrierte Produktentwicklung, 5. Überarbeitete und erweiterte Auflage, Carl Hanser Verlag, München, 2013 Lindemann,U.: Handbuch Produktentwicklung, Carls Hanser Verlag, München, 2016

3410 Tribology

Module name:	Tribology
Module code:	3410
Semester:	Summerterm
Module coordinator:	Prof. Dr.-Ing. Peter Kisters
Lecturer:	Karsten Schacky
Language:	English
Place in curriculum:	Compulsory optional subject: Design & Development
Timetabled hours:	Lectures: 2 HPW Practical Training: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	
Module objectives:	After passing the course the students are able to communicate about tribological phenomena. They identify tribo systems and understand basic mechanisms. The students differentiate between different types of friction and wear. They are aware of the importance of lubrication for the tribological system and distinguish between different kinds of lubricants and their influences on friction and wear. The students know different options for surface modification and their influence on the tribological system. After description of a given tribologically stressed system the students are able to analyse it and know how they can find root causes for existing wear problems. Based on that they develop and evaluate countermeasures against wear and tear by surface modification. Besides, the students are able to analyse the influence of wear and tear on the function of a product as well as ecological impacts. Some wear mechanisms require basic knowledge about fluid dynamics to explain the influence on machine components. Therefore, hydrostatic and hydrodynamic bearings will be introduced and discussed. After taking part in the practical trainings the students are able to describe engineering surfaces and know test methods to determine results for friction coefficients and wear rates under realistic load conditions. The students are able to run the required tests.
Content:	• Introduction - The term tribology - Importance of tribology - The tribological system - Surfaces, contact and loading of tribological systems

	• Friction - Static and kinematic friction - Sliding and rolling friction - Friction and lubrication conditions - Types of friction • Wear - Wear mechanisms - Types of wear • Lubricants - Lubrication systems and their application - Types and properties of lubricants - The selection of lubricants - Temperature influence - Ageing • Tribology and materials - Basic Principles - Metallic materials - Non-metallic inorganic materials - Composite materials • Basics of Surface Engineering • Wear testing methods • Case study: hydrostatic and hydrodynamic bearings
Assessment:	Graded: Final written examination
Forms of media:	Presentation, Board, Tablet, Lecture Slides
Literature:	Mang, Bobzin, Bartels: Industrial Tribology: Tribosystems, Friction, Wear and Surface Engineering, Lubrication, ISBN 978-3-52732057-8, Wiley, 2011 Menezes, Ingole, Nosonovsky, Kailas, Lovell: Tribology for Scientists and Engineers - From Basics to Advanced Concepts, ISBN 978-1-4614-1944-0, Springer, 2013 Lyubimov, Dolgapolov, Pinchuk: Micromechanisms of Friction and Wear, ISBN 978-3642351471, Springer-Verlag, 2010 Popov, Valentin: Contact Mechanics and Friction - Physical Principles and Applications, ISBN 978-3-642-10802-0, Springer-Verlag, 2010 Czichos, Habig: Tribologie-Handbuch: Tribometrie, Tribomaterialien, Tribotechnik: Reibung und Verschleiß, ISBN 978-3834800176, Vieweg-Teubner, 2010

3411 Thermodynamics of Power Systems

Module name:	Thermodynamics of Power Systems
Module code:	3411
Semester:	Summerterm
Module coordinator:	Prof. Dr.-Ing. Joachim Gebel
Lecturer:	Prof. Dr.-Ing. Joachim Gebel
Language:	English
Place in curriculum:	Focus field: Development and Design Compulsory optional subject
Timetabled hours:	Lectures: 2 HPW Exercise: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	Fundamentals of Thermodynamics
Module objectives:	On completion of this module the student is able to ... • analyse vapour power cycles in which the fluid is alternately vaporized and condensed • evaluate the performance of gas power cycles for which the working fluid remains a gas throughout the entire cycle • review the operation of reciprocating engines • solve problems based on the Otto, Diesel, Ericsson and Stirling cycle • solve problems based on the Brayton cycle • investigate ways to modify the basic Rankine vapour power cycle to increase the thermal efficiency • analyse power cycles that consist of two separate cycles known as combined cycles • analyse jet-propulsion cycles • perform exergy analysis of vapour and gas power cycles
Content:	1 Review of basics 1.1 Thermodynamic properties 1.2 Ideal gas law 1.3 First law of thermodynamics 1.4 Second law of thermodynamics 1.5 Carnot Cycle and Carnot efficiency 2 Vapour power systems

