Fluid mechanics and aerodynamics (1209)

Lecturer: Univ.-Prof. Dr. rer. nat. habil. Christian J. Kähler

Workload: 210 hours; Contact hours: 96 hours; Self-study: 114 hours

ECTS: 7 ECTS

Term: Autumn

Recommended prerequisites: Knowledge in mathematics and experimental physics

Content: Course in fluid mechanics
This module teaches the most important basic knowledge of classical fluid mechanics and considers flows in which friction (viscosity) is negligible:

1. introduction
2. description of the flow field
3. definition and properties of fluids
4. laws of friction
5. statics of fluids
6. dynamics of fluids
7. application of Bernoulli's equation
8. gas flows
9. momentum theorem
10. potential theory

Lecture Fundamentals of Aerodynamics
In this module, the generation of lift on flowing bodies (airfoil, aerofoil) is considered and the effects of friction (viscosity) and turbulence are discussed:

1. generation of lift
2. theory of thin airfoils (skeleton theory)
3. theory of symmetrical airfoils of finite thickness (droplet theory)
4. hydrofoil theory
5. flows with friction
6. boundary layer theory
7. transition
8. turbulent flows
9. closure approaches and wall laws
10. static theory of turbulence

Learning objectives:
Lecture Fluid Mechanics
Students are familiar with the most important concepts and ways of thinking in fluid mechanics and know how to apply these ways of thinking.

Students are able to estimate simple fluid mechanics problems using mathematical methods.

Students are able to understand and calculate compressible flow phenomena (vertical compression impact).

Lecture Fundamentals of Aerodynamics

Students master the most important calculation methods of the theory of thin airfoils (skeleton theory) and can apply the methods for calculating aerodynamic parameters of symmetrical airfoils of finite thickness on the basis of droplet theory.

Students understand the basic principles of the analytical description of aerofoils within the framework of aerofoil theory and are aware of the effect of geometric parameters of the aerofoil on its aerodynamic performance.

Students understand the physical phenomena of aerofoil flow with the influence of friction (laminar, turbulent, transition, separation) and are able to estimate the flow conditions on an aerofoil.

Students are able to recognise the degree of mathematical complexity involved in solving a given fluid mechanics problem, which solution methods exist and how problems can be simplified.

Teaching Material: English teaching material can be provided in form of books

Proof of performance: Written examination 150 minutes. Authorised aids: non-programmable pocket calculator

English exam possible: oral

This module extends over more than one term. Exam for part of the module is possible.

Bibliography:

- Anderson J.D.: Fundamentals of Aerodynamics. McGraw-Hill Book Company, 1984
- Bertin J.J., Smith M.L.: Aerodynamics for Engineers. Prentice-Hall, 1989
- Schlichting H.; Gersten, K.: Grenzschicht-Theorie. Springer Verlag, 2006
- Schlichting H., Truckenbrodt, E.: Aerodynamik des Flugzeugs. 2 Bände. Springer Verlag, 2001
- Zierep J.: Grundzüge der Strömungslehre. 7. Auflage (2008), Verlag Braun Karlsruhe. http://dx.doi.org/10.1007/978-3-8351-9208-9

Fundamentals of chemical thermodynamics (1226)

Lecturer: Univ.-Prof. Dr.-Ing. Christian Mundt

Workload: 90 hours; Contact hours: 36 hours; Self-study: 54 hours

ECTS: 3 ECTS

Term: Autumn

Recommended prerequisites: Knowledge of 'Thermodynamics', 'Chemistry' from materials science is required

Content:

In the Chemical Thermodynamics module, students acquire the basic knowledge for calculating and applying chemical processes in chemical equilibrium:

- Students are given an introduction to the importance of chemical thermodynamics in problems from the field of aerospace engineering. In particular, applications to combustion are taught.
- Based on the basic equations relating to the reaction rate, reaction enthalpy and chemical equilibrium, students learn the basics for calculating in particular

  State variables as a function of chemical potentials,
  Mixtures of ideal gases,
  Law of mass action,
  Standard formation functions.