	2.1 Modelling and analysing vapour power systems 2.2 Rankine Cycle 2.3 Improving performance 3 Gas power systems 3.1 Internal combustion engines - Fuels and combustion equations - Reciprocating engines - Otto Cycle - Diesel Cycle 3.2 Gas turbine power plants - Brayton Cycle - Ericsson Cycle - Stirling Cycle 3.3 Gas turbines for aircraft propulsion 3.4 Gas and steam turbine power plants (Combined cycles) 4 Exergy analysis 5 Practical Training 5.1 Practical training on air compressor 5.2 Practical training on steam engine 5.3 Practical training on Stirling motor
Assessment:	Graded: Written examination
Forms of media:	Whiteboard, PowerPoint, Projector, Tablet
Literature:	Michael J. Moran, Howard Shapiro: Fundamentals of Engineering Thermodynamics SI-Version, ISBN 978-0-470-54019-0 Robert Balmer: Modern Engineering Thermodynamics ISBN 978-0-12-374996-3 Yunus A. Cengel, Michael A. Boles: Thermodynamics An Engineering Approach: 7thedition in SI-Units, ISBN 978-007-131111-3 Claus Borgnakke, Robert E. Sonntag: Fundamentals of Thermodynamics, International Student Version, 7thedition, ISBN 978-0-470-17157-8

3412 Energy-efficient and Sustainable Drive Systems

Module name:	Energy-efficient and Sustainable Drive Systems
Module code:	3412
Semester:	Summerterm
Module coordinator:	Prof. Dr.-Ing. Dipl.-Wirt. Ing. Roland Schmetz
Lecturer:	Prof. Dr.-Ing. Dipl.-Wirt. Ing. Roland Schmetz
Language:	English
Place in curriculum:	Compulsory optional subject: Development and Design
Timetabled hours:	Lectures: 1 HPW Exercises: 1 HPW Practical Training: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	Courses Drive Systems or Drives and Power Electronics at undergraduate level
Module objectives:	After completion of the module students are able to • identify, classify, analyse and evaluate a wide range of machine elements for common and advanced drive systems • describe common and advanced drive systems containing components like epicyclic gears, CVT units, electric drives (including the most important control modes for them), energy storages, and efficient supplies • sketch and compose simple hybrid, combined and distributed drive systems for different applications • mention, recommend and explain a lot of potential measures for the increase of the energy efficiency and the sustainability of drives systems • perform life cycle analyses of simple drive systems and their components • follow safety and conduct instructions in laboratories and execute simple practical experiments as groups
Content:	• Mechanical Drive Systems with - Spur, Helical, and Epicyclic Gears - Multiple Disc and Double Clutches - Power Split and Power Merging - Variable Belt- and Chain-Drives - Toroidal CVT Units • Fluid Power Drive Systems with - Hydrostatic CVT Units

	- Hydrodynamic CVT Units • Electric Drive Systems with - Electric CVT Units - Most Common Control Modes • Advanced Drive Systems - Hybrid Drive Systems - Combined Drive Systems - Distributed Drives Systems • Additional Components for Advanced Drive Systems - Solar and Fuel Cells - Energy Storages and Energy Recovery Units - External Supplies • Design of Energy-efficient and Sustainable Drive Systems - Systematic Design - Design for Application - Design for Energy Efficiency - Design for Sustainability • Evaluation of Drive Systems - Evaluation Basics - Economic Evaluation - Strategic Evaluation - Energy Data - Energy Analysis - Sustainability Analysis • Case Studies
Assessment:	Graded: Written Examination
Forms of media:	Presentation, media board, practical demonstrations
Literature:	All drive systems related technical literature, which is available on floor 5 in the library of the Rhine-Waal University of Applied Sciences Course Materials from the Lecturer Exercises from the Lecturer Instructions for Practical Experiments

3413 Advanced Simulation Technologies

Module name:	Advanced Simulation Technologies
Module code:	3413
Semester:	Summerterm
Module coordinator:	Prof. Dr.-Ing. Hennning Schütte
Lecturer:	Prof. Dr.-Ing. Hennning Schütte
Language:	English
Place in curriculum:	Core subject
Timetabled hours:	Lectures: 1 HPW Practical Training: 2 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	Advanced Engineering Mathematics, Basic Courses in Statics, Mechanics of Materials and Dynamics. Preferably an introductory course in FEM
Module objectives:	After completing the course the students are able to: • Set up suitable simulation models for complex non-linear problems including large deformation and non-linear material behaviour • Students are able to identify the material and other physical properties necessary for the chosen simulation • Students are able to critically analyse the results of the simulations • e.g. for crash-simulations, rubber-like materials and non-linear contacts • Use Multiphysics approaches to simulate inherently coupled phenomena by coupling two or more physical phenomena of e.g. solid mechanics, heat flow, fluid flow, electromagnetics
Content:	• Fatigue analysis based on quasi-static simulations • Large strain analysis and non-linear material behaviour, e.g. rubber-like materials, soft-tissues, metal plasticity and metal forming and crash simulations • Transient dynamic problems with non-linear contacts, e.g. pile driving with hydraulic ram hammers • Multiphysics simulations of inherently coupled systems of for two or more physical phenomena of e.g. solid mechanics, heat flow, fluid flow, electromagnetics etc.