- The acquired knowledge is extended by applying it to combustion processes.

Learning objectives:

- Students are able to categorise the significance of chemical thermodynamics in technical problems in terms of purpose, process control and economy/ecology.
- Students will be able to quantify simple chemical conversions.
- Students acquire the ability to determine energy conversions and to influence the chemical composition by means of temperature control.

Teaching Material:

Proof of performance: Written examination 60 minutes or oral examination 30 minutes

English exam possible: written

Bibliography:

Kortüm G., Lachmann H.: Einführung in die chemische Thermodynamik. Verlag Chemie, 1981.

Software Development (1625)

Lecturer: Univ.-Prof. Dr.-Ing. Axel Schulte, Univ.-Prof. Dr.-Ing. habil. Markus Klein

Workload: 150 hours; Contact hours: 96 hours; Self-study: 54 hours

ECTS: 5 ECTS

Term: Autumn

Recommended prerequisites: No specific prerequisites

Content:
The "Software Development" module consists of two largely independent but complementary courses on different aspects of the field of software development for engineers. These are "Software Development - Programming" and "Software Development - Numerical Computer Applications with MATLAB". The course "Software Development - Programming" is primarily dedicated to teaching an imperative programming language as well as basic development and system aspects. The course "Software Development - Numerical Computer Applications with MATLAB" teaches the basics of applying numerical methods on the computer.

Proof of performance: Written examination 120 minutes

part 16251 & 16252 (Programming)

Content:
In the "Software Development" module, students acquire the basic knowledge for developing interactive software applications. In detail, this includes the following content:

Students learn how data is coded in a computer and the associated relevant number systems.

Students gain an insight into the structure of computers and their hardware components.

Students learn the difference between common design methods, with a particular focus on functional and object-orientated design as the most important paradigms.

Students receive an introduction to the implementation of software modules using the C/C++ programming language. In this context, they acquire knowledge in the following areas:

- Programming system environment
  (computer, operating system, compiler, input/output units)
- Imperative programming elements
  Data types and variables
  Expressions and operators
  Control structures
- Object-orientated concepts
  Classes and objects
  Blocks and methods
- Data structures
  Vectors/arrays

- Methods for inter-process communication such as middleware, shared memory areas

Learning objectives:

- Students understand the basic concepts of systematic software development.
- Students can systematically model straightforward problems that are characterised by the interaction of different functionalities and, where applicable, interactivity with users or other functionalities.
- Students are proficient in the most important language constructs of C/C++ and are able to implement simple problems in a C/C++ programme.
- Based on the knowledge they have acquired about imperative programming elements and object-oriented concepts using C/C++ as an example, students are able to learn other imperative object-oriented programming languages such as Java independently.

Teaching Material:

English exam possible: no

This module extends over more than one term. Exam for part of the module is possible.

Bibliography:

Software Development - Programming:

- Balzert H.: Lehrbuch der Softwaretechnik. Basiskonzepte und requirements Engineering. Spektrum Akademischer Verlag, 2009.
- Regionales Rechenzentrum für Niedersachsen, RRZN (Hrsg): C++ für Programmierer.
- Stroustrup B.: The C++ Programming Language. Addison-Wesley, 2000.

part 16253 (Numerical Computer Application)

Lecturer: Univ.-Prof. Dr.-Ing. habil. Markus Klein

Content:
With regard to prototype development and routine tasks that students will be confronted with during their studies and later in their careers, students learn the basic knowledge and functionalities of MATLAB.

Basic elements of procedural programming such as loops, functions, branches, text input and output are then introduced in the MATLAB programming environment.

Finally, the theoretical content of the Numerical Mathematics module is deepened by actively implementing it in the MATLAB programming environment. Students learn the work processes of algorithm development and analysis, programming, troubleshooting, validation, calculation and evaluation with graphical user interfaces.