Assessment:	Graded: 50% continuous assessment, i.e. finishing tutorial problems at home and presenting them in class 50% final project work and calculation report
Forms of media:	Whiteboard, PowerPoint, Projector
Literature:	- Lecture notes - Huei-Huang Lee : Finite Element Simulations with ANSYS Workbench 17 -

3415 Production Management

Module name:	Production Management
Module code:	3415
Semester:	Summerterm
Module coordinator:	Prof. Dr.-Ing. Alexander Klein MBA
Lecturer:	external lecturer
Language:	English
Place in curriculum:	
Timetabled hours:	Lectures: 2 HPW Exercises: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	
Module objectives:	After completing the course the students are able to identify specific actions to optimize existing factories and to design new factories with regard to good KPI such as productivity, ROCE, throughput time, delivery performance etc. The understand the importance of IT in modern production due to high number of variants, batch tracking, , short time to market and shorter product life cycles and strong competition in many areas. The students are able to design production networks, i.e. to distribute value creation over several production facilities in such a way that the network is optimized with regard to a specific target, a mixed objective and with compliance of boundary conditions.
Content:	□ Factory design - Factory layout - Factory sub functions (including warehouses) - Capacity calculation - Flexible and versatile factories - Conveying technology - Cost forecasting and investment planning - Technology selection - Ergonomics and workplace design - Order management - ERP enterprise resource planning - work planning

	- production logistics and priority rules - - performance metrics (KPI) Lean production - value stream mapping & value stream design Complexity management - impact of product design on complexity in production - internal and external complexity Dilemmas in production (target conflicts) and means to reduce them - Industrial IoT (digital transformation, “Industrie 4.0”)
Assessment:	Graded: Continous assessment
Forms of media:	Whiteboard, PowerPoint, Projector
Literature:	• Lecture notes • E. S. Pound, M. L. Spearman: Factory physics for managers (McGraw Hill) • Whitepapers

3416 Machine Tools and Automation

Module name:	Machine Tools and Automation
Module code:	3416
Semester:	Winterterm
Module coordinator:	Prof. Dr.-Ing. Alexander Klein MBA
Lecturer:	Prof. Dr.-Ing. D. Manoharan (external lecturer)
Language:	English
Place in curriculum:	
Timetabled hours:	Lectures: 2 HPW Practical Training: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	Manufacturing technology, controls, mechanics (elastostatics), technical design at undergraduate level
Module objectives:	After completing the course the students are able to: • distinguish the types of machine tools, know their field of application and their functionality, • understand the factors that influence the design and the performance of a machine tool, • understand the standard methods and apply them to evaluate the machine tool`s performance, • select the proper machine tool and its grade of automation, • understand the management of machine tools in the floor shop, • comprehend the impact of industry 4.0.
Content:	Machine tool classification, types and concepts: • machining, deforming, thermal cutting, hybrid etc. • configuration concepts (position of axes, kinematics) • visual inspection of machine tools (laboratory) Machine tool components: • structure (bed, guideways, housings, headstock, tailstock etc.) • feed drives • spindle drives • tool • sensors and encoders (e.g. position and speed) • visual identification of the components (laboratory) Machine tool dynamics: • static stiffness • dynamic stiffness, eigenfrequencies and eigenmodes

	• regenerative chatter and other instabilities • active and passive methods to reduce instability • measurement of force, stiffness and instability (laboratory) Thermal behaviour: • thermal growth and resulting inaccuracy • Thermal compensation and thermally neutral design Accuracy: • repeat accuracy • structural influences (guideways, spindles, backlash bearings etc.) • controls influence (axis lag) • positioning error and ISO standards • positioning test and correction (laboratory) Controls: • NC • PLC • safety concept and components • control loops (position, speed, acceleration, jolt control) • adaptive process control Automation: • systems for tool handling (e.g. tool magazine, tool correction,…) • systems for workpiece handling (e.g. workpiece changer, pallet changer, conveyor for multiple machines,…) • Machine tools for flexible manufacturing systems Industry 4.0: • concept and applications • hardware solutions and software platforms • influence in the design (modifications, simulations,…) • business impact (productivity, revamping, …)
Assessment:	Graded: Written Exam and/or reports
Forms of media:	Webex/Moodle
Literature:	• Lecture notes • Makhanov, Stanislav S., Anotaipaiboon, Weerachai: Advanced numerical methods to optimize cutting operations of five axis milling machines, Springer, 2007 • Kibbe, Richard R.: Machine tool practices, Pearson 2010 • Schmitz, Tony L., Smith, Kevin S.: Mechanical vibrations - modeling and measurement, Springer 2012 • Cheng, Kai: Machining dynamics - fundamentals, applications and practices, Springer, 2009 • Weck, Manfred; Brecher, Christian: Werkzeugmaschinen – Fertigungssysteme (1-5), Springer, 2006

	• Wang, Lihui: Dynamic thermal analysis of machines in running state, Springer 2014 • Machine Tool 4.0 for the new era of manufacturing, The International Journal of Advanced Manufacturing Technology 2017

3417 Manufacturing Technology Development

Module name:	Manufacturing Technology Development
Module code:	3417
Semester:	Winterterm
Module coordinator:	Prof. Dr.-Ing. Alexander Klein
Lecturer:	T. Oster (External Lecturer)
Language:	English
Place in curriculum:	
Timetabled hours:	Lectures: 2 HPW Exercises: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	
Module objectives:	After completing the course the students are able to: • Understand why and how to improve existing technologies and or develop new technologies • Create process models to reduce complexity and make the problem solvable • Make good technology decisions and determine the value of different options
Content:	• Definition of targets in development of new manufacturing technologies and enhancement of existing technologies • Creation of visions • Forms of cooperation with research facilities, business partners etc. • Determination of the value of a technology (and strategic impact) & the Gassmann technology portfolio • IP protection of manufacturing technologies • Advantages and disadvantages of physical experiments (experimental studies) (ditto for simulation strudies) • Design of Experiment (DoE) for physical experiments and for simulation runs • Model validation and calibration
Assessment:	Graded: Continous assessment
Forms of media:	Webex/Moodle
Literature:	• Lecture notes

3418 Data Analytics

Module name:	Data Analytics
Module code:	3418
Semester:	Winterterm
Module coordinator:	Prof. Dr. Alexander Struck
Lecturer:	Prof. Dr. Alexander Struck
Language:	English
Place in curriculum:	
Timetabled hours:	Lecture: 2 HPW Practical Training: 1 HPW
Workload:	45 h attendance 75 h preparation and review 30 h exam preparation
Credits:	5
Recommended prerequisites:	Mathematics (BSc. level), Programming
Module objectives:	Students understand the concepts of data science and get insight on how to evaluate and apply information technology and data-driven decision making into production processes and other fields of mechanical engineering They aquire basic skills on data categories, methods of data processing and various types of analysis. Basic ideas of machine learning will be discussed and applied to relevant problems in engineering Students can evaluate appropriate hardware, software and methods to implement data analytics into business cases.
Content:	• Types of data, Big Data • Tools of data analytics: Matlab, Python, R • Hardware and software requirements for Big Data • Data selection and aquisition • Descriptive and exploratory data analysis of quantitative and qualitative data • Machine learning overview: Supervised vs unsupervised learning, case studies, applications • Added value concepts in business Discussion and decision making arguments, pros and cons of data science projects
Assessment:	Graded: written examination
Forms of media:	Webex/Moodle
Literature:	***Further Readings:*** • Chirag Shah, “A Hands-On Introduction to Data Science”, Cambridge, 2020

	• Foster Provost, “Data Science for Business: What you need to know about data mining and data-analytic thinking”, O’Reilly, 2013 • Syed Muhammad Fahad Akhtar, “Big Data Architect's Handbook: A guide to building proficiency in tools and systems used by leading big data experts” • Nathan Marz, “Big Data:Principles and best practices of scalable realtime data systems” • U. M. Fayyad et al., „Advances in Knowlege Discovery and Data Mining“, 1996 • M. Ester, J. Sander, „Knowlege Discovery in Databases“, 2000 • Pavlo Baron, „Big Data für IT-Entscheider“, 2013