Learning objectives:

- Students learn the basics of the commercial software MATLAB for solving mathematical problems and graphically visualising the results.

- Furthermore, students learn the basics of procedural programming within this software environment.
- The acquired knowledge is applied and deepened by independently implementing numerical methods from the parallel module ‘Numerical Mathematics’.
- Students are then able to solve mathematical problems from all areas of aerospace engineering independently in a higher programming language using standard libraries.

Teaching Material:

English exam possible: oral

This module extends over more than one term. Exam for part of the module is possible.

Bibliography:

- Benker, H. Ingenieurmathematik kompakt – Problemlösungen mit MATLAB. Springer, Berlin-Heidelberg, 2010.
- Alfio Quarteroni, Fausto Saleri, Wissenschaftliches Rechnen mit Matlab, Springer 2006.
- Higham D.J., Higham N.J.: Matlab Guide; Philadelphia: SIAM, 2005.

Lightweight Construction (1627)

Lecturer: Univ.-Prof. Dr.-Ing. Philipp Höfer

Workload: 150 hours; Contact hours: 72 hours; Self-study: 78 hours

ECTS: 5 ECTS

Term: Winter

Recommended prerequisites: Knowledge of maths, technical mechanics (statics and strength of materials), materials science

Content:
The lightweight construction module focuses on analytical methods for the mathematical assessment of thin-walled structures with regard to strength and rigidity.

- Fundamentals of lightweight construction: material lightweight construction, mould lightweight construction, lightweight construction parameters
- Repetition of the basics of statics and strength of materials, basic equations of engineering mechanics: Equilibrium, geometric relationships, material law
- Stressing of thin-walled beams: deformation approaches, stresses due to normal force, bending and temperature stresses, stresses due to shear force, shear centre, stresses due to torsional stress (St. Venant's torsion, arching force torsion)
- Deformation of thin-walled beams: solution of differential equations, transfer matrices, deformation quantity (finite element method) and force quantity methods.
- Shear field beams: rectangular, parallelogram and trapezoidal fields, shear wall beams, general shear field beams

Learning objectives:

1. Students are able to categorize the significance of lightweight construction in technical problems in terms of purpose, savings potential and economy. They know how to differentiate between material and moulded lightweight construction and recognize the necessity of combining both lightweight construction principles.
2. Students acquire the ability to calculate the stresses on beam structures with thin-walled cross-sections with the help of the basic principles taught, to evaluate these and to make the necessary changes to the design.
3. Students gain an overview of calculation methods for determining the deformation of beam structures. After analyzing and classifying the problem, they will be able to select a suitable solution method and apply it safely.
4. Students will be able to explain the shear field theory and its application and apply the methods learnt to known problems.
5. Students are able to design lightweight structures with regard to strength and stiffness. They are able to check and assess calculation results.

Teaching Material: English teaching material can be provided in form of books

Proof of performance: Written examination, 120 minutes

English exam possible: written

Bibliography:

Text books:

- Hertel, H.: Leichtbau, Springer-Verlag 1980
- Czerwenka, G., Schnell, W.: Einführung in die Rechenmethoden des Leichtbaus, Band 1 & 2, BI-Hochschultaschenbücher
- Dieker, S., Reimerdes, H.-G.: Elementare Festigkeitslehre im Leichtbau, Donat Verlag 1992
- Klein, B.: Leichtbau-Konstruktion, Vieweg Verlag 2005
- Peery, D.J.: Aircraft Structures, McGraw-Hill 1950
- Wiedemann, J.: Leichtbau: Elemente und Konstruktion, Springer-Verlag 2006

Structural Calculation:

- Bruhn, E.F.: Analysis and Design of Flight Vehicle Structures, Tri-State Offset Company 1973
- Niu, Michael C.Y.: Airframe Structural Design, Conmilit Press Ltd. 1988
- IASB (Herausgeber): Handbuch Struktur Berechnung (HSB), IASB

Numerical Analysis (1210)

Lecturer: Univ.-Prof. Dr.-Ing. habil. Markus Klein

Workload: 180 hours; Contact hours: 96 hours; Self-study: 84 hours

ECTS: 6 ECTS

Term: Spring

Recommended prerequisites: Knowledge of mathematics

Content:
The Numerical Mathematics module teaches the fundamentals of computer applications for all numerical problems in aerospace engineering. Due to the increasing importance of the subject, the aim is to focus on the common fundamentals in accordance with the very different technical areas of the degree programme.
The lecture Numerical Mathematics I deals with numerical linear algebra including the concept of conditions and stability. The focus of the lecture is on efficient algorithms for LR, QR, Cholesky, singular value and eigenvalue decomposition as well as the search for zeros.
Numerical Mathematics II deals with interpolation, function approximation, quadrature methods, iterative methods for solving linear systems of equations and the numerical solution of ordinary differential equations.
In both lectures, particular emphasis is placed on familiarising students with the basic algorithms for the problems mentioned and weighing up their specific advantages and disadvantages.

Learning objectives:
Students will be able to independently convert mathematical problems from all areas of aerospace engineering into algorithmic form.

Teaching Material: English teaching material can be provided in form of books

Proof of performance: Written examination, 120 minutes

English exam possible: oral

This module extends over more than one term. Exam for part of the module is possible.

Bibliography:

- Michael Knorrenschild, Numerische Mathematik, Fachbuchverlag Leipzig, 2003.
- W. H. Press, B. P. Flannery, S. A. Teukolsky und W. T. Vetterling, Numerical Recipes in Fortran (in C, in C++, in Pascal), Cambridge University Press
- Josef Stoer, Roland Bulirsch, Numerische Mathematik 1 und 2, Springer, Berlin 1994, 1990.
- W. Dahmen und A. Reusken, Numerik für Ingenieure und Naturwissenschaftler, Springer Verlag, 2008.
- A. Quarteroni, R. Sacco, F. Saleri, Numerische Mathematik 1&2, Springer Verlag, 2000.
- Trefethen L.N., Bau D.: Numerical Linear Algebra. Philadelphia: SIAM, 1997.

Propulsion Systems (1216)

Lecturer: Univ.-Prof. Dr.-Ing. Dragan Kožulović

Workload: 120 hours; Contact hours: 48 hours; Self-study: 72 hours

ECTS: 4 ECTS

Term: Spring

Recommended prerequisites: Knowledge of 'Fluid Mechanics' and 'Thermodynamics' is required

Content:
In the 'Propulsion Systems' module, students acquire basic knowledge of aircraft propulsion systems using turbomachinery:

- Students are given an introduction to the structure, mode of operation, various types of construction and areas of application of aircraft propulsion systems.
- After learning the basics of aerothermodynamics, the derivation of the general thrust equation and important definitions for performance and efficiency, students will familiarise themselves in detail with the ideal and real process of single-flow turbine jet engines (turbojets). With the acquired knowledge and the derived basic equations, important engine parameters and the state changes in the engine components can be calculated and the main engine parameters can be optimised for design aspects.
- Students are familiarised in detail with the fluid mechanics principles of turbomachinery. The flow processes at the blades are taught using velocity triangles, among other things, and the arrangement of blades in the grid and the assembly of grids into stages are illustrated. This is rounded off with the definition of important parameters with which the turbomachinery can be characterised, evaluated and compared and the operating behaviour can be described. This acquired basic knowledge is not purely specific to aircraft engines, but covers the diverse field of general turbomachinery engineering

The module concludes with an overview of the main engine components such as intake, fan, compressor, combustion chamber, turbine and thrust nozzle. Students learn how the components work as well as typical designs and construction details using examples.