3603 Human Machine Interaction

Module name:	Human Machine Interaction
Module code:	3603
Semester:	Summerterm
Module coordinator:	Prof. Dr.-Ing. Ivan Volosyak
Lecturer:	Prof. Dr. Matthias Krauledat
Language:	English
Place in curriculum:	Focus field
Timetabled hours:	Lecture: 2 HPW Practical Training: 1 HPW
Workload:	45 h attendance 65 h preparation and review 40 h exam preparation
Credits:	5
Prerequisites:	
Module objectives:	The field of Human-Computer Interaction (HCI) is rapidly growing area of human-machine interaction. This highly multidisciplinary study course brings together research topics from: Interaction Design, Human-Robot Interaction, Artificial Intelligence, Psychology, Robotics and many other fields. The main goal of HCI is to enable machines to successfully interact with humans. The students understand the fundamentals of underlying technologies, as they relate to human-computer interaction, man-machine coupling, and ethics. The electrical potentials in the human brain, which can be detected with non-invasive and invasive methods, may be used for the establishing the connection between the human brain and the computer. The students can derive, from first principles, real architectures for modern Brain-Computer Interfaces (BCI). They are able to design and build, using specialized communications structures and sensors, systems for, among other things, the support of physically handicapped individuals (such as gesture recognition, speech processing etc.). They appreciate the safety and social aspects of modern HCI and BCI technologies and can name the relevant risks
Content:	• Introduction to Human-Machine Interaction • Human body as electrical system • The concept of a Brain-Computer Interface • Modern speech processing • Gesture recognition

	• Virtual and Augmented Reality • Data collection with non-invasive methods • Fundamentals of EEG • SSVEP, P300 and ERD/ERS based BCI • Applications for communication with and control of external machines
Assessment:	Attestation
Forms of media:	Whiteboard, PowerPoint, Projector, Demonstrations in the lecture
Literature:	• Ian McLoughlin, Applied Speech And Audio Processing: With Matlab Examples, Cambridge University Press, 2009, 00/YGK 2 • J. R. Parker, Algorithms for image processing and computer vision, 2011, Wiley, 00/TVV 51 • Jonathan R. Wolpaw, Elizabeth W. Wolpaw Brain-Computer Interfaces – Principles and Practice, Oxford University Press, 2012, 00/TVU33 *Further reading:* • Siuly Siuly, Yan Li, Yanchung Zhang EEG Signal Analysis and Classification, Springer, 2016, 00/WBK105 • Rajesh P. N. Rao Brain-Computer Interfacing, Cambridge University Press, 2013, 00/WBK78 • Course materials from the lecturer

3608 Sustainability

Module name:	Sustainability
Module code:	3608
Semester:	Winterterm
Module coordinator:	Prof. Dr.-Ing. Raimund Sicking
Lecturer:	Prof. Dr.-Ing. Raimund Sicking
Language:	English
Place in curriculum:	Core Subject
Timetabled hours:	Lecture: 2 SWS Exercises: 1 SWS
Workload:	45 h attendance 30 h preparation of presentation(s) 75 h self study and exam preparation
Credits:	5
Recommended prerequisites:	none
Module objectives:	After completing the course, students • understand the general interdependencies between human beings, technology and nature. • can distinguish between different dimensions of globalization. • are aware of global environmental changes, such as climate change. • have fundamental knowledge about sustainability concepts, strategies and areas of activity. • understand concept and principle of a circular economy. • know EU-directives and selected national regulations concerning circular economy and waste • know options for product and product integrated environment protection • recognize concept and structure of different life cycle assessments. • are able to apply methods for sustainable technology design. • Know methods for pollution-free environment
Content:	• Theories of nature, society and technology • Economic, political, cultural and ecological dimension of globalization • Global warming, carbon footprint, decarbonization

	• Weak and strong sustainability
	• The *factor 10* approach
	• Concept of
	  - dematerialization
	  - open lool
	  - low carbon
	  - restoration
	• Concept and principle of a circular economy
	• Basics of product and product-integrated environmental protection
	• Technology assessment
	• Social, ecological and classic life cycle assessment (LCA)
	• Low impact materials, renewable resources, energy efficiency, design for reuse and recycling
	• Handling harmfull substances
	• Methods for pollution-free environment

Assessment:	Graded: Examination + Group Presentation
Forms of media:	Webex/Moodle
Literature:	*Matthias Bank:* Basiswissen Umwelttechnik: Wasser, Luft, Abfall, Lärm und Umweltrecht *Karl Schwister:* Taschenbuch der Umwelttechnik *Ernst Worell, Markus A. Reuter (Ed.):* Handbook of Recycling *Iris Pufé* Nachhaltigkeit - Course materials from the lecturer - Exercises from the lecturer - Lecture notes compiled by class (open source)