Learning objectives:

- Students learn the essential aspects of thrust generation in aircraft engines using turbomachinery. They acquire the skills to evaluate and analyse simple designs of aircraft engines.
- Students acquire an in-depth understanding of the structure, process control and aerothermodynamic processes in single-flow turbojet engines.
- Students acquire the ability to calculate the engine process in detail in the characteristic planes of the engine and to carry out simple optimisations with the help of the basic principles taught.
- Students gain a sound overview of the theory of turbomachinery, which is of the utmost importance for efficient propulsion systems, as well as its functional principles. They will be able to carry out simple calculations of compressors and turbines and evaluate and pre-dimension these components. The knowledge acquired is directly applicable to other areas of application of turbomachinery.

- Students learn about the main components of aircraft engines, as well as their functional principles and construction methods.

Teaching Material: English teaching material can be provided as text

Proof of performance: Written Examination 75 minutes

English exam possible: oral

Bibliography:

- Bräunling W.: Flugzeugtriebwerke. Springer-Verlag, Berlin, 2015, 4. Auflage.
- Hagen H.: Fluggasturbinen und ihre Leistungen. Verlag G. Braun, Karlsruhe, 1982.
- Hünecke K.: Flugtriebwerke. Verlag Motorbuch, Stuttgart, 1978.
- Kerrebrock J.L.: Aircraft Engines and Gas Turbines. The MIT Press, Cambridge, 1992, 2nd Edition (engl.).
- Müller K.J.: Thermische Strömungsmaschinen. Springer-Verlag, Wien, 1978.
- Rolls-Royce: The Jet Engine. Wiley, 1996, 5th Edition (engl.).

Flying robots (3323)

Lecturer: Juniorprof. Dr.-Ing. Jane Jean Kiam

Workload: 90 hours; Contact hours: 36 hours; Self-study: 54 hours

ECTS: 3 ECTS

Term: Spring

Recommended prerequisites: Module 1294 (Mathematics I) and Module 1292 (Mathematics II)

Content:
The module consists of the lecture 'Flying Robots: Theory' and the corresponding exercises 'Flying Robots: Practice'.

In the theory part, students will learn about the basic functionalities of robotics in the following areas:

- Control, localisation and dynamic equations of motion,
- Task and motion planning for drones in three-dimensional environments,
- Communication architecture for robotics,
- Applied AI methods for drones,
- Coordination of a drone swarm.

In addition to the lecture 'Flying Robots: Theory', in-depth tasks are given in the practical sessions ('Flying Robots: Practice'). In the practical part, students also have the opportunity to take a closer look at the implementation of robotics-related functionalities in the form of individual or group work (a working group consists of a maximum of 3 people) by familiarising themselves with the common libraries for these functionalities.

At the end of the lectures, software and hardware-in-the-loop tests are carried out to validate the implementation.

Learning objectives:
After completing the module, students will be able to

1. describe the basic control and localisation technology of unmanned flying robots (and quadrocopters in particular) and analyse their advantages and disadvantages depending on the boundary conditions,
2. enumerate essential system components of intelligent flying robots and classify them according to functionalities,
3. integrate AI tools into the ROS framework,
4. implement basic robotics applications,
5. explain and illustrate the example applications of drones in the real world

Teaching Material: English teaching material can be provided in form of slides/books

Proof of performance: Portfolio, consisting of the following partial performances

- Preparation of a report (in group work, max. 3 persons per group), in which the results of the programming tasks are described and analysed (approx. 20 pages, net processing time 20h) - 60%

- Oral knowledge assessment (duration: 30 minutes) - 40%

English exam possible: oral

Bibliography:

- K. Nonami, F. Kendoul, S. Suzuki, W. Wang, D. Nakazawa: Autonomous Flying Robots. Springer 2010.
- Thrun S., Burgard W., Fox D.: Probabilistic Robotics. The MIT Press, 2005.
- Russell S., Norvig P.: Artificial Intelligence – A Modern Approach. Pearson Education, 2015.
- Fairchild C., Harman T.L.: ROS Robotics By Example. Packt. 2016